The Full Picture

GROUP ON
EARTH OBSERVATIONS

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Global Observation for Forest and Land Cover Dynamics
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FOREWORD FROM THABO MBEKI, PRESIDENT OF SOUTH AFRICA

It gives me great pleasure to express my support for *The Full Picture*. It is an excellent publication which will undoubtedly contribute to the ongoing international dialogue around Earth observation data and systems.

This dialogue, which started at the World Summit on Sustainable Development in Johannesburg in 2002, has led to the establishment of GEO, the Group on Earth Observations.

GEO was created to coordinate all the planet's observing systems and to promote the sharing of observation data. GEO will improve our understanding of the Earth system, while enhancing global policy and decision-making abilities to establish a broad range of basic benefits to society, including the reduction of loss of life and property from tsunamis, floods and other natural disasters; improved water resource and energy management, and a better understanding of environmental factors significant to public health.

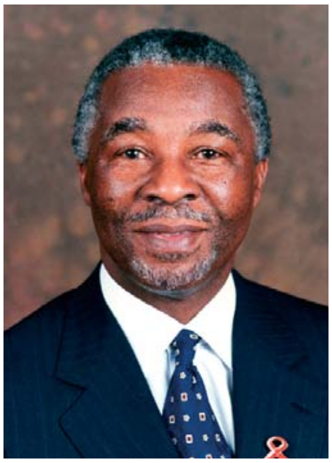
I am proud to say that South Africa has played a leading role in the development of the 10-year Implementation Plan of the Global Earth Observation System of Systems (GEOSS). For GEO to achieve its objectives, it is vital that the membership include more representatives from developing countries. South Africa is honoured to have been selected in Washington at the first Earth Observation Summit as one of the four co-chairs of GEO, with the specific responsibility of bringing developing countries on board and putting forward their perspectives. We believe that significant progress has already been made in this regard. Nevertheless, South Africa would like to urge the GEO to continue its outreach and public awareness efforts, which have already succeeded in significantly growing its membership since the first summit. The inclusion of regional initiatives such as the New Partnership for Africa's Development in the development of GEOSS has been critical. It is ultimately essential for GEO to interrogate and resolve issues such as making Earth observation data available to developing countries at affordable costs.

We should continue to be guided by global engagements such as the Johannesburg Plan of Implementation and the Millennium Development Goals. Indeed, the creation of GEOSS is a significant landmark and one of the first concrete realizations of the commitments made in Johannesburg in 2002.

The GEOSS is an excellent example of how countries around the world, both north and south, can pool our meagre individual resources into a powerful international observation for global public good.

In conclusion, it gives me great pleasure to report that South Africa is eager to foster even stronger relations within GEO, and to work towards realizing the objectives of the GEOSS, which will ultimately improve the well-being of all our people. We look forward, as one of the GEO co-chairs, to continuing our committed, active participation in the partnership.

Thabo Mbeki
President of South Africa



Introduction

JOSÉ ACHACHE,
DIRECTOR, SECRETARIAT, GROUP ON EARTH OBSERVATIONS

Two years ago, the Group on Earth Observations, embarked on an ambitious journey to build a system that will give us the full picture of global environmental trends.

In the following pages you will visit the construction site for this global infrastructure, one that will change the way we do business in the 21st century. Written by the construction crew itself, *The Full Picture* describes the progress made on building the Global Earth Observations System of Systems. I believe this book offers compelling evidence that these achievements have been nothing short of remarkable.

Since its inception in 2005, GEOSS has gained momentum towards becoming a comprehensive, near-real-time information system that will coordinate present and future observation systems, monitor the entire Earth, track changes in all of its physical, chemical and biological systems, and serve as an essential decision-support tool for a vast range of issues and user groups.

The first section of *The Full Picture* includes supporting statements from GEO's four Co-Chairs and from other committed leaders representing countries and organizations that have made the rapid start-up of GEOSS possible. Chapter One features a series of national and regional reports demonstrating the strong commitment that the GEO Member governments have made to this cooperative venture. Interestingly, while GEOSS was conceived as an instrument for international cooperation, it has also succeeded in promoting greater cooperation within countries.

Chapter Two describes the progress made on various systems for collecting and, crucially, disseminating information to decision makers, as well as in establishing an architecture for GEOSS which will ensure that all contributed observation systems are interoperable. These activities form the essential foundation upon which the entire GEOSS project will rest.

Chapter Three focuses on the user side of the equation. With an essential role in GEO, user groups include decision-makers and professionals in the fields of disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. The projects presented demonstrate the value of Earth observations for environmental management, social and economic progress, and human well-being.

Many of the activities described in Chapters Two and Three are being presented at the Cape Town Ministerial Summit in November 2007. These Early Achievements are the first 100 steps towards an effective GEOSS.

I extend my warm appreciation to all GEO Members and Participating Organizations which are contributing their systems and services to GEOSS and my congratulations to the authors of the articles appearing in this book. Their commitment has been the true inspiration behind the dramatic progress that has been made towards the construction of the Global Earth Observation System of Systems.

José Achache
Director, Secretariat, Group on Earth Observations

STATEMENT FROM MOSIBUDI MANGENA,
MINISTER OF SCIENCE & TECHNOLOGY, REPUBLIC OF SOUTH AFRICA

Regrettably, natural disasters continue to devastate the lives of people across the globe. According to the United Nations, in 2007 South Asia experienced some of the worst monsoon flooding in living memory. South Africa's northeastern neighbour, Mozambique, is recovering from the combined effects of drought, Cyclone Favio and floods which hit that country in the first quarter of this year.

These disasters highlight, once again, the critical need for international collaboration on Earth observation to improve global capacity to predict disasters and mitigate their effects. Shared Earth observation data can also assist us to tackle the challenges of sustainable development, environmental degradation and climate change.

I believe it is fitting that the fourth ministerial summit of the Group on Earth Observations (GEO) takes place in South Africa, under the same African skies it was first conceptualised – at the World Summit on Sustainable Development in 2002.

Since then, GEO has grown to incorporate 71 member countries, the European Commission, and 46 participating organizations. We have endorsed the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan, and formally established the GEO to implement it.

South Africa is honoured to host this summit, and we see it as an acknowledgement of Africa's contribution to the promotion and development of Earth observation. Already, 15 African countries have signed up as members of GEO, with Morocco and South Africa sitting on the GEO Executive Committee. This is a clear demonstration of Africa's commitment to active participation in developing sustainable societies. Understanding the Earth system is crucial to enhancing human health and safety, and alleviating poverty, which are priorities for African governments.

Africa, which often bears the brunt of environmental change, looks to this forum to help us realize a future where economic and developmental decisions will be informed by coordinated and comprehensive Earth observations.

As the GEO we have a responsibility to ensure that we deliver on the targets set in the GEOSS 10-year Implementation Plan. I believe that this is an opportune time to reflect on the progress made in implementing the plan, and to consider matters affecting its future successful implementation.

The Full Picture is a landmark publication, which illustrates and draws attention to the social and economic benefits the GEOSS Implementation Plan can bring.

Paging through this book, we can be proud of the way the science and technology community is working towards the realization of the commitments made at the World Summit on Sustainable Development in Johannesburg five years ago.

Mosibudi Mangena
Minister of Science & Technology, Republic of South Africa

STATEMENT FROM DR ZHENG GUOGUANG, ADMINISTRATOR OF CHINA METEOROLOGICAL ADMINISTRATION AND GEO CO-CHAIR

Global change is a common issue that must be addressed by the world communities together, as it affects almost all aspects of national economic and social development, the ecological environment, energy and water resources, human health and the sustainable development of human societies. In response to this challenge, the Group on Earth Observations (GEO) was created in 2005 as an intergovernmental organization to lead and coordinate existing Earth observation systems and to plan for the development of the Global Earth Observation System of Systems (GEOSS), on which nine key areas — the 'societal benefit areas' — were based.

Remarkable progress has been achieved by the GEO community. GEO has become the largest international organization in the field of Earth observations with 71 countries, the European Commission and 46 Participating Organizations. As a core data dissemination component of the GEOSS, GEONETCast (composed of EUMETCast, FENGYUNCast, and GEONETCast-America), has started to provide global users with Earth observation data and products and has brought about a fundamental change in global data sharing. GEONETCast has also removed the huge costs associated with the unnecessary duplication of satellite ground stations, as well as making access to data far easier. This has been made possible by the use of Digital Video Broadcast-Satellite communication technology. In the Asia-Pacific region, the Chinese Government has donated seventeen FENGYUNCast user-reception systems to developing countries to help receive Earth observation data. The GEOPortal constitutes another widely recognized achievement, which links existing Earth observation networks and provides users with data, decision making tools, and information visualization services. Through the GEOPortal, decision-makers, researchers and the general public have all the required data at their fingertips for direct application.

With strong support from the GEO Secretariat, this year the Asia-Pacific region has held two workshops, in Tokyo and in Beijing. The former focused on the social benefits of GEOSS and the latter addressed GEOSS data sharing issues. These events promoted the development of Earth observation systems in the region as well as highlighted the upcoming GEO Ministerial Summit. I would like to take this opportunity, to appeal to all countries to work together toward a quicker completion of GEOSS, so as to make an even greater contribution to disaster prevention and mitigation, to economic development and to social progress on a regional and global scale.

Dr Zheng Guoguang,
Administrator of China Meteorological
Administration and GEO Co-Chair

STATEMENT FROM JANEZ POTOČNIK,
EUROPEAN COMMISSIONER FOR SCIENCE AND RESEARCH

In my view, the Group on Earth Observations (GEO) initiative is an outstanding example of international cooperation in the domain of science and technology. Systematic monitoring of the Earth's systems will support our global efforts to achieve the UN Millennium Development Goals, thereby improving human welfare while maintaining dynamic economies and sound ecosystems. We will see the results in improved decision-making on essential issues that concern the well-being of the planet and its people.

The European Commission is pleased to be a co-chair of the GEO initiative. The European Community is also proud to offer its contributions to the Global Earth Observation System of Systems (GEOSS), examples of which are as follows:

- The 7th Framework Programme for Research and Technological Development is open to international participation and supports Earth observation activities in the areas of environment, space activities, and information and communications technologies.
- Operational Earth observation activities are being pursued through the Global Monitoring for Environment and Security (GMES) initiative. GMES will not only serve European needs for information services, but exchange data with our international partners.
- The 'Infrastructure for Spatial Information in Europe' (INSPIRE) directive provides measures that address exchange, sharing, access and use of interoperable spatial data and services in Europe. INSPIRE will contribute to establishing global standards for geospatial data and information and provide a backbone for the proposed European Shared Environmental Information System (SEIS), which is intended to provide an efficient and interoperable infrastructure for sharing environmental information.
- Specific support is being provided for sustainable geo-information and capacity building projects in the African Caribbean and Pacific (ACP) group of states to ensure that developing countries master the technology they require, while allowing their own capacities, knowledge base, institutions and infrastructure to grow without duplication.

I think it is appropriate that the GEO IV Summit should take place in South Africa, five years after it hosted the World Summit for Sustainable Development that took landmark decisions to combat poverty and promote environmental sustainability. The progress, demonstrated in this book, in developing the GEOSS is a clear response to the calls for action to meet global challenges in areas such as health, the environment and climate change. These efforts have my full support.

Janez Potočnik
European Commissioner for Science and Research

STATEMENT FROM DR PHIL MJWARA, DIRECTOR-GENERAL, DEPARTMENT OF SCIENCE & TECHNOLOGY, REPUBLIC OF SOUTH AFRICA, AND GEO CO-CHAIR

South Africa is pleased with the progress being made by the Group on Earth Observations (GEO) in intensifying and sustaining gains made since the last Earth Observation Summit in Brussels, in 2005. During this period we have experienced growth not only in GEO membership, but also in progress with the capacity-building strategy, which is particularly important for the Global Earth Observation System of Systems (GEOSS). This publication is timed to celebrate GEO's successes.

GEOSS will never succeed as intended if we do not ensure that all the nations of the world have access to Earth observation (EO) data. However, all partners agree that access to such data is meaningless unless it is coupled with the necessary resources. Providing the infrastructure and developing the skills base required to manage data and translate it into useful information will go a long way to enabling developing countries to store, disseminate and make meaningful use of EO data.

To South Africa these issues are paramount, as we are convinced that a lack of capacity and infrastructure has the potential to derail the process of attaining GEOSS targets. We will therefore continue to advocate for developing countries to move from being consumers of EO data to being providers operating their own EO systems. In this publication we propose a vibrant partnership between those whose capacity needs to be developed and those who can assist in developing the requisite capacity.

In this regard it is important for South Africa to support regional initiatives aimed at addressing skills shortages in countries that are still struggling with resources, and South Africa is therefore committed to the provision of resources, expertise and information to its neighbours in the GEO community. We also encourage developing countries to take advantage of the 2007 EO Ministerial Summit in Cape Town and, with increased awareness of the instrument's potential for global good, to add their efforts to the realization of GEOSS.

South Africa is privileged to have been one of the GEO pioneers. It has been a rewarding and enriching experience to see our country's participation in GEOSS increasing in user forums, as well as in scientific and technical advisory roles, and we are optimistic that the EO community will find this publication useful.

Dr Phil Mjwara
Director-General, Department of Science
& Technology, Republic of South Africa, and GEO Co-Chair

STATEMENT FROM VADM CONRAD C. LAUTENBACHER, JR., US NAVY (RET.), UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE AND US CO-CHAIR, GEO

As the US co-chair of the intergovernmental Group on Earth Observations (GEO), I am privileged to express my enthusiastic support for the emerging Global Earth Observation System of Systems (GEOSS). The progress we document and celebrate at this fourth Earth Observation Summit is truly remarkable.

For decades, scientists have discussed the potential applications of integrated observing technology. However, it was not until the first Earth Observation Summit some four years ago that political will caught up with scientific vision. At that summit, nations came together at the ministerial level to express their commitment to linking their various observational platforms into a global network and sharing the information for the benefit of all.

The impetus for this commitment was a realization that sound policy decisions about economic growth, public safety and environmental health must rest on sound scientific data. The growth of GEO through the next two summits has demonstrated that GEOSS will be the realization of this vision to 'take the pulse of the planet.'

In the United States, we are institutionalizing GEOSS through the United States Group on Earth Observations (USGEO), a subcommittee of the National Science and Technology Council. Some fifteen federal agencies and three White House offices coordinate through USGEO to leverage our domestic Earth observation operational and research and development assets in the most effective way for our nation, and also to inform and integrate our US contribution to the intergovernmental GEO process.

Our world is increasingly connected. Just as economic and environmental challenges know no geographical boundaries, the prospective benefits of a comprehensive Earth observation system are without limitation. Working together — locally, regionally and globally — we can provide our leaders with the information necessary to promote the safety of our citizens, the sustainable growth of our economies, and the effective management of our planet's precious resources.

VADM Conrad C. Lautenbacher, Jr., US Navy (Ret.)
Under Secretary of Commerce for Oceans
and Atmosphere and US Co-Chair, GEO

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STATEMENT FROM WOLFGANG TIEFENSEE, GERMAN FEDERAL MINISTER OF TRANSPORT, BUILDING AND URBAN AFFAIRS

The world around us is changing at a rapid pace. If we want to not only observe but also shape global change, we have to learn how to understand it. We will not succeed in sustainably ensuring peaceful coexistence among people and the prudent use of our natural resources unless we comprehensively understand global processes.

Given the complexity of global change, learning to understand it means above all learning from one another. The Group on Earth Observations has realized this.

If we want to meet global challenges, we have to look beyond national boundaries and develop strategies jointly. The information that the Group on Earth Observations provides to policymakers is an important basis for this.

The Group on Earth Observations has set itself ambitious goals. We want to make optimum use of the observation systems and models that are already available throughout the world. We also want to jointly seek new approaches and methods, and expand our knowledge of the global environmental context.

The Federal Republic of Germany is playing its part in ensuring that the goals of the Group on Earth Observations are achieved. We are contributing our experiences and knowledge of the operation of observation systems, as well as providing innovative methods for the evaluation and analysis of the data.

There are already some success stories to report. Globally coordinated earth observation provides the states involved with important findings to help them evolve their strategies and programmes effectively. What we have achieved so far should encourage us to continue with the idea of the Group on Earth Observations.

Wolfgang Tiefensee
German Federal Minister of Transport, Building and Urban Affairs

**STATEMENT FROM CRISTINA NARBONA,
MINISTER OF ENVIRONMENT, SPAIN**

The growing vulnerability of today's society, which is faced with the evolution and processes taking place on our planet, has meant data and information about our planet have become fundamentally important, not only for real time activities but also scheduled strategic activities and, of course, research. The need to have as much data as possible to ensure its quality, and that these are processed quickly and efficiently, especially in emergency situations, justify the high priority given to the implantation of a Global Earth Observation System of Systems (GEOSS) to coordinate and foster all these activities.

Two years after the GEO was created as the driving force behind the global implantation of the GEOSS, some encouraging results have been obtained, but there is still a lot to be done. The quick, efficient delivery of data and predictions regarding communities at risk of the effects of adverse phenomena must be ensured. It is also necessary to ensure that any new technology projects are introduced appropriately in the social and human contexts they are to serve, taking into account their own specifics and requirements, and ensuring that suitable training is given and the highest degree of responsibility is accepted for their operation and maintenance.

Extensive training and diffusion activities must also be developed, processes must be simplified and administrative obstacles must be removed, to facilitate collaboration and the quick, efficient introduction of projects and systems. Perhaps the most important aspect is the progressive construction of an extensive planetary awareness that we all depend on each other to achieve decent, healthy living conditions on Earth. I think GEOSS plays a key role in all of this and that initiatives such as this book, *The Full Picture*, within this framework may contribute to greater understanding and dialogue concerning this planetary challenge, something to which the Spanish Government is firmly committed.

Cristina Narbona
Minister of Environment, Spain

**STATEMENT FROM DR KEIJI TACHIKAWA,
PRESIDENT OF THE JAPAN AEROSPACE EXPLORATION AGENCY**

We are now facing difficulties on the Earth. Problems that were caused by ourselves are forcing us to change our lifestyles and living environments. And if we are facing these problems now, what might we be facing in 30 years' time?

Presently, there are many global issues such as shortage of water resources, desertification, and increasing natural disasters, which seriously impact our community. To overcome such problems and take appropriate measures against them, it is necessary for many countries to cooperate and ensure the establishment of comprehensive, coordinated and sustained Earth observation, enabling accurate policy decisions based on correct information.

The Global Earth Observation System of Systems (GEOSS) is working toward a solution for the Earth's environmental issues, which is one of its current priorities for sustainable growth and development. Contributing to the GEOSS implementation, the Japan Aerospace Exploration Agency (JAXA) has Earth observation programmes such as disaster and crisis monitoring, as well as water cycle and climate change observation, to contribute towards a safe and secure society.

The issue of climate change is no longer a question; it is a reality. I hope that GEOSS will give high priority to this issue, which threatens people around the world. GEOSS could play a critical role here.

GEOSS should also pay attention to the many regional issues, and the need for regional cooperation — GEOSS can lend valuable support to regional Earth observations.

JAXA promotes the Sentinel Asia Project with disaster prevention organizations and space agencies in the Asia Pacific region to share disaster information. I believe that the project can contribute to solving local issues in the region.

Japan has been and will be calling on other non-member countries to join GEO. GEOSS is a very timely and very important programme for the Earth's environment. JAXA is looking forward to working for this critical programme.

Dr Keiji Tachikawa
President of the Japan Aerospace Exploration Agency

**STATEMENT FROM JEAN-JACQUES DORDAIN,
DIRECTOR GENERAL OF THE EUROPEAN SPACE AGENCY**

At the dawn of the third millennium, humankind faces many severe challenges. Our collective responsibility is nothing less than to manage a planet, our planet, for the benefit of all the citizens of the world, and even more importantly, for the generations that follow. What should give us confidence in this undertaking is the fact that we have already successfully developed the tools and means required, and also, that we have learned to cooperate.

GEO, the Group on Earth Observations, represents such an endeavour. It is the result of an intergovernmental effort to advance our understanding of Earth and consequently managing life thereon.

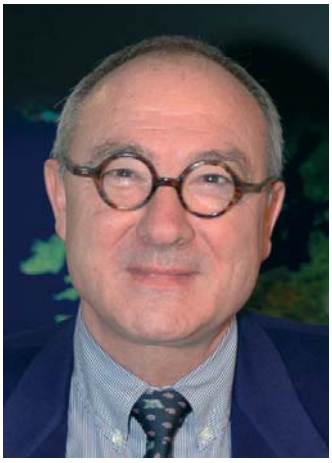
Space technologies constitute a tool to support this challenging objective. We have learned to develop platforms that use of the unique capabilities space offers, in order to deliver applications for the benefit of all. Communication, navigation and observation form the magic triangle of space applications.

ESA's Earth observation satellites, such as Envisat, the world's largest environmental satellite ever built, provide huge amounts of daily data for users and institutions worldwide. The view from Earth observation satellites gives us a new perspective: what has always seemed an unimaginable expanse has been transformed in to a blue sphere that can be orbited in just 90 minutes.

More than ever, satellites play a vital role in managing our lives and understanding the human impact on our environment. They feed Earth system sciences, the global climate change discussion, applications, business cases and disaster management efforts. As such, space has become a type of natural asset. GMES, the Global Monitoring for Environment and Security programme managed by the EU and ESA, constitutes the European contribution to GEO.

It is a demanding task the GEO faces to integrate all these efforts, from space and in situ observations, to governments and organizations, from regions and countries, to systems and stations. I am convinced that GEO's mission should be at the top of political agenda. It's a difficult task. But I am confident that the GEO, in establishing a Global Earth Observation System of Systems, will succeed in providing decision makers with all data they need to act quickly and confidently. Such a success will benefit every single one of us.

Jean-Jacques Dordain
Director General of the European Space Agency



**STATEMENT FROM MICHEL JARRAUD,
SECRETARY-GENERAL OF THE WORLD METEOROLOGICAL ORGANIZATION**

The World Meteorological Organization (WMO) evolved in 1950 from the International Meteorological Organization (IMO), which in 1873 received from the First International Meteorological Congress the mandate for the safety of life and the protection of property through the provision of services in weather and climate, and to coordinate the appropriate observation systems. In 1951 WMO became a specialized agency of the United Nations System and shortly thereafter, in 1959, it received an additional mandate in water. Today, the *vision* of WMO is to provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources and related environmental issues and thereby contribute to the safety and well being of people throughout the world and to the economic benefit of all nations.

While 90% of natural disasters are of hydrometeorological origin, it is indeed possible to protect our societies and to save lives through a clear understanding of the potential threats, reliable early warnings and efficient disaster reduction and mitigation efforts. Systematic observations of weather, climate and water, as well as the derived assessments, predictions and warnings are daily disseminated through WMO's World Weather Watch and the National Meteorological and Hydrological Services (NMHSs) of WMO's 188 Members.

Building upon the well-established and consolidated services provided in their mandated areas of competence by WMO and other organizations, a Global Earth Observation System of Systems (GEOSS) will provide a key opportunity to serve additional users and to share a broader-scoped environmental monitoring and prediction system with the global community. The possibility of new observational partnerships with organizations in such diverse fields as food and energy production, human and ecosystems or health and biodiversity, will significantly contribute to mitigate further the impacts of natural disasters and to increase the socio-economic benefits.

The Fifteenth World Meteorological Congress (Geneva, May 2007) endorsed the GEOSS concept as a key initiative to enable WMO to better address the challenges of the coming decades, and emphasized that the relevant WMO components should also be GEOSS components. WMO contributions to GEOSS would include WMO's unique systems as well as its co-sponsored systems. WMO participation in GEOSS would be on a basis of mutual benefit, to maximize synergies and minimize duplication, and to facilitate the free and unrestricted exchange of data, metadata and products, in particular to make available all *essential* data, as defined in WMO Resolution 40 (Cg-XII), through the GEO interoperable arrangements to serve the needs of the global community.

The Full Picture comprises an excellent overview of WMO's contributions towards GEOSS as well as expectations in terms of what could be achieved as GEOSS develops into a true "*system of systems*", to enable us to better comprehend and monitor our planet, and to increasingly provide to the global community all the information that is needed to meet and to respond to the challenges that societies will be facing in a changing environment.

Michel Jarraud
Secretary-General, World Meteorological Organization

I

NATIONAL & REGIONAL REPORTS

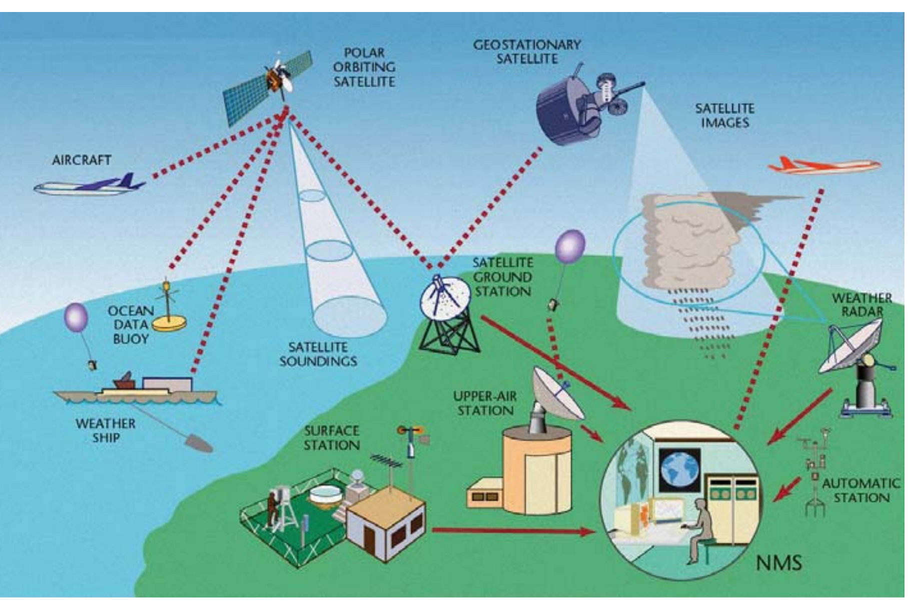
Delivering GEOSS — the value and the vision

Dr Susan L. Barrell, Australian Bureau of Meteorology

It is said that information is power. In terms of the global environment, however, shared information is even more powerful — and the more effectively data can be shared, the greater and more widely distributed are the benefits.

Earth system observations are made and compiled for good reasons — because of a need to answer a question, to understand or explain an outcome or a trend, to confirm or refute a thesis, or to support a predictive model or a management process. The characteristics of the data gathered, that is, the quantity measured, its value at a point in time, its rate of change and spatial distribution, the accuracy and frequency with which it is measured, and many other attributes, are intimately related to the nature of the questions posed and, historically at least, gathered just for that reason. In some cases, the questions are large-scale and require the establishment and maintenance of extensive networks of data gathering systems and considerable continuity across the systems in both space and time. In other cases, the questions, once asked and answered, might be resolved and retired, the observations ceased and either discarded or kept for later research or historical reference.

The earth system is complex, multidimensional and highly interdependent, changing and changeable on all spatial and temporal scales. For example, meteorological events occur from the smallest local scale through to near global long-term climate events, impact on health, agriculture, ecosystems, energy generation and many other societal activities, and they influence and inform decision-making processes from individuals through to global policy development. The meteorological and other environmental observing systems that exist now, and that are under development for the future, represent the evolution of our understanding about the environment and our need to repeatedly, for many different reasons, compare the present with the past and predict the future.



The Global Observing System, which is coordinated by the World Meteorological Organization's World Weather Watch and operated by its members, contributes to GEOSS observations that are essential to many socio-economic benefit areas beyond simply weather and climate

The establishment of the Group on Earth Observations (GEO) and its decision to plan and implement a Global Earth Observation System of Systems (GEOSS) reflects the growing recognition that informed decision-making on all matters relating to the environment benefits from access to and use of a wide range of environmental, biological, economic, statistical and other data and, more importantly, the ability to integrate, analyse and evaluate different types of data within a common framework.

It is through the mechanisms for sharing information that GEOSS will add its greatest value and deliver the greatest benefits. GEOSS can add value above and beyond that of the individual observing and data acquisition systems in a number of ways, including through bringing together data providers and users across a wide range of socio-economic benefit areas to develop integrated statements of requirements and to facilitate the sharing of data and lessons learned across the various sectors. Two aspects are critical to the immediate and long-term success of GEOSS, and will enable GEOSS to add value to the overall data access, utilization and service delivery processes: a realistic and achievable interoperability framework to support the exchange and utilization of data across multiple users and socio-economic benefit areas; and the long-term GEOSS governance mechanism.

The GEOSS interoperability framework

GEO does not itself own or operate observations systems; rather it aims to facilitate access to and utilization of the data that are available through the systems that are owned and operated by its members. Similarly, the data access, distribution, data management and processing systems are contributed by the members, groups of members and the participating organizations, many of which themselves have an even broader membership than GEO. Where new needs for data are identified, GEO may facilitate the enhancement or strengthening of existing systems (including observing, information, dissemination systems, etc.) or the estab-

The Willis Island Observing Office, which is operated by the Australian Bureau of Meteorology, is illustrative of the many dimensions of meteorological observations, from early warning of tropical cyclones to global climate monitoring

lishment of new systems, but the ownership of those systems remains with the members or groups of members.

A fundamental contribution of GEOSS, and the area where it can add unique value, is through the definition of an effective interoperability framework through which the data from the various systems, disciplines, earth system regimes and socio-economic benefit areas can be exchanged, shared, integrated, distributed and — critically — used. Even within individual socio-economic benefit areas, the challenge of bringing together regional and global communities to harness experience, to develop common solutions to shared problems, or to implement successful practices and systems in less developed countries, will require a robust common operating framework. To share data between entirely different user communities is an even greater challenge, but the rewards of addressing the cross-disciplinary nature of GEOSS successfully would be immense.

An interoperability framework is much more than defining common data formats and protocols. It is much more than defining a geospatial reference framework against which spatially distributed and point-value data can be mapped. An effective interoperability framework will take into account not just the characteristics of the data, but the characteristics of the systems themselves, the owners of the systems, the rationale for gathering the data, and the requirements of the existing and potential users of the data.

It follows, therefore, that an effective GEOSS interoperability framework will be complex and multidimensional, and it will evolve as the envelope of membership, systems and users expands. Some key aspects that need to be considered in defining an interoperability framework include:

Understanding user needs and capabilities — for using and accessing data

Understanding the full extent of data and systems available (and needed) for sharing — observations systems, databases, metadata, information systems, derived information and products, etc.

Data policy framework — data exchange, sharing, access, publication, forwarding, cost (free and unrestricted vs. charge for use)

Mapping and grids for geographic referencing of data — such as spatially distributed (e.g. satellite imagery), point-value data (e.g. in situ surface-based instrumentation) and trajectories (e.g. disease vectors)

Standards — for observations, data and metadata formats, storage, transmission, etc.

Data access mechanisms — such as web-based portals and information access interfaces. Recognizing there will be a range of technical sophistication amongst members contributing and accessing data

Infrastructure for data access — e.g. low cost satellite reception, bandwidth-friendly communications

Data and database management systems — shared and/or interoperable

Methodologies and assimilation systems — for mixing data of different spatial and temporal characteristics, as well as spatial and point data, real-time and historical data

Guidance and standards for digitization of paper records — to optimize electronic cataloguing and availability of data, and to support effective data rescue programmes

Capacity building requirements — to enable benefits of GEOSS to be exploited for decision making; training in

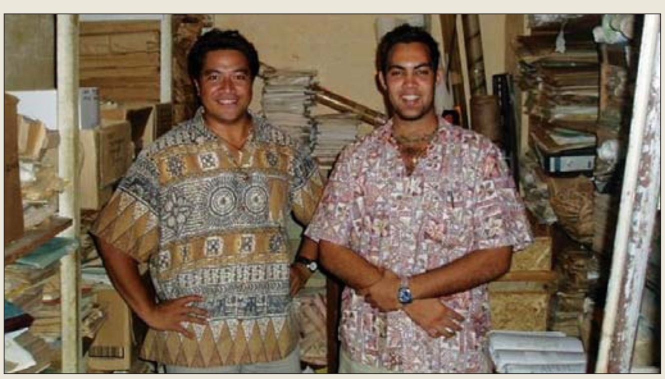
all aspects of observations and data access, development of data analysis and interpretations skills, etc.
Cross linkages — to governance and/or coordination mechanisms for component systems
Cross linkages to documented experience — pilot studies, published experiments and success stories, mentoring opportunities
Mechanisms — to enable GEOSS to support effectively information and service delivery systems at international, regional and local level.

The full benefits of GEOSS will only be achieved when membership is global and when the data, systems and experience of each are shared with all others. To this end, the effort expended in making it as easy as possible to participate in GEOSS as a contributor and/or user of data, via the interoperability framework will be repaid many times over. Alongside this, the GEOSS principles of system ownership remaining with members and of system mandates being undisturbed by GEOSS (except by mutual arrangement) should be continually reinforced.

One challenge of defining an effective interoperability framework is ensuring that barriers to entry are reduced to the lowest level; that technical guidelines and standards reflect the range in socio-economic circumstances and technical capacities of all members. It is important, for global participation, that none are disenfranchised by the bar being set too high for them to participate. Importantly, this relates not just to their capacity to access and use data and systems contributed to GEOSS by others, but also to their own capacity to contribute their data and systems to GEOSS.

The scope of GEOSS, as laid out in the GEOSS *Ten-year implementation plan*, is aspirational and will take the full ten years to get close to achieving what it ambitiously set out to achieve at the Third Earth Observation Summit in Brussels in February 2005. The interoperability framework, in all its dimensions, is critical to providing the "overall conceptual and organizational framework to build towards integrated Earth observations to meet user needs," and it will need to be supported and to evolve long after the ten years are up if GEOSS is to continue to meet user needs.

Data rescue



In Samoa, as in many developing countries, much of the historical data record that is critical to understanding current environmental issues, such as climate change, are retained only as fragile paper records. GEOSS, through its interoperability framework and effective data rescue programmes, can remove barriers to sharing such data for the benefit of users nationally, throughout the region and globally

Future governance model for GEO and GEOSS

The intergovernmental Group on Earth Observations (GEO), comprising its members and participating organizations, was established in February 2005 on a voluntary and legally non-binding basis, with voluntary contributions to support its activities. It is supported by a Geneva-based secretariat and guided by an elected executive committee.

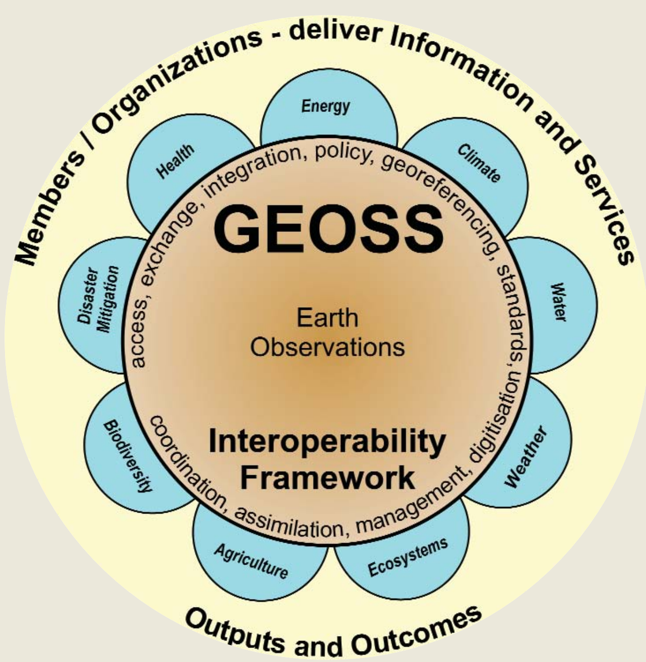
The driving forces behind establishing firstly the ad hoc GEO and then the intergovernmental GEO were clearly the founding members, who vested significant national effort and resources into turning the concept of a comprehensive, coordinated and sustained system of systems into a living implementation plan. The governance model that was adopted reflected the desire to move forward at a rapid pace, without the encumbrance of a UN-style bureaucracy, and to record early successes for GEOSS. While the ability to directly engage interested parties and individuals and to respond quickly and without the overheads of bureaucracy may have been key factors in the early progress, it was not long before GEO plenary decisions more explicitly embraced open and transparent recruitment, reporting and review processes.

A key challenge for GEO in the future, as well as for the established international organizations and around 200 countries that contribute to, and benefit from, the existing global Earth observing systems, will be to maintain the momentum and consolidate a high level of cooperation and coordination. It is not clear whether all the individual countries that contribute to the existing systems will ever choose to become members of GEO per se, but as contributors nonetheless to the system of systems, their needs and voices are inextricably intertwined with the future of GEOSS.

As discussed above, the critical value that GEOSS adds to the component systems is through the interoperability framework that facilitates more effective access to, and utilization of, observations to inform decision-making across many sectors, societies, regions and the globe. While the GEOSS mandate aims to vest ownership of any new systems back to the Members themselves, it is inevitable that there will be a sense of collective GEOSS ownership of some systems, such as the GEONETCast system and the developing capacity building and outreach programmes. Supporting, developing, maintaining, communicating and promoting the interoperability framework on an ongoing basis will be an essential task of GEO that will require sustained secretariat effort and engagement by the membership.

Whether the current governance arrangements will remain appropriate in the long term is a key question, and one that must be kept under periodic review if the GEOSS vision is to become an ongoing reality. Recognizing the objective of global participation and benefits, a robust future governance model may be provided by borrowing from the experiences of existing long-lived global observing systems. Some of them have been in operation for more than 50 years and have evolved to respond to changing requirements, technologies and societal circumstances.

GEOSS interoperability framework



The GEOSS interoperability framework will facilitate access, integration and application of earth observations and related information by members and participating organizations (and their members) in support of information and service delivery, research and all manner of decision-making

GEO future governance model

A schematic of a possible future governance model for GEO, in which GEO is established as a joint subsidiary mechanism of some of the high-level UN agencies, programmes and other designated bodies that govern or benefit from the established global systems. Some of the UN bodies that may have an interest are mapped indicatively against the nine SBAs

Under the broad umbrella of GEOSS, they will likely evolve further and deliver even greater benefits to their members both directly and through GEOSS. The international programme framework of the WMO World Weather Watch, for example, provides such a model, building upon the data sharing policies of WMO Resolution 40 and an end-to-end service delivery concept.

One option for a sustainable long-term governance structure is to establish GEO as a joint subsidiary mechanism of the multiple high-level UN agencies, programmes and other designated bodies, such as the Conventions, that govern the established (and new) systems or utilize the data to inform regional and international policy development on global environmental and related issues. The benefits of such a governance model include:

- It would have the support and engagement of established global organizations and deliver substantial benefits back to the organizations and their members
- With multiple sponsors, rather that just one or two, no single one of them would dominate GEO or be able to indelibly stamp it in their image
- By focusing principally on its value-adding facilitating role through the GEOSS interoperability framework, GEO would not challenge the operation and mandate of the sponsors, which would enable it to exhibit a considerable degree of operating independence
- Perhaps most importantly, it would minimize the risk of duplication and competition between GEO and the international organizations that are responsible for the established global observing systems.

Many of the relevant UN organizations are already associated with GEO and a number of them (WMO, UNEP, FAO, UNESCO, IOC) are working actively together to coordinate their participation in GEO and GEOSS.

To some extent, the possible governance model illustrated to the left parallels the Intergovernmental Panel on Climate Change, which is a joint body of the World Meteorological Organization and United Nations Environment Programme, but which is seen externally and is highly respected as a body and authority in its own right.

With the benefit of a more robust governance framework, GEO could then genuinely focus on its interoperability and integration role, optimizing its capacity building and outreach activities through synergy with its sponsoring organizations. Together, GEO and its sponsors would represent a truly end-to-end service delivery concept that would ensure the benefits of coordinated, comprehensive and sustained global earth system observations were delivered to all users and communities.

The Ministerial Declaration of the Third Earth Observation Summit in Brussels (16 February 2005) resolved to conduct a mid-term assessment of GEO by 2010. This would be a good time to set a process underway for transitioning GEO from a multilateral intergovernmental organization into one that is fully integrated within the UN structure.

Coordinating GEO in Canada

The Canadian Group on Earth Observations

Canada's vast oceans, inland waters, land surfaces, as well as its atmosphere require a wide array of measurements and surveillance in order to monitor and understand their current condition and to predict their future states. These Earth observations (EO) contribute every day to the health and safety of Canadians, the protection of Canada's natural environment and to Canada's economic prosperity. Reliable and sustained EOs are fundamental to hazard warning, weather prediction, the understanding of climate cycles, health protection, optimising agricultural and forestry practices, resource assessments, infrastructure planning and environmental protection.

The Canadian Group on Earth Observations (CGEO) was established in 2003 at the federal level as part of Canada's contribution to GEO and its goal of promoting the development of a comprehensive, coordinated and sustainable Earth observation system — a system designed to improve our ability to understand and address global environmental and economic challenges.

CGEO is coordinating Canada's position and engagement in GEO as well as advancing coordinated EO within Canada. Core federal participants on the CGEO committee are Agriculture and Agri-food Canada, the Canadian Space Agency, Environment Canada, Fisheries and Oceans Canada, Foreign Affairs Canada, Natural Resources Canada, and Public Safety and Emergency Preparedness Canada. Associate federal participants are the Canadian International Development Agency, Health Canada and Industry Canada. The group is also engaging Statistics Canada, Parks Canada, and the Department of National Defence. CGEO is responsive to the Assistant Deputy Minister Steering Committee and the Director-General Coordination Committee.

Photo: Canadian Group on Earth Observations

Canadian Group on Earth Observations (CGEO): Coordinating GEO in Canada

Canada's challenges

Canada is a large nation with a 9.1 million-km² landmass that is sparsely populated with many remote regions that are difficult to access. Canada borders three oceans giving it the longest coastline in the world at 243,000 km. Also, Canada has a large polar area with a variable and hazardous climate as well as a sensitive and rapidly changing environment. Much of Canada's economy is resource-based and issues such as resource inventory, transportation and environmental impact are important. Other key Canadian issues are northern development and security.

Within this context, the challenges for Canada are:

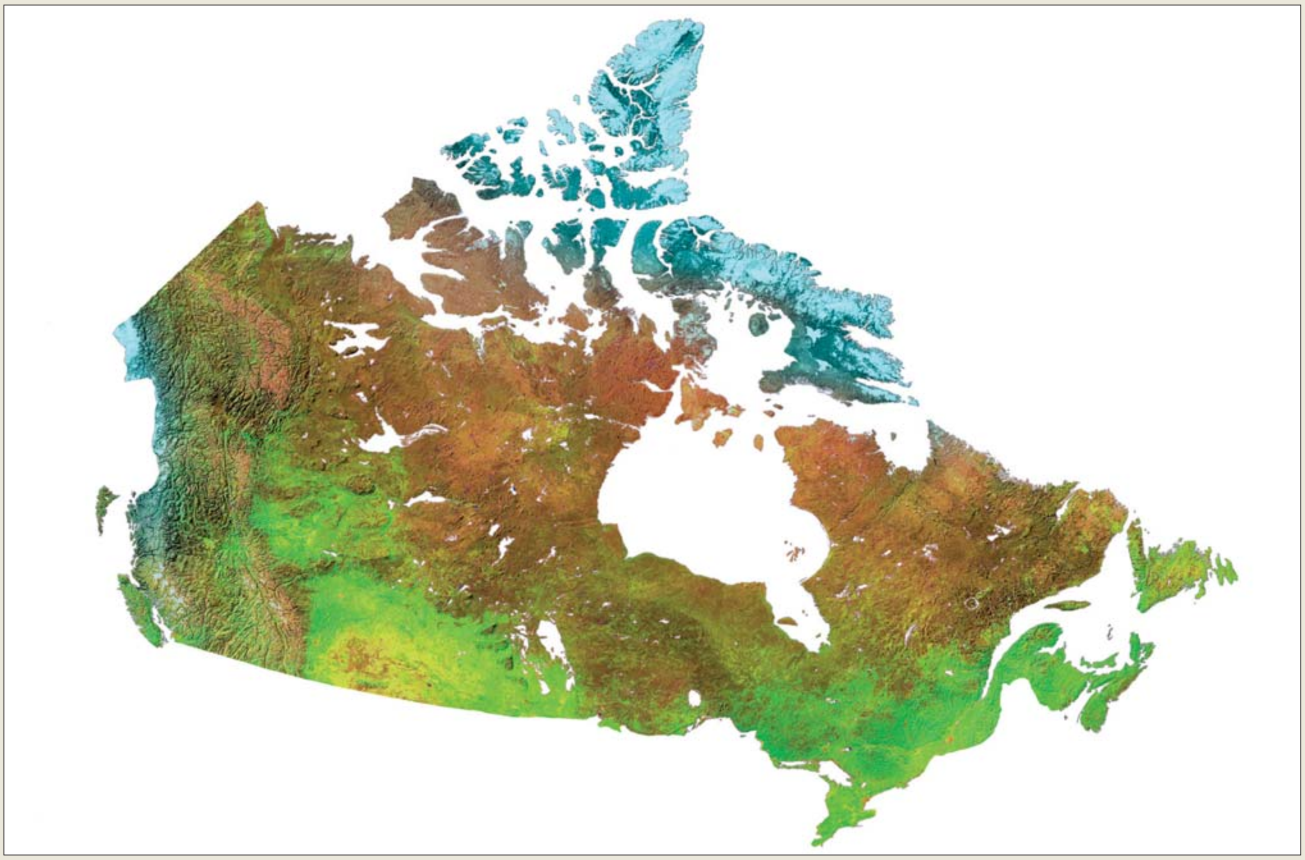
- How to establish sources of reliable, relevant and accessible EO information and products for Canadian decision makers
- How to better integrate and use governments' investment in EO
- How to leverage international collaboration to ensure Canada's access to essential global EO information
- How to position Canada to be a contributor to global EO efforts
- How to fully engage Canadian players in the coordination processes.

CGEO has undertaken a number of activities in response to these challenges, including a stakeholder inventory to identify policy drivers, information requirements, EO networks and organizations, analysis and modelling capacity, standards, products and services. It has also undertaken a data policy survey and established early collaborative projects on the Arctic, water cycles and soil moisture and EO 'enablers'. In addition, it is initiating Canadian earth observation strategies on a federal (FEOS) and national level.

Federal Earth Observation Strategy

As part of Canada's undertaking to the Global Earth Observation System of Systems (GEOSS), CGEO has committed to completing a Federal Earth Observation

Satellite image of Canada



Canada has a 9.1 million-km² landmass that comprises a variety of climates including a large Arctic area. It also has the longest coastline in the world at 243,000 km

Source: Natural Resources Canada

Strategy (FEOS) in conjunction with other levels of government, industry and academia. The ultimate aim is to develop a truly national partnership and plan. FEOS is intended for senior decision makers whose responsibilities include EO, the generation of information products based on EO, or the use of EO to achieve benefits for Canadians.

The objective of FEOS is to ensure that Canada's non-military needs for high quality and sustained information on the state of the Earth are met as a basis for policy and decision making in every sector of society. The FEOS is founded on and is meant to complement existing programs, focusing initially on nine societal benefit areas:

Disasters — reducing loss of life and property from natural and human-induced disasters
Health — understanding environmental factors affecting human health and well-being
Energy — improving management of energy resources
Climate — understanding, assessing, predicting, mitigating and adapting to climate variability and change
Water — improving water resource management through better understanding of the water cycle
Weather — improving weather information, forecasting, and warning
Ecosystems — improving the management of terrestrial, coastal, and marine ecosystems
Agriculture/Forestry — supporting sustainable agriculture and forestry, and combating land degradation
Biodiversity — understanding, monitoring, and conserving biodiversity.

FEOS intends to improve coordination of efforts, address critical gaps, promote common standards and sharing of information, and lead to better understanding and satisfaction of user needs.

Achieving the long-term benefits of FEOS will require close and ongoing collaboration between all federal departments and agencies involved in CGEO while respecting the mandates of all of the organizations. Successful implementation of FEOS will require that appropriate mechanisms and resources, existing or new, be mobilized toward achieving the shared interdepartmental long-term outcomes.

An integrated monitoring, assessment and prediction network

The development of a national EO approach is an important step in developing a common vision and in focusing EO communities' efforts. Engaging in discussion and

Framework — Federal Earth Observation Strategy

Vision	Benefits	Goals	Strategies
Coordinated, comprehensive, and sustained Earth observations contribute to a healthy, secure and prosperous Canada	Reduce loss of life and properties Improve quality of life Improve use and management of natural resources Adapt to climate change Improve water management Improve weather forecasting Improve management of ecosystems Support sustainable agriculture, forestry, and fisheries Understand, monitor and conserve biodiversity Strengthen sovereignty and security	The required observations are acquired through coordinated networks Users have timely access to observations and products Useful information products are developed and routinely produced Data and information products are widely integrated into decision making processes	Active participation of user communities Collaborative approach to observation, analysis and delivery Optimal investment in Canadian Earth observations, infrastructure and capacity Integration into decision making processes Establishment of policy and sustained funding frameworks

Source: Canadian Group on Earth Observations

identifying short-term actions are being initiated. The objective of the network is a future where EO data are used more effectively than today with minimal interdisciplinary and organizational or political barriers to the exchange of data, information and knowledge. The network's guiding principles are designated as integrated monitoring, assessment, prediction and network.

Integrated monitoring indicates Earth observations of the physical, chemical, and biological environment. This includes the observation of current conditions (e.g. sea level, soil moisture, radiation, fauna and flora), the detection of trends (e.g. climate, seismicity, pollution levels) and the evaluation of risks (e.g. statistical analysis, extreme events). Assessment includes characterizing and drawing conclusions about a given situation, for example forest inventory, evaluation of mineral deposits, groundwater quantity and quality, impacts of change scenarios.

Prediction indicates the use of any technique or model to structure, integrate and extract information from the available data, and to derive value-added information about the past, current or future states. These models can be used in either predictive or scenario-based modes. They include, for example, atmospheric models for weather, climate and air quality applications, predictive geo-hazard warnings, reverse-trajectories of aquatic and atmospheric pollution, crop yield estimation, and ecosystem models for natural habitat management and impact assessments. The network includes a coordinated, distributed and connected ensemble of subsystems, which is the responsibility of many different players all working collaboratively toward a common goal.

This clearly categorized approach will help provide a mechanism for effective coordination between federal departments, as well as between various levels of government. In addition it will help define priority actions for short-term successes.

International context

CGEO is contributing to GEO by co-chairing the GEO User Interface Committee and the EOS-IV Task Force 2 Report on Progress document, as well as participating on numerous other GEO committees. There is a high level of participation on many GEO 2007/2008 workplan tasks. Also, CGEO is working with the United States on US-Canada cooperation on trans-border EO interests such as air quality, water security and Arctic land cover change.

CGEO is actively promoting the worldwide effort to invest in the ten-year implementation plan for the GEOSS, which is a comprehensive, coordinated and sustained system of Earth observation systems to better monitor the Earth. GEOSS has the potential to help Canada in its compliance with multilateral environmental agreements, such as the Convention on Biological Diversity, the Montreal Protocol and the United Nations Framework Convention on Climate Change. Further, GEOSS will be instrumental in helping Canada achieve a number of its foreign policy goals including the economic development of emerging economies and promoting human security.

Conclusion

Canada's large and multifaceted physical geography requires reliable and sustained earth observations in order to ensure the health, safety and prosperity of Canadians, while also protecting Canada's natural environment. Canada is thus a strong supporter and contributor to GEO and GEOSS, which provide an important context and stimulus to advance coordinated EO within Canada.

The multi-agency Canadian GEO is demonstrating its ability to address crosscutting EO issues by undertaking many activities with the GEO and within Canada. The Federal Earth Observation Strategy as well as the Integrated Monitoring, Assessment and Prediction Network for Canada constitute important steps in the development of a common vision that focuses efforts on achieving desired Canadian outcomes for Canada's people and Canada's environment.

Chinese space-based Earth observation system — a contribution to GEOSS

China Meteorological Administration

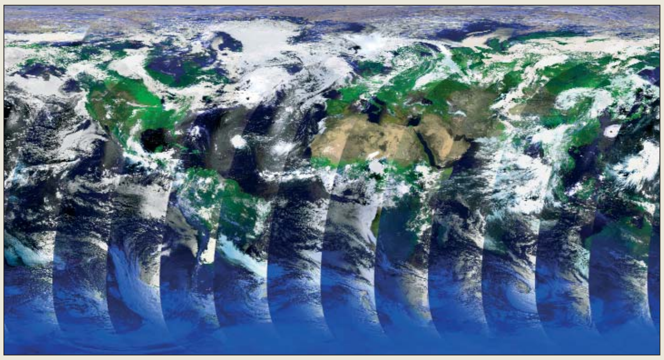
The 21st century is a new age that will see a global boom in Earth observation science. In recent years, there has been great progress in space-based Earth observation systems in China. Chinese satellites, including the FengYun meteorological satellite series, Resource satellite series, Ocean satellite series and Environmental and Disaster Reduction satellite series, have developed and continue to do so. With all these satellite series in place, a Chinese integrated Earth observation system, enhancing the scope and levels of Earth observation, will come into being. Based on this primary established Chinese Earth observation system, China has taken full advantage of these satellites in weather, disaster monitoring, and resource and environment management.

Meteorological satellite

China began to develop its meteorological satellite independently in the early 1970s. The first polar orbiting experimental meteorological satellite (FY-1A) was launched successfully in the late 1980s. So far, a total of eight meteorological satellites have been successively launched, including four polar orbiting satellites and four geostationary satellites. As a result, two major series (the polar-orbiting and geostationary series) of meteorological satellite systems have taken shape — a network of two geostationary satellites has been created to observe, and the orbiting satellites are backed up operationally. In order to satisfy the increasing demands of economy and society, China plans to launch its second-generation polar orbiting meteorological satellite (FY-3A) in 2008. This will carry 11 payloads, and will be able to make all-weather global Earth observations with high spatial resolution.

Since the early 1980s, meteorological satellite data has been applied gradually to weather forecasting/prediction and ecological environment monitoring, among other things. With the constant deepening of application research on satellite meteorology and continuous optimization of satellite remote-sensing products, the polar orbiting and geostationary meteorological satellite data have been applied widely to many fields such as weather forecasting, climate prediction, natural disaster monitoring, crop production estimation, environmental monitoring and space weather. Important remote sensing information arising from meteorological satellites has been provided to governments and relevant departments for their decision-making, thus playing a vital role in many fields such as disaster prevention and reduction, and economic development.

Global multi-orbit mosaic image



This image is made from FY-1C multi-orbit data on 9 August 2000. It shows how the satellite scans and circles around the Earth. As the influence of the solar zenith angle is not corrected, the edges where orbits meet are obvious. Global image mosaic is the basic form for global environment monitoring and data application

National Satellite Meteorological Center, China Meteorological Administration

Resource satellite

The China-Brazil Earth Resource Satellite (CBERS) was jointly financed by China and Brazil. The CBERS project was set up in 1986, and the protocol on research and production of the Earth resource satellite was signed by both governments in 1988. According to the protocol, CBERS is based on a Chinese concept, with 70 per cent of overall funds financed by China and 30 per cent by Brazil. China is responsible for the satellite system concept; the development of the thermal control subsystem, attitude and orbit control subsystem; the ultra short wave tracking, telemetry and command system (TT&C); onboard data management; onboard overall electro circuit; charge-coupled device (CCD) camera; infrared multi-spectrum scanner; CCD data transmission; onboard digital high-density magnetic recorder; infrared data transmission; the space environment monitoring system and the integration, electronic test and large-scale test of the first CBERS. Brazil is responsible for the development of the structural subsystem, power subsystem, S-band TT&C, data collection subsystem, and development of

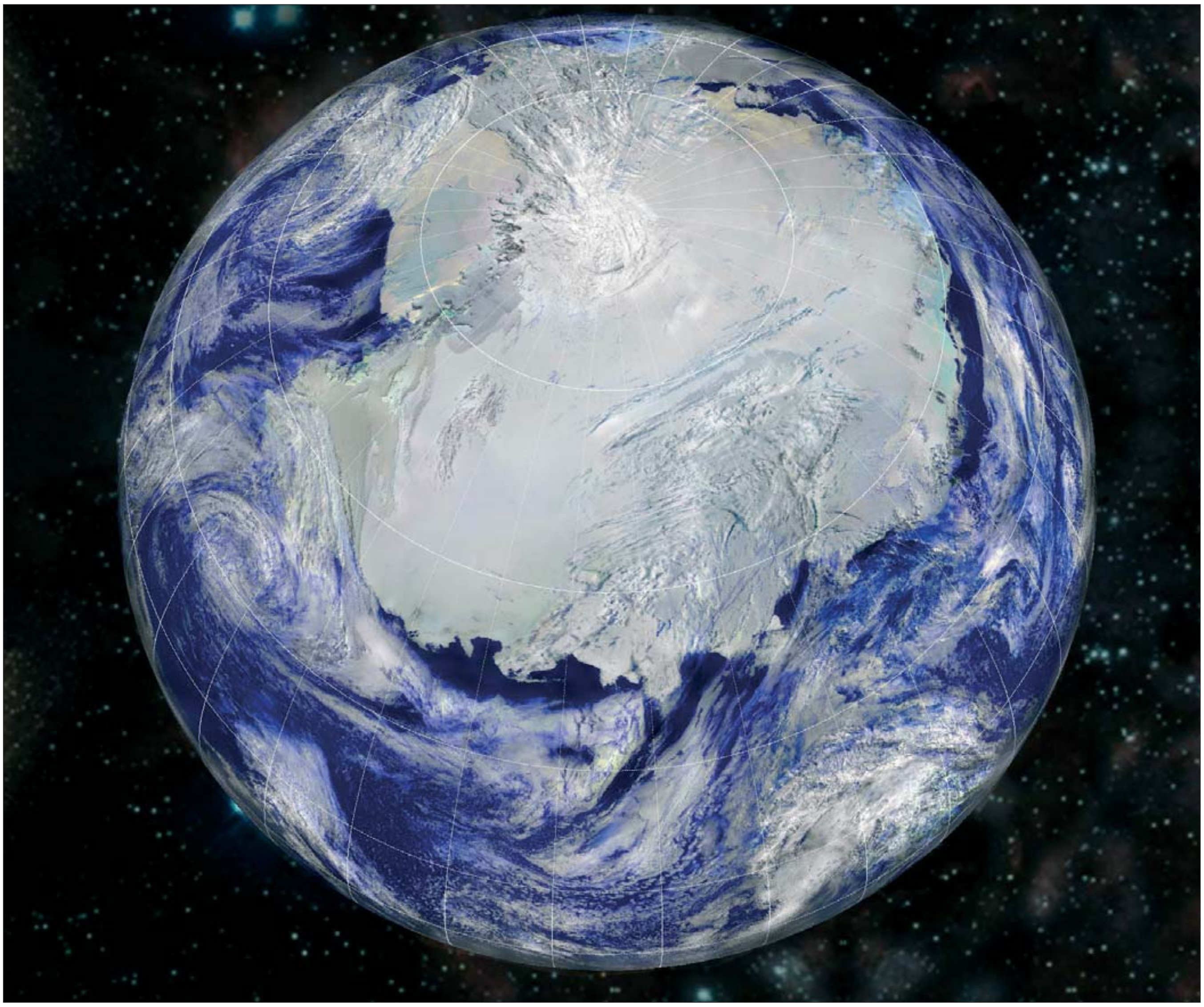


Image: National Satellite Meteorological Center, China Meteorological Administration

Composite imagery of the Antarctic by FY-1C GDPT Channel 1,2,3

the wide-field-of-view imager. Both sides agreed that the CBERS-1 would be assembled and integrated in China, and CBERS-2 in Brazil. CBERS-1 was successfully launched from China's Taiyuan satellite launch center on 14 October 1999. On 2 March 2002, the satellite was officially delivered for service. CBERS-1 has operated successfully during its two-year life-expectancy, and more than 230,000 satellite data pictures have been received from it. These have been widely applied in various areas of social and economic development for both countries.

CBERS initiated the first high-tech space cooperation between two developing countries, and former Chinese president Jiang Zemin hailed the project as an "excellent example of south-south cooperation." Brazilian president Fernando Henrique Cardoso also spoke highly of the cooperation. Following the successful launch of CBERS-1 in October 1999 and CBERS-2 in October 2003, the governments of China and Brazil signed an additional protocol to jointly develop CBERS-2B, CBERS-3 and CBERS-4 and to cooperate in a data application system, which kept the continuity of the China-Brazil Earth Resources Satellite data and broadened its application within regional and global scopes. CBERS-O2B was launched successfully on 19 September 2007, and is a core contribution to the Earth Observation Ministerial Summit.

Ocean satellite

China's first Ocean satellite (HY-1) is an experimental and operational satellite for detecting ocean colour and sea surface temperature. It was successfully launched on 15 May 2002 as a piggyback satellite on the FY-1D satellite using the Long March rocket. The payloads on satellite include a ten-band Chinese Ocean Colour and Temperature Scanner (COCTS) and a four-band CCD imager. HY-1 satellite is the beginning of a new era of China's ocean remote sensing; it also ended China's historic lack of ocean satellites. It has an operational lifespan of nearly two years and is used widely for marine environmental monitoring. The second Chinese ocean colour satellite, HY-1B, was successfully sent into orbit on 11 April 2007. The Ocean satellite series will be developed soon.

The main use of HY satellite is to detect the marine environmental parameters of the China Seas, including chlorophyll concentration, suspended sediment concentration, dissolved organic matter and pollutants, as well as sea surface temperature. The satellite will play an important role in developing and utilizing the marine bio-resources, constructing and managing the harbour, detecting ocean pollution, investigating and developing coastal resources and studying global environmental changes.

Other satellites

A small satellite called Beijing No. 1, created with the cooperation of Beijing Land-view Mapping Information Technology Co., Ltd. and Surrey Satellite Technology Co., Ltd., was launched on 27 October 2005. Its sensor measures four metres, and it is considered to have the highest resolution among all the transmission-type micro-satellites made in China. The satellite can send 32-metre long spectrums and cover an area of 600 kilometres. It has the greatest width among the same type of satellites produced in the world. The satellite can work in space for at least five years.

In the coming few years, China will create an environment and disaster monitoring satellite constellation by deploying a number of optic and synthetic aperture mini-satellites in space. The satellite constellation will become the world's first space-earth based integrated disaster management system, taking advantage of both ground disaster information systems and space resources. The constellation will be constructed in two phases. Phase I was completed between 2005 and 2006, during which two optic mini-satellites and one synthetic aperture mini-satellite were deployed. The 2+1 deployment pattern will produce a 48-hour satellite return visit capacity to meet partial disasters alleviation needs. The Phase II project is scheduled to become operational in 2010. By that time the 4+4 deployment pattern (four optic mini-satellites and four synthetic aperture mini-satellites) will make a 12-hour return visit possible.

China Integrated Earth Observation System; a 10-year plan

In response to the international GEOSS 10-Year Implementation Plan, China is now organizing the experts of different ministries and commissions to schedule the China Earth Observation 10-Year Plan, which will be made up of one collectivity section and five important observation system plans: the China climate observation system plan; the China atmosphere chemistry observation system plan; the China ocean observation system plan; the China hydro cycle observation research plan, and the China carbon cycle observation research plan.

Meanwhile, the Chinese Ministry of Science and Technology has added the 'Earth Observation and Navigation Techniques' research field to the National High Technique Research and Development Program, and expects to establish an integrated research and development system for Chinese Earth observation and navigation technology.

China Meteorological Administration, donation of FENGYUNCast user stations

International cooperation

China encourages bilateral and multilateral international and regional cooperation in space programmes. Since 1985, China has signed a series of intergovernmental and interdepartmental agreements, protocols and memorandums on space science and technology and its application in foreign countries, and has established a long-term cooperative relationship with these countries.

The Galileo project is the largest cooperation project in science and technology between China and EU so far. China and the European Space Agency (ESA) successfully launched TC-1 and TC-2 and implemented the Geo-space Double Star Exploration Project, managed by China and ESA. In 1997, the Chinese Ministry of Science and Technology and ESA began long-term cooperation on projects such as the applications of ERS-1/2 satellite data and the Dragon Project in 2003 for the application of ENVISAT data in the field of agriculture, forestry, environment and city planning. They also began working together on exchanges and training in aerospace field.

China, is working in close cooperation with EUMETSAT, the National Oceanic and Atmospheric Administration (NOAA), the World Meteorological Organizatoin (WMO) and many prospective data provider partners to develop GEONETCast, a global network of satellite-based data dissemination systems providing environmental data to a worldwide user community. China attaches great importance to the Asia-Pacific region. The China Meteorological Administration, on behalf of the Chinese Government, donated six sets of FENGYUNCast user receiving stations to Bangladesh, Indonesia, Iran, Mongolia, Pakistan and Thailand in 2006. In October 2007, another 11 sets of FENGYUNCast user receiving stations were donated to the Democratic People's Republic of Korea, Kyrghyz, the Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, the Philippines, Sri Lanka, Tajikistan, Uzbekistan and Vietnam. At present, 17 countries in the Asia-Pacific region are able to receive Earth observation data through the FENGYUNCast. In this regard, a positive impact has been made in initiatives for disaster prevention and reduction, economic and social development and promoting the implementation of GEOSS in the region.

Building the GEOSS is an inexorable trend whether due to the demands of society or the development of science and technology. This will establish long-term and stable Earth observation satellite systems and coordinated national satellite remote sensing application systems, which are especially designed for specific departmental operations. China will continuously promote the establishment of the GEOSS, working to realize stereo viewing and dynamic monitoring on land, atmosphere and ocean the world over.

Getting the full picture: the European Commission and GEOSS

European Commission

The European Commission is a major contributor to the Global Earth Observation System of Systems (GEOSS). The policies of the European Union (EU) in environment, agriculture, fisheries, transport and energy place Europe at the forefront of international negotiations concerning global warming and biodiversity, all within a realistic, sustainable development approach.

In this context, the European Commission provides support to Europe-wide coordination actions to encourage a strong European contribution to the GEOSS. These contributions include many national initiatives in the 27 EU member states, as well as programmes led by the European Environment Agency and by inter-governmental European organizations such as the European Space Agency (ESA, 17 member states), the European Organization for the Exploitation of Meteorological Satellites (Eumetsat, 19 member states), the European Centre for Medium Range Forecasting (ECMWF, 18 member states) and many others.

The Global Monitoring for Environment and Security (GMES) initiative, the Framework Programme of Community Research, an ambitious environmental data policy, and a development policy in the areas of science and technology are the pillars that make Europe a major world actor in research and monitoring of the global environment.

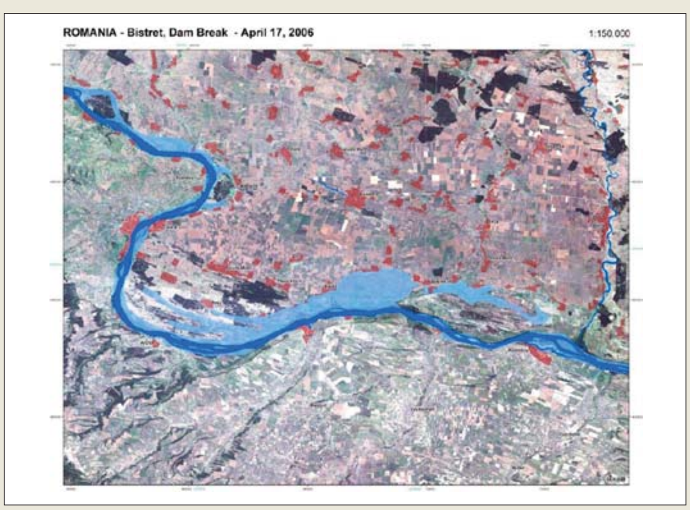
Operational services (GMES)

GMES is the European response to the needs of citizens in Europe to access reliable information on the status and evolution of their environment and ensure improved security. GMES aims to deliver operational information services, based on Earth monitoring data, (collected from space, air, water and land) that correspond to identified users' needs and can support EU policies.

GMES is not limited to the boundaries of the EU, but is foreseen to support the implementation and monitoring of European policies with global reach too.

The operational services are gradually built on existing operational capacities and experiences gained from projects funded at national level in Europe and by the European Commission and the ESA. The service development is continually accompanied by user consultations at national as well as European level in

GMES Emergency Response Core Service



With GMES, European civil protection agencies will have access to a 24/7 service delivering information that facilitates their interventions and contributes to saving lives during extreme events

Source: PREVIEW, RISK-EOS, RESPOND, TERRAFIRMA Projects order to deliver a reliable, fully operational and user-driven service portfolio by 2012.

The priority areas selected for such operational services are emergency response, land, marine and atmosphere. The target date for demonstrating the early phases of such operational services is the end of 2008, but significant progress has already been made toward achieving this goal.

GMES Emergency Response Core Service — The objective of the Emergency Response Core Service is to reinforce the capacity to respond to emergency situations associated with meteorologically-driven hazards (e.g. storms, fire, floods), geophysical hazards (e.g. earthquakes, tsunamis, volcanic eruptions, landslides), and deliberate and accidental man-made disasters and humanitarian disasters.

The highest priority of the service is to improve an immediate response to disastrous events through the robust rapid mapping capacity. The service will evolve to cover crisis prevention and early warning systems as well as post crisis reconstruction, situation assessments and monitoring of post crisis development — this is particularly relevant to the scope of the service outside the EU. The ongoing documentation of the risk vulnerabilities and development of harmonized risk level nomenclature is another benefit of the service evolution process.

GMES Land Monitoring Core Service — The GMES Land Monitoring Core Service aims to provide timely, continuous and independent observations about the use of soil and other land resources and changes in the land environment for responsible and farsighted policy-making.

The Land Monitoring Core Service is targeting a wide spectrum of terrestrial parameters (land use, soil degradation, crop patterns, yield forecasts, impact of agriculture on environment, forest cover and biodiversity, quality of water bodies etc.). Once operational, it will address many of the GEOSS societal benefit areas such as water, ecosystems, and agriculture.

GMES Marine Core Service — The Marine Core Service aims to produce regular and systematic reference information on the sea state and dynamics of the global ocean and regional European seas. This service is expected to include real-time and archived observational data to provide information about relevant variables needed to describe sea state and the primary ecosystem. Additionally it will include assimilation and modelling capacity based on a global and several regional models.

Once operational, the Marine Core Service will address most of the GEOSS societal benefit areas and in particular disasters, energy, climate, water, weather and ecosystems.

GMES Atmosphere Core Service — The Atmosphere Core Service will deliver standard European and global information products and information services about the atmosphere in order to support European policies and provide information on global issues linked to the processes in the atmosphere and their effects. The Atmosphere Core Service will in particular deal with aspects related to air quality and climate change monitoring. Once operational, it will address most of the GEOSS societal benefit areas and in particular health, climate and weather.

Research programmes

In parallel with the GMES core services, major research projects in the fields of environment and various applications of information and communication technologies to support sustainable development are funded by the EU and conducted by European consortia.

Environment and climate change — The nature of environmental research is such that Earth observation data and activities are needed for most of the topics of the environment theme supported through the Framework Programme of Community Research (FP). This point, implicitly in the previous FPs, was outlined in the 6th FP (FP6), and now appears explicitly in the recently-launched 7th FP (FP7), which covers the year 2007-2013. A specific section on Earth Observation was introduced under the environment theme of the FP7 program. Moreover, the FP7 decision makes an explicit reference to the GEOSS initiative with the aim to support the development of Earth and ocean observation systems and monitoring methods for the environment and sustainable development.

Many projects supported under the FP6 Environment theme already contribute to GEOSS. This is the case, for instance, with the Tropical Eastern North Atlantic Time-Series Observatory (TENATSO) project, which studies the dynamics of the North Atlantic Ocean. Also, the

The FP7 actions are directed towards:

1. *Integrating European research activities within GEOSS*
   Projects will facilitate the integration of European Earth observation environmental research relevant to GEOSS through collaboration with similar existing initiatives in other continents/countries to the GEOSS.

2. *Crosscutting research activities relevant to GEOSS*
   Projects will develop crosscutting research activities relevant to the societal benefit areas of GEOSS in the environment domain.

3. *Enabling emerging Earth observation systems*
   Projects will support the development of European Earth observation systems and related activities in areas of environmental research needed for GEOSS where observing/monitoring systems are lacking or need to be significantly completed.

4. *Developing capacity building activities in the domain of Earth observation*
   The projects will provide support to international research initiatives to contribute to observing systems and safeguard/protect observation data in countries where capacities in the domain of Earth observation need to be developed.

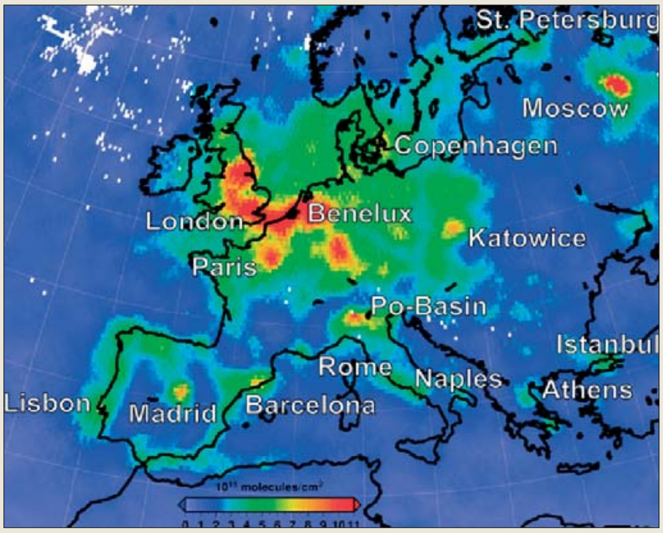
Following the first actions started in 2007, a significant effort will be made in 2008 to contribute to:

- Development of the necessary architecture and data management approach to bridge activities under the Infrastructure for Spatial Information in Europe (INSPIRE) directive and tasks overseen by the GEOSS Architecture and Data Committee
- Monitoring and assessment of the impact of energy exploitation on the environment
- Monitoring and observation of oxygen depletion in all the components of the Earth system
- Building observation capacities in the new countries of the EU and third countries.

Beyond 2008 key activities could be launched to:

- Structure Earth observation capabilities in Europe
- Contribute to Earth observation and monitoring required for meteorological hazards
- Support Earth observation activities for the European Technology Platform on Mineral Resources
- Investigate environment and health issues.

GMES Atmosphere Core Service



Air quality over Europe, showing the impact of large urban and industrial concentrations

Source: GMES, PROMOTE Projects

Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) project is focused on the effect of global warming on the Arctic region, and the Global Earth Observation and Monitoring of the atmosphere (GEOMON) project measures and models the fluxes of carbon dioxide through the atmosphere.

The first actions to be supported under the Environment theme of FP7 will deal with priority areas of GEOSS, namely monitoring of the carbon cycle at global level; contributing to a global biodiversity observation system; monitoring the ocean interior, seafloor, and sub-seafloor; developing a global soil observing system; building a geo-resource information system for Africa; improving observing systems for water resource management, and developing GEONETCast applications for developing countries.

The coordinated development of data and data processing systems, data archiving, and spatial data infrastructures for effective data updating and exchange should be continued. Finally, modelling and prediction capabilities will need to be improved and expanded so that a new generation of models is made available to ensure advancement in predicting high-impact events.

Information and communication technology — In the field of information and communication technology applied to environment management, the main research objectives are to design tools and systems architectures for improved technical interoperability, and to develop or demonstrate collaborative systems for environmental management.

Many projects co-funded under the FP6 programme are directly contributing to some of the ongoing GEOSS tasks, for example on Sensor Web Enablement (SWE). This technique can be described as follows: "With advances in communications technology and ground-based in situ technologies it is now feasible to consider webs of sensors on all types of platforms with rapid access for observations. This technology has been developed under the names of sensor webs and sensor networks. A sensor web is a system of distributed sensors that can be deployed to monitor and explore new environments."

Demonstration projects such as OSIRIS, led by industry, apply this technique to innovative in situ monitoring systems, in particular based on intelligent low-cost sensors, self-organizing reconfigurable sensor networks and sensor web architectures for environmental data acquisition and integration. In addition, modern tools are developed for public safety communication, including work on the integration of alert systems, communication to and from the citizen and rapidly deployable emergency telecommunications systems.

Legal framework

The Infrastructure for Spatial Information in Europe (INSPIRE) directive adopted by the EU in 2006 provides measures that address exchange, sharing, access and use of interoperable spatial data and services in Europe. INSPIRE will also contribute to establishing global standards for geospatial data and information.

INSPIRE is a European directive that establishes the legal framework for setting up and operating an Infrastructure for spatial information in Europe, based on infrastructures operated by member states. The purpose of such infrastructure is to support formulation, implementation, monitoring and evaluation of the EU's environmental policies and overcome major barriers still impeding availability and accessibility of pertinent data: inconsistencies in data collection with gaps and duplication, incomplete documentation of available data, incompatibility of spatial data sets and services, lack of interoperability of infrastructures, cultural, institutional, financial and legal blockage preventing data sharing.

The collaborative process leading to the formulation of the directive was based upon the following principles:

- Spatial data should be collected once and maintained where most appropriate
- Seamless combination from different sources across the EU should be possible
- Data collected at one level should be shared with other levels of government

The Ny-Ålesund station on Spitsbergen

The station will play an important role in the implementation of GEOMON to study key compounds like HCL involved in stratospheric ozone depletion

Source: Osiris project

A Sensor Web enabled environmental data collection network

Source: Osiris project

- Conditions of access to data required for good governance should not impede their extensive use
- Retrieval of data, evaluation of its relevance and its conditions of use for a specific purpose should be easy.

The *GEOSS 10-year Implementation Plan* advocates the use of existing spatial data infrastructure components as institutional and technical precedents in areas such as geodetic reference frames, common geographic data, standard protocols and interoperable system interfaces.

INSPIRE contributes to the crosscutting initiatives, technologies and systems of GEOSS through the provision of standard protocols improving data access and sharing, interoperable system interfaces, mechanisms for allocation, transfer and use of data and detailed specifications and standards. It demonstrates the value of an underlying architecture based upon a system-of-systems approach through the infrastructures operated by member states.

Development

The World Summit on Sustainable Development in 2001 recognized the use of satellite data for sustainable development and an urgent need for action in Africa.

Several European activities concentrate on natural resources monitoring and food security, with programmes like the African Monitoring of the Environment for Sustainable Development (AMESD), to be implemented and coordinated by the African Union. AMESD is a first step in increasing the use of Earth observation data in natural resource management and in moving toward a continental approach to cross-border issues. Support to the African Union Council's department responsible for environment is foreseen in the area of environment integration as a component of the larger programme to develop African capacity.

Whilst addressing all African, Caribbean and Pacific (ACP) countries, the focus will be on the African continent in the initial phase. The ACP Observatory will support three main domains: sustainable management of natural resources, food security, and crisis response/monitoring for security. A thematic and geographical coordination mechanism will be put in place between the different actions.

The European Development Consensus emphasizes the importance of the integration of development objectives into its research and development and innovation policies. The EU will continue to assist developing countries in enhancing their domestic capacities in the areas of science and technology. The EU should ensure that its principles, and values such as convergence and harmonization, effective participation and ownership by developing countries and predominant focus on user needs, are effectively implemented within GEOSS. Furthermore, international endeavours such as the Global Knowledge Partnership emphasize the urgent need to stimulate conservation and use of indigenous and local knowledge in a world with increasing exogenous information overload. A central aspect of these efforts will be the development of local capabilities to generate reliable information on the location, condition and evolution of environmental resources, food availability and crisis situations.

Conclusion

The European Commission is actively contributing to the implementation of the GEOSS through major initiatives like GMES, the FP of Community Research, INSPIRE and capacity building activities (AMESD and PUMA).

GEOSS represents a major international cooperation framework for solving global problems affecting our planet. It provides a unique platform for the exchange of and access to strategic observations needed to better understand the Earth system and its functioning. The understanding of the physical and biochemical mechanisms affecting the environment as well as the monitoring of the impact of policies is a cornerstone of the sustainable economic development promoted by Europe.

GMES and GEOSS: towards a new era in Earth observation

V. Liebig, Director, ESA Earth Observation Programmes

The year 2007 marks the fiftieth anniversary of the beginning of the space era. During half a century of space flight, we learned to live in space, to explore it and to profit from it. Paradoxically, one of the most striking discoveries proved to be the starting point: Earth. Understanding the complexity of Earth remains a paramount challenge. Earth observation satellites are our constant assistants in this quest. Their era began less than two years after Sputnik, before the first humans were sent into space, showing an intrinsic interest in looking back on Earth right from the beginning of the space age.

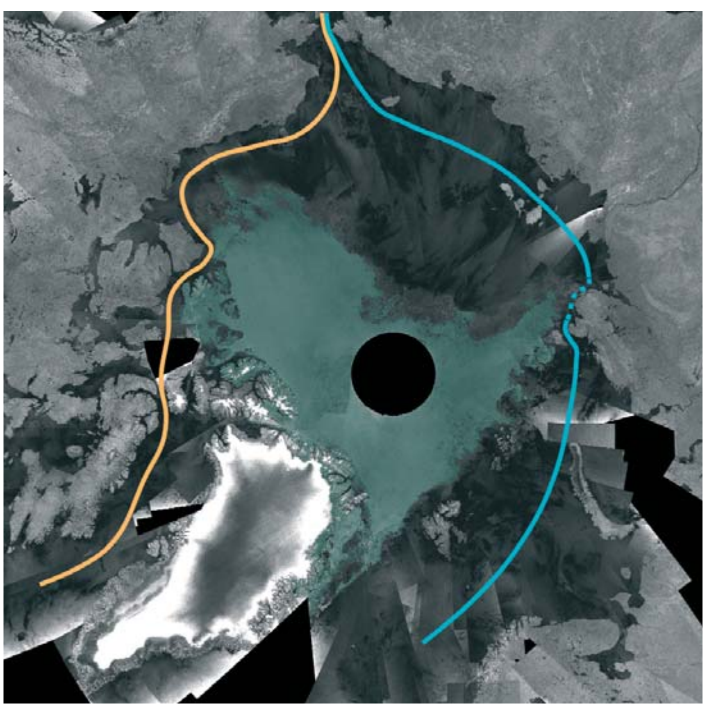
Space capacities

Today, Earth observation satellites are used for a wealth of scientific studies and applications. When the United Nations Intergovernmental Panel on Climate Change (IPCC) published its *Fourth Climate Assessment Report* in spring 2007, focusing international media attention once more on the climate change debate, a significant part of the findings presented was based on satellite data. Their observations have detected an accelerated level of global warming and sea level rise; they have shown the shrinking of the Arctic ice cover and a decrease in snow extending to both hemispheres; they help us to understanding global change processes by monitoring clouds and aerosols, greenhouse gas concentrations, vegetation extent, ocean salinity and many other aspects. At the same time, data from space are used for a wealth of practical applications, ranging from oil spill, crop or iceberg monitoring to disaster management.

In spite of the progress made over the past years, demand has grown faster. We need accurate, long-term data for periods allowing us to make the correct assumptions, build the right models and undertake predictions. Data continuity is therefore a key challenge for space agencies and governments.

Likewise, we need to progress in deploying evolutionary sensors and systems, based on previous experience but also building on new technologies and focused needs. The Earth Explorer missions of the European Space Agency (ESA) are an effort to launch high-end satellites targeted at specific science areas.

Image: ESA



Envisat ASAR mosaic of the Arctic Ocean for early September 2007, clearly showing the most direct route of the Northwest Passage open (orange line) and the Northeast passage only partially blocked (blue line). The dark grey colour represents the ice-free areas, while green represents areas with sea ice

A new era for European Earth observation

The new era we are facing is not marked by a major step forward in technology — it is the conception that space is a key asset for the *political* Europe. And it is the political conception that a key contribution of space lies in the delivery of applications and services to the European citizen. The European Space Policy adopted by ministers at the Space Council on 22 May 2007 emphasizes "the unique contributions space-based systems can provide to the overall research effort and to applications responding to European policies and objectives".[1] The political recognition of space assets for the benefit of life on Earth is a decisive step forward. A concerted policy among the nations of Europe that envisages concrete goals for space exploration and utilization is its direct outflow.

Two flagship programmes are being developed as the first tangibles of the cooperation between the European Union (represented by the European Commission) and ESA, responding to the calls of the European Space

Policy: these are Galileo, and Global Monitoring for Environment and Security (GMES).

Europe and the making of GMES

GMES is the first operational monitoring system for environment and security. Its goal is to guarantee services to support EU and national policies, responding to user needs and requirements. Having started in 1998 with a manifesto calling for a global, satellite-based monitoring system for Europe, GMES is today in the process of deploying what will become a full European capacity. The European Commission, acting on behalf of the European Union, and ESA are developing GMES together, with ESA being responsible for the management and coordination of the space component.

In order to realize a global monitoring capacity for Europe from space, three things are essential: an infrastructure comprising satellites and ground segments; the coordination of this infrastructure, and the guarantee of long-term system sustainability. We are responding to the first requirement by developing and launching dedicated satellites, called the Sentinels. They are based on a careful user-driven gap-analysis with regard to future data needs versus existing and planned capacities, and comprise five missions: a SAR imaging mission; a multi-spectral imaging mission; a global ocean and land monitoring mission, and two missions for atmospheric monitoring both from a geostationary and a low Earth orbit, plus the related ground segments. Whereas the industrial work for the first three Sentinels is taking off at the moment, the last two will likely be embarked as payloads on the next-generation EUMETSAT missions.

With regard to the second requirement — coordination — ESA is in charge of establishing a mechanism to concert the multitude of European observational missions, like national missions, EUMETSAT missions or commercial missions. Data access and data provision to European users must be streamlined. Only with a coordinated multi-element infrastructure throughout Europe, can GMES be a true success. To achieve this, ESA can build on its experience as third-party mission coordinator for almost 30 years.

GMES has to run as an 'end-to-end capacity', so satellite and ground segment infrastructures are only one side of the coin. Any concrete service, like the daily forecast of sea ice movement in northern Europe, is a complex infrastructure in itself! It requires development, testing and dissemination. Therefore ESA has, since 2002, progressed in the establishment of the so-called 'GMES Service Element', preoperational services for European policy areas. Today, having matured and successfully proven the concept of operational Earth observation, these services are injected into the three 'fast-track services' set up by the European Commission, to form the nucleus of actual GMES Services as of 2008 onwards. Those three key areas focus on land monitoring, marine monitoring and emergency response, covering a wide area of policy applications. Two additional services on atmosphere monitoring and security will be added.

A contribution to the global effort of GEO

What do the four letters 'G-M-E-S' indeed give to citizens, and how can they intermediately contribute to global efforts undertaken by GEO? GMES is an independent, sustainable capacity. Its independence allows it to act on the basis of its own capabilities, for example in environmental obligation verification. Its sustainability will allow it to provide inputs or lead the discussion for global, common political goals. Europe can take this responsibility for the long-term based on a coordinated structure, abandoning dispersed or ad-hoc acting. Last but not least, GMES is the European contribution to the Global Earth Observation System of Systems (GEOSS).

Image: ESA — P. Carril

GMES Sentinel-1 artist's impression

For the last two years, ESA has been chairing the Strategic Implementation Team (SIT) of CEOS. CEOS has been defined as the appropriate body coordinating the space segment for GEO, and the SIT has been asked to work on the responses of countries with Earth observation capacities to GEOSS and GCOS requirements. In this context the concept of virtual constellations has been developed, and the next years will show whether this concept will be successfully implemented. Space is an essential, integral part of understanding and managing Earth, and likewise we face the challenge of translating the potential that space offers into concrete deliverables.

Outlook

GMES might be the nutshell vision for a global observational, operational capacity. But more than that, it is no longer a vision; it is a concrete system with hardware and applications in the making. It is a mosaic piece for the GEO picture, but it is in itself a mosaic, successfully streamlining Europe's operational Earth observation.

If GEOSS is successful, space assets will not only be a tool for certain regions of the world, but for all citizens of this planet.

Implementing GEOSS in Germany

Jörn Hoffmann, D-GEO Secretariat, German Aerospace Center (DLR), Space Agency

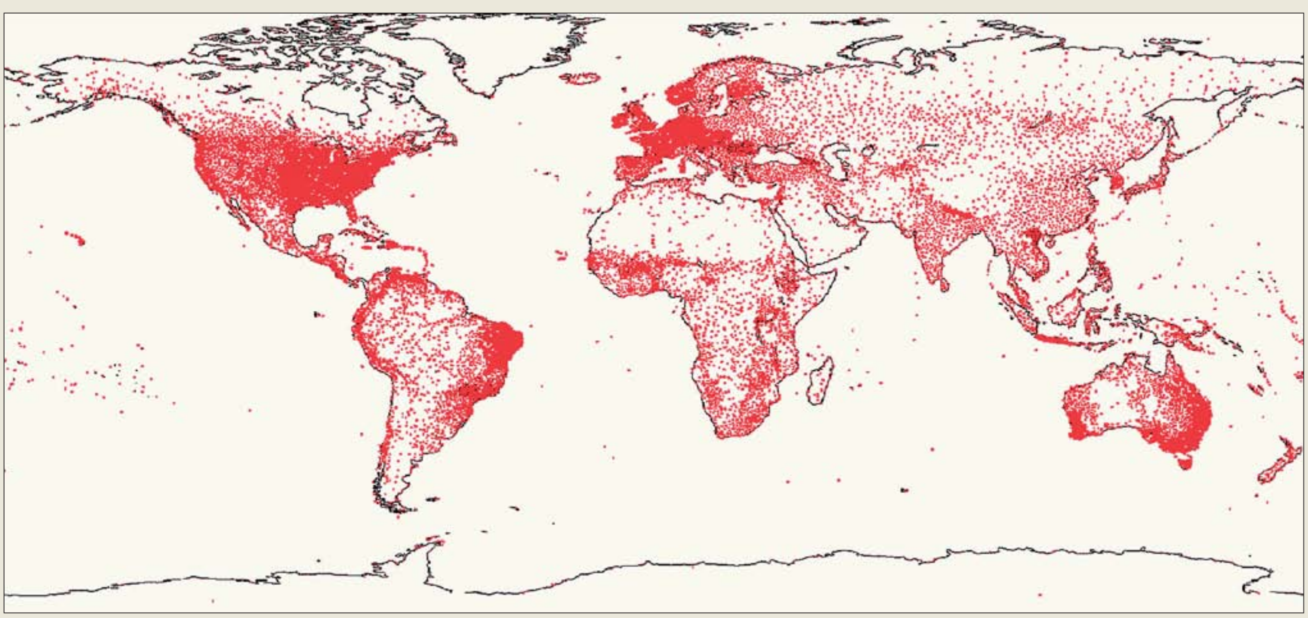
From the beginning Germany has been actively engaged in building the foundations of the Global Earth Observing System of Systems (GEOSS). Germany believes that coordinating earth observation (EO) activities internationally is a useful and effective means for improving knowledge about the state and processes of the earth system. While this improved understanding can benefit society in many ways, it is without an equal for defining knowledge-based environmental policies, in particular with respect to climate change.

The value that GEOSS can bring to the global society has been recognized by the German government, which has committed to support GEO in implementing GEOSS. In addition the government have realized that GEOSS also opens specific opportunities for providers and users of EO information in Germany. The German government has therefore placed the responsibility to represent Germany in GEO and lead the national implementation of GEOSS with the Federal Ministry of Transport, Building and Urban Affairs (BMVBS). This organization also oversees several important federal agencies responsible for various aspects of earth observation. These include the German Meteorological Service (Deutscher Wetterdienst, DWD), the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH), the Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG), and the Federal Office for Building and Regional Planning (Bundesamtes für Bauwesen und Raumordnung, BBR).

These agencies also host prominent GEOSS-relevant service centres in Germany and are therefore important national contributors to GEOSS. The responsibility of BMVBS thus underlines the German expectation that GEOSS will not only benefit research projects, but also support operational agencies in fulfilling their mandate and directly serve German citizens.

To identify national priorities and recommend concrete steps towards implementing GEOSS at the national level BMVBS has set up an advisory group (D-GEO), which comprises members from key federal agencies whose mandate includes the provision, interpretation or use of earth observation information. Since its creation this group has worked on identifying the key institutions concerned at the national level and the level of the federal

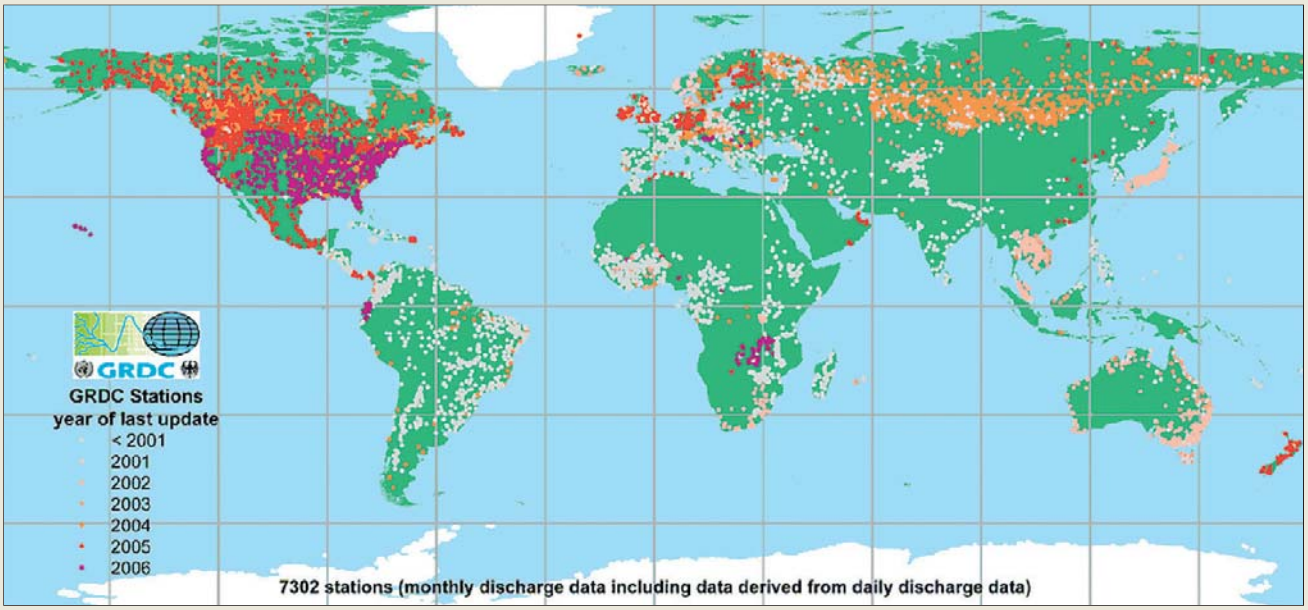
Precipitation stations in the GRDC database with 10-year data record



Spatial distribution of monthly in situ precipitation stations with at least ten years of data in GPCC Data base (Total number of stations in July 2006: 43028)

Source: Global Precipitation Climatology Centre

Global Runoff Data Centre



The Global Runoff Data Centre, operated by BfG, collects stores, and disseminates discharge data from rivers around the world

Source: Global Runoff Data Centre

states (*Länder*), their potential contributions, needs and requirements. During 2007 D-GEO drafted a national GEOSS implementation plan (DGIP) that will be presented to the government during 2008. A strategic summary will be available before the end of 2007.

The main objective of this implementation plan is to present national priorities and recommend a strategy for realizing GEOSS benefits through concrete steps. A national GEO secretariat has been set up to coordinate the German participation in the GEO committees and federate the involvement of key national stakeholders. Through its coordination of the D-GEO group and national information activities the D-GEO secretariat has been very successful in raising the profile of GEO in Germany. German institutions and experts are contributing to well over 50 of the 72 tasks in the current work plan, directly, and indirectly through international participating organizations. Many of the most important German contributions to GEOSS are made through European and international programs and initiatives.

At the international level Germany contributes among others to the Global Observing System (GOS) of the World Meteorological Organization (WMO), and the Global Ocean Observing System of the International Oceanographic Commission (IOC) of UNESCO. At the European level it contributes for example to the Global Monitoring for Environment and Security (GMES) program, activities in the context of the European directive for establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), the earth observation satellite programs of the European Space Agency (ESA), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

These projects highlight that the principal framework of Germany's involvement in GEO is a European one. The German participation in GEO and contribution to GEOSS uses the available European and other international mechanisms and institutions where this is possible and effective.

National priorities for building and implementing GEOSS are driven by long-term political and societal challenges that can benefit from internationally coordinated earth observation activities. During the current, initial phase of building GEOSS, fundamental cross-cutting issues of the system architecture and data policy must receive the appropriate attention. User engagement at different levels (eg federal agencies, Länder agencies, EO service industry) is viewed as equally fundamental to the long-term support and ultimate success of GEO.

At a technical level we try to ensure that the data and information standards and protocols implemented for INSPIRE or the German national spatial data infrastructure (GDI-DE), which conforms to INSPIRE, feed into the work of the relevant GEO tasks to ensure compatibility. This is achieved primarily by the personal involvement of the experts tasked with setting up the GDI-DE in the GEO architecture tasks.

Several of the national data policies will need to be reviewed over the coming months and years for implementing INSPIRE and GMES, in particular. GEOSS will likely encourage a broadening of this discussion at the national level.

Activities to engage additional users in Germany have been initiated by the national GEO secretariat and it is likely that this will be pursued even more vigorously after the national GEOSS implementation plan has been published. Again, these activities can build on and often coincide with user engagement for GMES, thus amplifying its effectiveness.

Germany was actively involved in the preparation of GEO's 10-Year Implementation Plan (TYIP) and its more extensive reference document. Consequently, thematic priorities in Germany are reflected in this plan. And in fact, as the TYIP focuses on global issues, most of them also concern Germany. Some issues receive particular attention though, in their prominence on the political agenda, their echo in the media or their relevance for the German business community. Climate change is one of these issues, sustainable energy, water supply and disaster management are others. Importantly, these issues are each understood in their national and global facets. Not only have these issues stirred public discussion and prompted the development of national policies; they have also strongly influenced German development cooperation for many years.

To mitigate the effects of climate change Germany is highly active in pursuing the evolution of international agreements on climate change, and implementing them nationally. Germany also set up a national research program, '*klimazwei*', which focuses on investigating adaptation measures for climate change. This is in addition to a substantial climate change priority in the current seventh European research framework programme.

Climate-relevant observation networks in Germany are coordinated with international efforts through the World Meteorological Organization (WMO) and the activities of its world climate programme in particular. These are the main building blocks of GEOSS in the 'climate' context — and Germany has both benefited and contributed to these efforts for several years. Because the relevant observation networks are operated by different national entities, national coordinators have been identified for the Global Climate Observing System (GCOS) at the DWD and for the Global Ocean Observing System (GOOS) at the Federal Maritime and Hydrographic Agency, respectively. These arrangements facilitate the international coordination.

International agreements on standards and protocols for climate monitoring, including the GCOS Climate Monitoring Principles, are implemented by the responsible national agencies. The DWD also funds and operates the Global Precipitation Climatology Centre (GPCC), which analyzes the global distribution of precipitation based on in situ observations. It also leads the EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF). Similarly, the Federal Institute of Hydrology has taken the responsibility for operating the Global Runoff Data Centre (GRDC), which collects, stores, and disseminates discharge data from rivers around the world. The World Data Center for Remote Sensing of the Atmosphere at the German Aerospace Center (DLR) and the Integrated Global Carbon Observation components of the Max-Planck Institute in Jena constitute other important German contributions in this context.

Even though Germany is rarely directly affected by major natural disasters like earthquakes, volcanic eruptions, or hurricanes, these events concern Germany through its many and diverse relationships with other countries. Also, Germany's high population density, concentration of economic value and sensitive infrastructure frequently result in relatively high damage figures due to storms or floods, even though the events themselves may not appear dramatic compared to those occurring in other parts of the world.

Operational processes using earth observation information for disaster management in Germany mainly exist in the form of severe weather warnings by the DWD and flood warning centres. However, substantial research and development activities during recent years have created competences and demonstrators that are now approaching a level of maturity to be considered for operational implementation. The Center for Satellite-Based Crisis Information (ZKI) at the German Remote Sensing Data Center (DLR-DFD) has demonstrated convincingly how satellite data can be integrated with other available information to support specific tasks in emergency response activities.

ZKI has contributed to GEOSS through several European research projects in preparation for GMES and has supported the activities of the International Charter Space and Major disasters. Another substantial contribution towards supporting GEOSS in achieving its goals in the 'disaster' area was the successful launch of the TerraSAR-X satellite. This was not only the most prominent achievement of the national space program during 2007, it will also be a valuable element of a future 'virtual constellation' for risk management.

The way forward

Numerous projects and systems for observing the state of the earth system and its changes have been implemented and are available as contributions to GEOSS. The crucial first steps for GEO, as well as at the German national level, involve coordinating the plethora of efforts and ensuring the long-term availability of the key systems.

The national GEO secretariat has been set up to coordinate EO initiatives across disciplines and organizational divides, bridging gaps between governmental agencies and research institutions within Germany. The secretariat is also responsible for connecting Germany to the international GEOSS.

The work of the D-GEO secretariat has been largely successful, and the D-GEO advisory group is making good progress towards presenting their national implementation plan. The next challenge will be to broaden participation in the D-GEO progress to stakeholders of those SBAs that do not yet make significant use of EO information, or are unaware of it. Bringing these players together and agreeing on common requirements for shared EO systems will constitute a substantial benefit from GEOSS in Germany.

Building and sustaining these shared systems in Germany and Europe will remain a national and European enterprise, though the activities will be coordinated with related activities around the world within GEOSS. Consequently, working to ensuring the long-term financing and operation of the European and German EO systems is the most significant contribution Germany can offer to GEOSS.

While GEO has helped raise the visibility of these systems and thereby supported arguments for their sustained operation or improvement, the main challenges remain with the owners of the system. Germany has been working hard to ensure a truly sustainable implementation of GMES by the European Union and will continue to do so. We will also continue to maintain national in situ networks, operate them according to agreed protocols and make data and metadata available through the national spatial data infrastructure, according to the provisions of the INSPIRE directive. And while we continue to support GEO in building GEOSS, we will be learning to use it in new ways, many of which we may not even be able to anticipate ourselves yet.

Earth observations — JAXA's role

Kazuo Umezawa, Japan Aerospace Exploration Agency

In the mid-1980s, several space organizations recognized the need for international coordination in the effective and efficient collection of Earth observation data. As a result, they decided to establish Committee on Earth Observation Satellites (CEOS).

Then, during the 1990s, CEOS members felt strongly that observation data should be utilized more effectively by research communities. The Integrated Global Observing Strategy (IGOS) was organized among communities focused on elements such as the ocean, land and atmosphere.

Today, IGOS has 14 international organizations including CEOS, which are undertaking work on several themes, including ocean, water and atmospheric chemistry. However, more work was needed as it became clear that satellite Earth observation could be indispensable to the public and society. This led to creation of GEOSS.

The second Earth Observation Summit was held in April 2004, and adopted the framework of a ten-year implementation plan, aimed at the establishment of an integrated earth observation system of systems known as the Global Earth Observation System of Systems (GEOSS).

Agreement on a ten-year Implementation plan for GEOSS was reached by the participating countries and organizations of the ad-hoc Group on Earth Observations (GEO) at the Third Earth Observation Summit held in Brussels, in February 2005; on that occasion GEO was also formally established.

Based on this background, the Council for Science and Technology Policy in Japan issued the *Earth Observation Promotion Strategy* in December 2004 to clearly state Japan's basic policy on Earth observation and identify important issues to be strategically resolved.

In addition, the Council for Science and Technology has proceeded collaterally with the consideration of essential policies for establishing the Third Science and Technology Basic Plan. The council indicated in its report that it is necessary to carefully select and promote significant technologies that form the basis for sustainable development of the nation. These will be promoted via a long-term national strategy.

As a sound policy decision toward ensuring the sustainability and welfare of mankind, and with consideration of the Japanese nation's prominent position in Earth observation, Japan's basic strategy on Earth observation consists of the following three aims:

1. Constructing an integrated Earth observation system driven by user needs
2. Maintaining Japan's autonomy while exercising leadership in the integration of international Earth observation systems
3. Establishing an Earth observation system through strengthened collaborative relationships with the Asia and Oceania regions.

In this context, the Japan Aerospace Exploration Agency (JAXA) has been developing a future Earth observation programme to contribute to GEOSS in cooperation with other space agencies. At the second summit, JAXA committed to contribute to GEOSS the use of satellites such as the Advanced Land Observing Satellite (ALOS), known as Daichi; the Greenhouse gases Observing Satellite (GOSAT), and the Global Precipitation Measurement (GPM) project, mainly focused on observations of disaster, global warming and water cycle. In addition, JAXA will propose a series of satellites for establishing a GEOSS to monitor climate change. JAXA is studying the Global Change Observation Mission (GCOM) to contribute to the process of study, the prediction of global change phenomena and the preservation of global environments.

ALOS

ALOS is the first step in JAXA's contribution to the safety and security of the world, which should be realized in the GEOSS era. The main mission of ALOS is mapping, which means that it also performs Earth observation, including disaster monitoring. ALOS images have been distributed around the world as a result of JAXA's signing the international charter Space and Major Disasters in 2005. These images are already being used in planning measures for disaster areas, which means that the first steps have been taken toward this goal.

Related ministries have been holding discussions and hearings on disaster monitoring, to generate ideas for future satellites. In addition, the Space Activities Commission is discussing four satellites that can observe the Earth at all times for future disaster monitoring. So apart from JAXA, the Japanese Governments, local governments and corporations are initiating these kinds of disaster prevention and reduction activities. In 2006, the private sector set up the Disaster Mitigation Strategy (DiMS) Forum with the aim of reducing damage from future disasters. This forum advises the Government, related ministries and local governments so they can respond quickly to disasters in Japan as well as other Asian countries. In addition to the space agency, industry, academia and governmental institutions have all started working on disaster issues.

International collaboration on ALOS made it possible to establish a network called Sentinel Asia, which uses satellite data for disaster management in the Asia-Pacific region. The network enables online sharing of disaster information such as images taken by Earth observation satellites, particularly in the Asian region, where the number of natural disasters is great. This activity is promoted by space agencies that are members of the Asia-Pacific Regional Space Agency Forum (APRSAF), and Asia's disaster-prevention institutions. Last year, two project team conferences were held with the participation of 19 countries, to discuss the utilization of satellite information in detail.

JAXA is also planning to launch the Wideband InterNetworking engineering test and Demonstration Satellite (WINDS) at the end of 2007. The satellite will especially benefit our Internet society by enabling speedier communications.

Sentinel Asia

Sentinel Asia is a very good example of an application of the societal benefits dealt with by GEOSS. In addition, it is also a good model of local user participation and capacity building for GEO.

Sentinel Asia aims to observe and monitor the disaster area in the Asian region. Sentinel Asia is a joint project of members of APRSAF in cooperation with disaster management organizations from the area. Nineteen Asian countries, 45 national organizations and seven international organizations currently participate in this project.

Data from MODIS and ALOS are used in relation to forest fire and floods, and it is expected that data from the Indian and Korean satellites will be available to this project soon. The system is such that observation data are delivered to local disaster management agencies through a data-sharing platform, which will be called Digital Asia. At the time of a disaster, ALOS will observe the disaster area cooperating with the Asian Disaster Prevention Center (ADRC). Furthermore, a capacity building programme to utilize these systems, satellite data and images will be carried out with the Asian Institute of Technology (AIT) of Thailand.

GOSAT

The Greenhouse gases Observing Satellite (GOSAT) project, which monitors the global distribution of greenhouse gases, is a Japanese contribution to understanding climate change. GOSAT will be launched in 2008, and will measure the columnar density of carbon dioxide and methane globally, every three days.

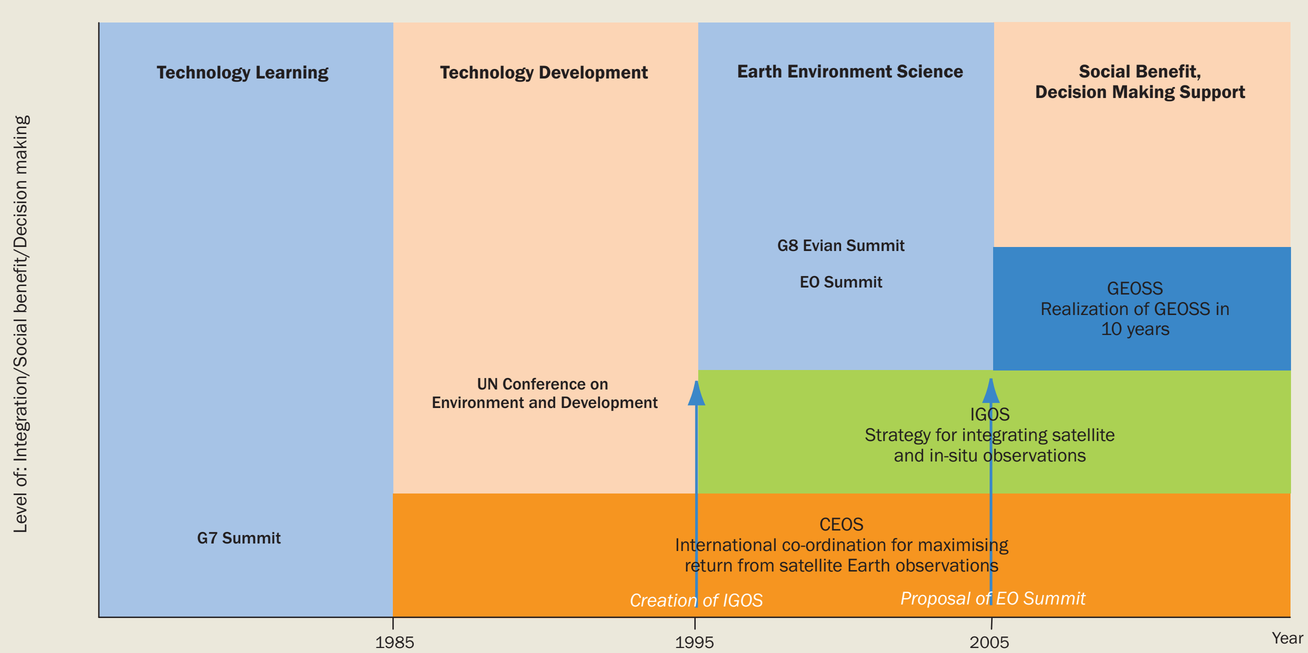
The analysis of observation data from GOSAT is expected to enable estimation of the amount of a discharged greenhouse gas on a per-continent level. Around the year 2015, JAXA is hoping to achieve a discharge estimation of greenhouse gas on a per-country level, through the improvement of the atmospheric model. GOSAT is expected to cooperate with the NASA project Orbiting Carbon Observatory (OCO), from which data will be available at the same period.

GCOM

Global Change Observation Mission (GCOM) is a project that aims to construct systems to enable observation of geophysical parameters over a long term about 10 to 15 years so that the global mechanism of climate change and water circulation can be clarified.

As mentioned in the 4th assessment report of the intergovernmental Panel on Climate (IPCC), warming of the climate system is unequivocal as is now evident from observations of increases in global average air and ocean temperatures and widespread melting of snow and ice. However, climate change signals are generally small and modulated by the natural variability, and also they are not necessary uniform over the Earth. Therefore,

International Coordination for Global Earth Observations



Credit: Copyright JAXA

the observing system of the climate variability should be stable, and should cover long-term period and entire Earth. GCOM is to be designed to have two polar orbiting satellite series and multiple generations to respond to the necessity.

GCOM is also expected to cooperate with the US National Polar-orbiting Operational Environmental Satellite System (NPOESS) to realize an integrated Earth observation system in the GEOSS context.

EarthCARE

The Earth Clouds, Aerosol and Radiation Explorer (EarthCARE) mission is a joint project of European Space Agency (ESA) and JAXA to measure the three dimensions structure of clouds and aerosol distribution with a combination of cloud radar and lidar in order to improve the predictability of global warming.

JAXA and Japanese National Institute of Information and Communications Technology (NICT) develop the space-borne cloud profiling radar (CPR) jointly for this mission.

GPM

Global Precipitation Measurement (GPM) is a follow-on and expanded mission of the current ongoing Tropical Rainfall Measuring Mission (TRMM). GPM is one of the Earth observation satellite programmes, mainly initiated by JAXA, the National Institute of Information and Communications Technology (NICT) and the National Aeronautics and Space Administration (NASA).

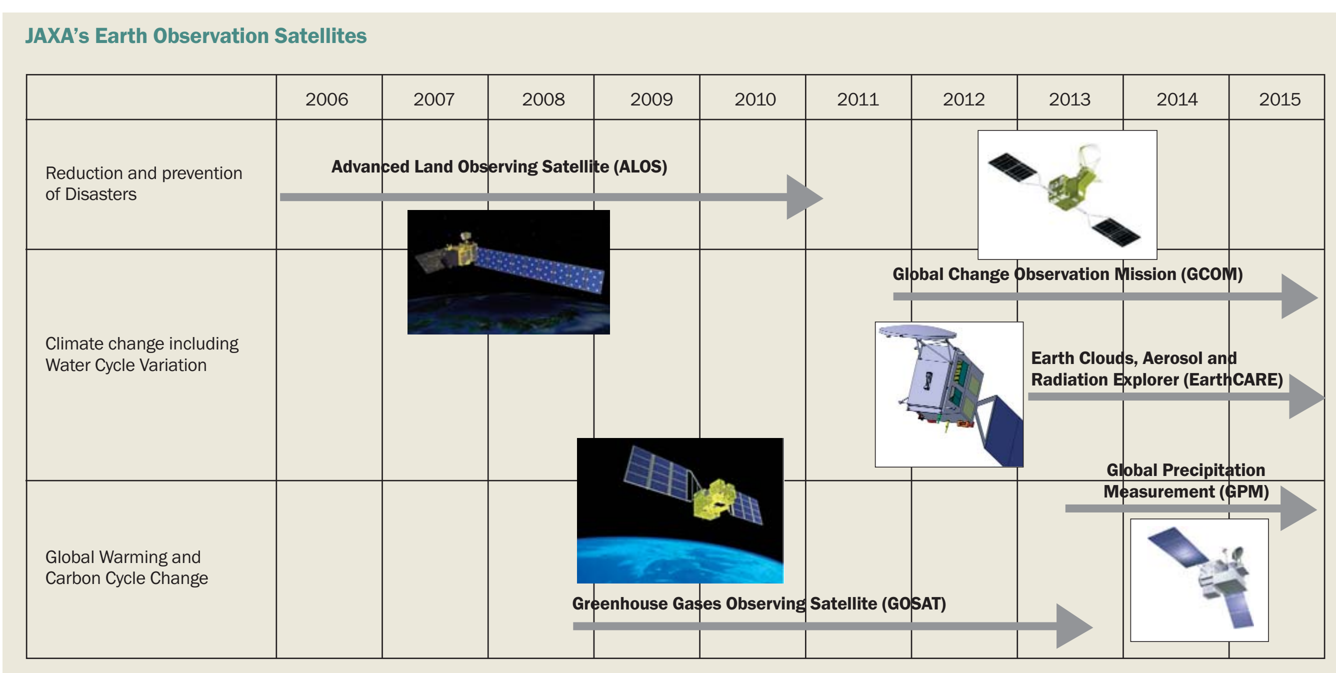
In addition to the core satellite, a sub-satellite constellation comprising around eight satellites will be launched by NASA, the European Space Agency (ESA) and other space organizations across the world. The microwave scanning radiometers aboard these eight polar orbit satellites collect and process data, making it possible to obtain global rainfall distribution every three hours. GPM plans to transmit this global rainfall distribution data in real time, so it can be used not only for scientific research, but also in social disciplines such as weather forecasting, flood prediction or water resource management.

Based on the anticipated success of GPM in realizing these objectives, a recent study has recommended that an operational programme of satellite-based global precipitation measurements be developed after GPM ends.[1] The Integrated Global Water Cycle Observing scheme (IGWCO) strongly supports GPM.

The GEOSS Ten-Year Implementation Plan Reference Document contains a target to facilitate the development of effective sensors and missions for precipitation (GPM), and the GEO 2006 Work Plan task (AR-06-10) endorses the timely implementation of GPM and encourages more nations to contribute to the GPM constellation.

The future

Although great things are expected of the GPM programme, there remains an enormous challenge given the need to sustain precipitation observations globally and continuously at high resolution. GPM is scheduled to operate in the period from 2013 to at least 2016. The CEOS Precipitation Constellation will explore how the observation programmes of all space agencies with an active interest in precipitation monitoring might be better combined, adapted, modified or harmonised to provide a continuous record — including before 2013 and beyond 2016. The concept of the 'CEOS Constellations for GEO' has been proposed as the basis for a process aimed at addressing shortcomings in the international planning process for space-based Earth observations without eroding the independence of individual agencies. The Precipitation Constellation will seek to apply this principle to secure a sustained supply of information on precipitation — of potentially huge societal significance.



Credit: Copyright JAXA

Earth observation in South Africa — an increasingly pivotal function

Department of Science and Technology

Having failed to persuade the voters of the United States to elect him as their president, losing candidate Al Gore thereafter focused his attention on the subject of climate change and global warming. His subsequent efforts, and his film *An Inconvenient Truth* did much to publicize the parlous state of our planet and the recklessness with which many of us are dealing with its fragile environment. Gore has become a successful publicist for some of the disciplines of earth observation, and for this reason the GEO family are much beholden to him.

As has been so ably demonstrated at Sterkfontein, South Africa's history of earth observation dates back several million years. But now, with access to an increasing variety of satellites, and the addition of the latest remote sensing technologies, earth observation is poised to play a pivotal role in the nation's growth plans.

Yet research reveals that many interested South Africans have not grasped the distinction between 'earth observation', and 'remote sensing', so it's as well to clarify this. Earth observation is something that humans have been doing since they first stepped out of caves. Our ancestors noted the climatic and environmental conditions around them, and, with the changing of the seasons, began to observe a pattern which had an effect on their lifestyles. Today we do precisely the same thing, but much more effectively, with ground stations, communications infrastructure, personal observations, and, more recently, a virtual plethora of satellites equipped with increasingly sophisticated sensing and monitoring equipment. We employ additional techniques that include classic photography, water-vapour recognition, infra-red, and radar. Thus remote sensing is but one element in modern earth-observation techniques.

For several years now, South Africa has had the good fortune to share in the remarkable capabilities of a number of high-tech satellites from various sources, and at extremely economical rates, (we have had access to some systems at no charge). Programmes initiated through America's Landsat series have made a conspicuous contribution; the NASA System's Modis has been of enormous help; and the European second-generation MeteoSat has been equally beneficial. Now, significantly, South Africa is to be invited to share access to a satellite which will soon be launched by a partnership of Chinese and Brazilian interests.

So what exactly have South Africa's observers been up to? The good news is that earth observation in South Africa has started to cover a remarkably broad field of activity.

Current activities range from gathering information to aid the development of effective health systems, to imagery designed to assist agricultural policy. Some groups are using the technologies to study desertification and deforestation, while others are engaging with the systems to deepen their understanding of biodiversity. Increasing numbers of interest groups are recognizing the capabilities of the technologies, but significantly, many who might benefit are not yet aware of the potential.

Science manager Alex Fortescue reveals that during the past year the whole of South Africa has been photographed from space at a resolution of 2.5 metres. This means the observer can identify an area as small as your house, and there are numerous applications for this. A similar operation will take place annually, for comparative purposes, over the next few years. This data also aids the latest developments in the National Land Cover project, which was set up to determine the composition of the country in terms of forests, deserts, agricultural development, urban spread, etc, and to measure the changes that are occurring.

National electricity parastatal Eskom is using the technology for their electrification distribution plan. It's part of the National Electricity Plan, under which government aims to supply electricity to all of South Africa's people by 2014. But where are the people? Eskom can now access pictures that show where they are, and in what numbers, and this leads to better-informed decisions on priority projects.

Another good example followed the recent devastating bush fires in Mpumulanga province. Naturally, National Disaster Management immediately wanted to know what areas, homes and businesses had been affected. The national mosaic, (photograph) provided them with an instant answer, so that they were quickly able to marshal their resources for an effective response. At the same time the system answered the questions of the insurance companies who had extended cover in affected areas, and reassured the electricity-supplier that the fire was not sparked by faulty Eskom power lines.

Local municipalities are also starting to use these systems to speed up service delivery in terms of spatial development planning. Here the stress is on delivery of bulk service infrastructure to low income areas, and again the earth observation technologies are effective in determining where the people and the informal settlements are located, and, more importantly, whether, and how quickly they are spreading.

In a curious twist of events, earth observation technologies can also be used to monitor the behaviour of tax payers. Under South Africa's (relatively new) Water Act, water is not free. If rain falls on your farm, runs off into your dam and you pump that water onto your land you are liable to pay an irrigation tax. A satellite survey, using the infra-red band, in the Vaal catchment area, in 2001, was able to determine differences between irrigated and non-irrigated land according to erf number. When these statistics were compared to the rates bills related to the same properties, it was evident that only 2 per cent of farmers were telling the truth about what they had registered to irrigate when compared with what had actually been irrigated.

Many professional scientists working in the field of earth observation feel that we already have much of the information necessary to propel our country forward into the next stages of its development. However, they also deduce that the people most likely to be able to make effective use of this information are either unaware of its existence, or are incapable of accessing it, or it is only available in a form, which for all practical purposes, is unintelligible.

This is a problem. Bob Scholes, a senior scientist at the CSIR, and a man who has spent many years in this field, says: "Suppose I want an answer to a simple question. Is it going to rain next year, or isn't it going to rain? In response you send me a whole file of ones and zeroes; an enormous file that I can't open, and even if I did I wouldn't understand what 'advective precipitation co-efficient' means.

"This is one of the most important things the GEO partnership has to deal with. You've got to make a connection between the guys who're counting the butterflies and the birds on the ground, and the guy in the sky who's got the picture of where to find the flowers. It could be that there's another patch of flowers over the hill. The two bits of information independently are useless, but together they can answer the question, 'how do we connect the birds and the butterflies with the flowers?', and that's what GEOS is all about.

"If I show you a picture, it doesn't have any intrinsic value, that is to say, no value in its own right. The real value comes when you can add understanding to that; in other words the interpretation of it. And that is in fact where you need to start assembling, in an integrated fashion, a whole bunch of other information."

So according to this prognosis, the main challenge ahead is not putting more satellites into the sky, but making more people aware of what already exists, and putting more resources into connectivity and access.

"It must be understood that practically all this information is in the public domain", explains Bob Scholes. "It is quite evident that the only way South Africa can benefit from this data is to share it, and this has been recognized and agreed at cabinet level. Although my own impression is that news of this agreement has not yet reached all affected parties, some of whom continue to treat the state's information as their own.

"To these people I repeat that it has been agreed by government that information collected with public money, with rare exceptions, should be accessible by any party who has a legitimate need for it. The exceptions are of course things like national security, but that's a tiny fraction of the data."

There is a call to put in place national mechanisms to facilitate information interchange, and the country's increasing access to larger bandwidths should encourage this movement. Most data already exists. And in a surprising number of cases, it exists together with processes designed to make it readily compatible with other systems.

Alex Fortescue, an expert on remote sensing, is particularly delighted with South Africa's access to the new Chinese/Brazilian satellite. "It's a question of developing countries helping developing countries — no more commercial motive, although the Chinese and the Brazilians invested millions in developing this satellite. And there's a big component of GEO that are very proud of the fact that Africa is going to have this free data. This is the first time that it's been made accessible from source."

Bob Scholes was part of a team which used satellite technology, high altitude research aircraft and ground-based instruments to map the atmospheric circulation pattern of southern Africa. The project was called 'Safari'.

"It would not have been possible for any individual to undertake this project", explains Scholes. "But lots and lots of people from different institutions, with different observing capabilities, have played a part. Safari worked on the principal that air circulation in Southern Africa is united; united by the fact that a big high-pressure cell sits over the whole sub-continent, for half of the year. So what is produced as air-pollution in Mpumulanga doesn't just exit over the sea, but has an effect on what's happening as far away as Tanzania as well. And the smog seen in the winter time in Gauteng is in fact partly caused by veld fires in Angola.

"The Safari project puts all this together. By happy coincidence it was an early application of the sensors on board NASA's Terra satellite which was launched in 2000, and that's where most of the funding came from. But Safari really demonstrated the capability of putting together many different elements — maps of soils and vegetation together with field-collected information about the emissions from individual leaves and fires — to the effects of population distribution, to satellite observations in a lot of different spheres. Putting all this together can answer questions which are important either from the point of view of policy or individuals. There is now a Southern Africa policy group that works on trans-boundary pollution, and that came out of this initiative."

Of course South Africa's work on domestic and regional earth observation is just a small part of a world-wide attempt to more accurately map the earth, and so become more aware of its foibles and idiosyncrasies, and consequently make life on earth more predictable, enjoyable and productive. To this end the country is engaged with numerous multi-national bodies, most significantly, GEO, whose present membership is now said to outnumber that of the United Nations.

The future of earth observation in South Africa is an exciting one. There are problems to be addressed: problems of awareness; of communicating to a wider audience the potential of the capabilities of the various systems. There are also problems of access, both in terms of permissions, and in complications arising from non-compatible computer programmes. But for people with ideas, energy and imagination these are relatively simple obstacles to overcome. The fact is that our ability to observe the behaviour of our favourite planet, in the most minute detail, has never been greater, and the challenge is to use that ability to map out a better South Africa and a better world. And South Africans have always been up for this kind of challenge.

The INM's Izaña Atmospheric Research Centre, a GEO-oriented experience

Emilio Cuevas, Director, Izaña Atmospheric Research Center,
Instituto Nacional de Meteorología (INM), Spain

In 2004, IGOS/IGACO made the following statement: "Observations have clearly shown that human activity is changing the composition of the Earth's atmosphere. Research has demonstrated that there are important consequences of such changes for the climate, human health, and the balance of ecosystems." This statement has been made possible, in part, thanks to the observational and research activities performed by a few selected stations around the world which are part of the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) programme.

GAW provides data for scientific assessments and for early warnings of changes in the chemical composition and related physical characteristics of the atmosphere that may have adverse effects on our environment. Monitoring priorities have been given to greenhouse gases for possible climate change, ozone and ultraviolet radiation for both climate and biological concerns, certain reactive gases and the chemistry of precipitation for a multitude of roles in pollution chemistry, and aerosols for their impact on both air quality and climate.

The Izaña-ARC manages one of the GAW stations situated on Tenerife's Izaña mountain, where an important number of atmospheric measurement programs are performed on a long-term basis. The current emphasis of GAW is mainly on surface monitoring of the atmospheric composition. However, the GAW mandate includes the integration of satellite and aircraft observations with surface measurements, as well as the integration of chemical data and numerical models.

Increasing standardization and interoperability

Efforts on the coordination of ground-based networks for the monitoring of the atmosphere continue in Europe. The building of integrated (ground and space) systems is supported by the WMO as a contribution to IGACO and GEOSS. In the case of ozone, there are two world ground-based networks, formed by Dobson and Brewer spectrophotometers, respectively. The Izaña observatory was officially acknowledged by the WMO-GAW as the Regional Brewer Calibration Centre for Europe (RBCC-E)[1] in November 2003. A set of three MK III Brewer spectrophotometers has been set up as the regional reference triad (RRT) to transfer the calibration scale of the World Brewer Triad (WBT) to the regional network.

The main goal of the RBCC-E is to transfer the absolute calibration to the European Brewer spectrophotometer network. Intercomparability with the Dobson network is assured by periodical joint exercises with the Regional Dobson Calibration Centre, located at the GAW Hohenpeissenberg Observatory (DWD, Germany). However, the role played by the regional centres goes beyond maintaining a quality assurance system of ground-based networks. An important activity is to carry out the calibration of satellite sensors and to act as a link between the ground-based and space-based ozone observations.

During the last few years, emphasis has been given to the issue of interconnections between ozone depletion and climate change. Future increases in greenhouse gas concentrations will contribute to the average cooling rates of the stratosphere, which leads to greater ozone destruction, which may in turn slow down the recovery of the ozone layer. Twenty years after the Montreal Protocol was signed, precision observation systems are needed to detect signs of recovery.

In the study of aerosols, which play an important role in climate, the IZAÑA-ARC has been contributing to the global observation system as a Cimel master-sun calibration site for PHOtométrie pour le Traitement Opérationnel de Normalisation Satellitaire (PHOTONS) network[2] since June 2004. This network is part of the AErosol RObotic NETwork (AERONET)[3] Cimel sunphotometer network.

Increasing the capacity of observational tools

The Network for the Detection of Atmospheric Composition Change (NDACC) is a major component of the international upper atmosphere research effort and has been endorsed by national and international scientific agencies, including WMO. NDACC provides an independent calibration of satellite sensors of the atmosphere. The four ongoing programmes at Izaña within NDACC are:

- Total column ozone with Brewer spectrophotometer
- Vertical ozone profiles with ECC ozonesondes
- FTIR (managed by IMK-Germany)
- DOAS/UV-VIS (managed by INTA-Spain).

All the programmes have, as a high-priority goal, the validation of satellite sensors. Validation of ESA GOME and SCIAMACHY/ENVISAT, NASA/KNMI and

OMI/AURA, with more than a dozen atmospheric components, using advanced scientific instrumentation, has been performed at Izaña. The FTIR will participate in the Total Carbon Column Observing Network (TCCON). It focuses on the detection of total amounts of greenhouse gases with a precision higher than 0.1 per cent. New instruments and methodologies are being tested and developed at Izaña, such as high-accuracy water vapour with GPS, FTIR, photometric techniques and radiosondes, total column CO^2 with spectral sunphotometers, and new developments of Brewer spectrophotometers for accurate measurements of aerosols and other atmospheric compounds.

The Izaña-ARC has introduced to the air-quality field new methodologies and instrumentation, which are normally used in atmospheric research. Nano-particle counters and multi-angle absorption photometers have been used in urban areas for a better estimation of aerosols from vehicle exhaust emissions. The scientific DOAS technique is used in Santa Cruz de Tenerife to quantify reactive gases in two sectors of the city, in an operational way.

Improving the rate of implementation and capacity

A new proposal on the WMO Sand and Dust Storm (SDS) Warning System (WS) was accepted at the Scientific Steering Committee meeting for the SDS project (November 2006, Shanghai, China). The main project objective is to establish a WMO-coordinated global network of SDS forecasting centres that deliver products useful for a wide range of users in reducing the impact of SDS.

For Europe, Africa and the Middle East, Spain is currently creating a WMO regional centre for SDS. A partnership of three research institutions comprises the regional centre: the INM, through the Izaña-ARC, the Barcelona Supercomputing Centre (BSC), and the Earth Sciences Institute 'Jaume Almera' (IJA-CSIC). This regional centre will deal with both operational and scientific aspects related to atmospheric dust monitoring and forecasting. The system is primarily based on the Dust Regional Atmospheric Model (DREAM), which provides daily dust forecasts for the above-mentioned region;[4] the Meteosat Second Generation, from which new space and temporary hi-res dust products can be obtained, which are helpful for SDS monitoring; other satellite-based products, and the existing ground-based networks of lidars and sunphotometers.

The first national UV Index (UVI) forecasting model in Spain was developed by the Izaña-ARC. It covers the Iberian Peninsula, the Balearic and Canary archipelagos and northern Africa. Diffusion campaigns about the UVI and solar protection were carried out in collaboration with dermatologists and pharmacists. The first measurement programme for pollen and spore content in the atmosphere was implemented in the Canary Islands by the Izaña-ARC in 2004. Nowadays, it provides essential information to allergologists. The Izaña-ARC also collaborates with epidemiologists on studies focused on the relationship between PM10 (particles measuring 10μm or less) and mortality in the Canary Islands.

However, the most ambitious programme related to health focuses on meningitis epidemics over the Sahel. Certain environmental factors, such as low absolute humidity, land cover types and dusty atmospheric conditions, may play an important role in meningitis. The relationship between dust intrusions over the Sahel and meningitis epidemics will be studied by the SDS WS for Europe, Africa and the Middle East. Links between dust meningitis and large scale climate indexes, will be explored as well. A work package on that subject, coordinated by the Izaña-ARC in collaboration with the BSC, CSIC and WMO, is presented within the GEMS-MACC proposal to the EU-7FP.

Photo: INM

The high altitude Izaña super site

Developing capacity-building activities

The Izaña-ARC manages a network of three multichannel, narrow-band radiometers (NILU-UV6) at the permanent Argentinean bases of Ushuaia (55°S), Marambio (64°S) and Belgrano (78°S); in Antarctica since 1999, in cooperation with the Dirección Nacional del Antártico (DNA/IAA Argentina), and the Centro Austral de Investigaciones Científicas (CADIC, Argentina). The selected stations are of scientific interest for the monitoring and research of ozone, visible and UV radiation in the region.

The three-station network is strategically designed to obtain continuous ozone and UV transects from inside to outside the polar vortex. Data is routinely published in WMO Antarctic bulletins.[5] The Brewer spectrophotometer from the Instituto Antártico Uruguayo (IAU, Uruguay) installed at the Artigas Antarctic base was fitted and calibrated at the Izaña-ARC. Personnel from the IAU have also been trained in ozone and UV observation techniques at the centre.

Within the WMO-GAW programme, the Izaña-ARC maintains a 'twinning' partnership with the Ushuaia

GAW station in Argentina, concerning the surface ozone programme (calibration and data validation/evaluation software) and data acquisition system management. This 'twinning' is reinforced by the implementation of a long-term ozonesonde programme at Ushuaia, in collaboration with the Servicio Meterolológico Nacional (SMN, Argentina); the Tierra del Fuego Government (Argentina) and the Instituto de Técnica Aeroespacial (INTA, Spain).

In addition, a close 'twinning' partnership between the Izaña-ARC and the Tamanrasset-Assekrem GAW station (Algeria) was initiated in September 2006. A Cimel sunphotometer was deployed at this station under the joint SALAM project with the Office National de la Meteorologie (ONM, Algeria) to characterize the Saharan air layer. This instrument has been integrated into the PHOTONS and AERONET networks. This collaboration is currently being reinforced thanks to the Agencia Española de Cooperación Internacional (AECI, Azahar programme), which has financed a double Brewer spectrophotometer for the Tamanrasset station and a multi-channel moderate bandwidth radiometer for the Assekrem station. This new infrastructure, situated in a strategic site in the middle of the Sahara, will fill an important gap in the GAW observational capacity, and will constitute a unique ozone, UV and aerosol ground-truthing facility for space-based sensors.

The AECI has also financed, through WMO Trust Funds, three Cimel sunphotometers that will be deployed by the Izaña-ARC in Egypt, Tunisia and Morocco in 2008. These three new stations in the Magreb region, together with the existing station at Tamanrasset, will reinforce the real-time monitoring system of the SDS WS for Europe, Africa and the Middle East. These new stations will also be integrated into the AERONET and PHOTONS networks.

Photo: INM

Intercomparison of instruments at the Izaña super-site terrace

GISTDA's viewpoint towards GEOSS

Dr Thongchai Charuppat, Director, GISTDA

The Geo-Informatics and Space Technology Development Agency (GISTDA) was officially established on 3 November 2000 as a public organization under the supervision of the Minister of Science and Technology. GISTDA's mandates are in the area of the development of space technology and geo-informatics activities. The three main areas of activities are in providing satellite data services, leading operational research using satellite data, and promoting public awareness and transferring knowledge and technologies in the form of training, seminars, workshops, conferences and exhibitions.

In the area of providing satellite data services, data are received from satellites owned by various countries such as Landsat, RADARSAT, ALOS and MODIS. However, by the end of 2007, Thailand will launch its own satellite, named the THailand Earth Observation System (THEOS), providing assurance of high-resolution data accessibility to the country. The satellite data are also processed in a form that can be readily used. These value added products are very useful and less time consuming for end users.

In operational research, GISTDA has carried out various application projects using satellite data in the areas of agriculture, forestry, disaster and urban planning. GISTDA has a leading role in the application of satellite data for the country, and assists other government agencies in developing the use of satellite data for the interests of their agencies.

Photo: GISTDA

GISTDA's role has evolved from that of a satellite data user to a data provider

As for public awareness and technology transfer, GISTDA has actively organized many exhibitions on various occasions all over Thailand, and provides more than 12 formal training courses a year.

GISTDA realizes the important role that Earth observation data play across a very wide spectrum of applications. However, in some societal benefit areas of the country such as reducing loss of life and property from natural and human induced disasters, which is itself a complex cluster of issues with many players, the end results sometimes may not meet with expectations.

To tackle societal problems such as this there must be an effective mechanism in which actions across the agencies can be coordinated and integrated to make efficient use of resources and synergize overall beneficial results to society.

Apart from coordination and integration at a national level, it is important to address the wider area of agro-ecological and natural resources at regional and international levels. The Earth's resources are not bound by national borders, and need to be managed accordingly, as manifested by several examples in recent years. The Indian Ocean tsunami in 2004 caused extensive damage to life and property in many countries; the forest fire in Indonesia created smoke and caused air pollution in some parts of southern Thailand, and flood problems occurred where the river passes through different countries (river basin). These issues required regional/sub-regional cooperation. Establishing a cooperative mechanism at these levels can accelerate collaboration among international agencies.

The Global Earth Observation System of Systems (GEOSS) is a cooperative mechanism established by Group on Earth Observations (GEO) to involve all countries of the world, and to cover in situ observation as well as airborne and space-based observations. The focus of GEOSS is on observations relevant to large parts of the world, and related issues that require comprehensive information to be addressed optimally. The design of GEOSS builds on existing systems and data to be integrated into national, regional and global plans in a cost effective, technically possible and institutionally feasible manner.

GISTDA is the national space agency of Thailand, the national focal point of GEO, and has been an active member of the GEO Executive Committee since 2005. It

Photo: GISTDA

The Thailand Earth Observation System (THEOS) will provide high-resolution data accessibility to the country

Photo: GISTDA

GISTDA has a leading role in educating the public and provides more than 12 training courses a year in Thailand

avails itself to working towards an integrated Earth observations system that can meet user needs at global and regional levels. GISTDA has continuously supported GEOSS in several activities.

GISTDA's role has evolved from that of a satellite data user to a data provider. This will be particularly enhanced with the launch of THEOS, by the end of 2007. GISTDA is in a position to continuously contribute and share its data in case of emergency, particularly to neighbouring countries in Southeast Asia.

Thailand has developed a spatial database under the framework of the National Spatial Data Infrastructure (NSDI) to facilitate the recording and storage of data in clearly defined formats for easy access by end users. 'Digital Thailand' is an example of a product being developed to achieve data accessibility to and interoperability among the various government agencies as well as national end users through the Internet map server system.

NSDI is designed to ensure that spatial data are available from multiple sources and can be easily integrated. Specific requirements are put on relevant agencies that collect, use or disseminate geographic information to ensure that the resulting data, information or products can be readily shared and integrated among user agencies. The NSDI should be developed so that all participants interface with each other through interoperability specifications based on open, international standards to facilitate users at all levels, from national to regional and global. The adherence of NSDI to advanced Spatial Data Infrastructure (SDI) regional/global standards will bring about synergy among regional and global decision support systems through this data-sharing concept.

Thailand, as a member of GEO, recognizes these important issues and the necessity of pursuing the following goals:

- Further strengthening national coordination mechanisms in meeting national development needs by collective efforts across various government agencies
- Establishing a regional/sub-regional cooperative mechanism for the implementation of space application projects of common interest, and minimizing duplication of efforts
- Supporting and coordinating an operational Earth space information database and its network with a more advanced spatial data infrastructure on a regional/global scale.

In order to achieve these goals, a high-level forum of ministerial conference is a necessary step towards intensifying regional and global cooperation, mobilizing stronger political will and collectively addressing a range of issues. The third Ministerial Conference will be convened on 30 November 2007 in Cape Town, South Africa to address these issues towards the *10-Year Implementation Plan* for GEOSS. On this occasion GISTDA commits itself to participate actively in supporting GEOSS activities.

The UK piece of the GEO puzzle

Mark Churchyard and Ruth Kelman, BNSC Partnership

The British National Space Centre (BNSC) supports many activities that provide valuable information and data which contribute to helping us understand our environment and climate change through both national and international projects, especially through the UK's membership of the European Space Agency (ESA), European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and as a member of the Group on Earth Observations (GEO).

Observations are the key to understanding our complex environment. Without such observations we would not be able to comprehend the processes that shape our world, or the impact that changes to our environment have on our lives. Furthermore, in order to understand our environment we need to be able to combine the many types of observations such as those of the atmosphere, oceans and ecosystems taken at various scales and using different media in many formats. The UK supports GEO and the Global Earth Observation System of Systems (GEOSS), as GEO facilitates the type of interdisciplinary research and international collaboration that the UK believes are essential to determining how and why our environment is changing. The GEOSS ten-year Implementation Plan (IP) provides a good framework in which to work.

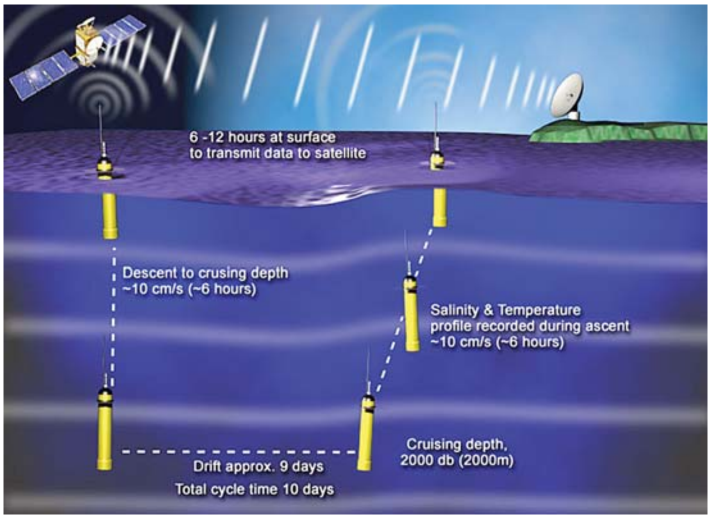
Ministerial responsibility for GEO in the UK lies with the Department for Environment, Food and Rural Affairs (Defra) which is both a partner of, and supported by colleagues in, the British National Space Centre (BNSC). The UK recognizes the importance of raising GEO/GEOSS nationally and continues to support its development. A number of BNSC Partner priorities are closely aligned to the objectives of GEO and will be reflected in the developing BNSC space plan. For example, the Natural Environment Research Council's (NERC) strategy Next generation science for planet Earth (2007-2012) outlines how NERC aims to support research that will lead to an improved understanding of environmental issues including natural climate variability, the impact biodiversity has on human health and the geological processes responsible for earthquakes and tsunamis. Such a strategy aligns very well with some of the societal benefit areas (SBA) identified in the GEOSS IP.

The UK is an active participant in many of the international organizations that contribute to GEO such as the Committee on Earth Observation Satellites (CEOS), Global Ocean Observing System (GOOS), Global Climate Observing System (GCOS) and Integrated Global Observing Strategy (IGOS). An example of such support is the UK contribution to GOOS, which is recognized as the main oceanographic component of GEOSS. Since 2001, one of the main UK contributions to GOOS has been its participation in the Argo profiling float programme. Over 200 floats have been deployed since 2001 with one float surviving for over five years and reporting 185 profiles. Funding is provided by four BNSC partners: Defra, the Ministry of Defence (MoD), Met Office and NERC. Argo data was used by the UK Met Office to increase confidence before issuing its forecast for a colder than average winter in 2005–2006, which proved to be the case, particularly in southern regions. UK floats have also been used as part of the UK-led system for monitoring the Meridional Overturning Circulation. GEO recognizes that it is the combination of satellite and in situ data that provides the information to monitor our Earth's systems and brings the two together, helping to construct the full picture.

Photo: ESA

Cryosat will enhance the data over the ice sheets (artist's impression)

Source: NERC



Argo floats use a combination of in situ and satellite observation technologies working together

In order to improve the coordination of Earth observation activities in the UK, two centres have been created. The Centre for Earth Observation Instrumentation (CEOI) is currently jointly funded by BNSC Partner organizations NERC and the Department of Innovation Universities and Skills (DIUS), and aims to bring together people from academia and industry in order to provide the UK with an internationally competitive Earth observation instrumentation and technology research and development programme. The second centre is the complimentary National Centre for Earth Observation (NCEO), which is currently under development and due to become operational in spring 2008. This centre will build on the considerable Earth observation expertise in the UK and will use data from Earth observation satellites to monitor global and regional changes in the environment, so that we might predict future environmental conditions. In addition, the NCEO will provide training in Earth observation and will be responsible for knowledge transfer activities, including increasing awareness of initiatives such as GEO within the UK Earth observation Community.

The UK's commitment to Earth observation, and the use of Earth observation data to address many of the problems facing our society, is best highlighted through example.

Polar observation

Researchers, from the UK's Centre for Polar Observation and Monitoring (CPOM) have been monitoring the scale of changes in Antarctic glaciers using satellite data. Scientists are studying radar images of four Antarctic glaciers, the Totten and Cook glaciers on the eastern Antarctic ice sheet, the Pine Island Glacier and the Thwaites glaciers on the western Antarctic ice sheet. They have discovered that over the past five years these glaciers have been moving between 20 per cent and 100 per cent faster than in previous decades and are adding more water to the oceans, contributing to rising sea levels.

Earthquakes

Researchers from the UK's Centre for Observation and Monitoring of Earthquakes and Tectonics (COMET) have been using radar images from ESA's ENVISAT satellite to pinpoint the location of earthquakes. In December 2003 an earthquake with a magnitude of 6.5 hit the town on Bam in Iran killing 40,000 people. In the month following the quake, COMET researchers joined scientists from the Geological Survey of Iran to find the source of the quake. Radar images revealed that the earthquake occurred on a rare blind 'strike-slip' fault. In strike-slip faults the blocks of crust move sideways relative to one another, as the blocks are moving sideways, rather than up and down. In this case, only small traces of the fault slip reached the surface, and signs of movement in previous earthquakes had been buried by layers of sediment. In addition to showing the location of a fault, satellite images of earthquakes enable us to visualize the structure of an entire region, which helps us to understand the cause and impact of a quake. At the moment, radar images of quakes can be used to locate the source of an earthquake and to help predict and therefore minimise the impact of future quakes. However, as the number of radar satellites increases, the repeat time between passes will be reduced, and the time taken to determine the location of a quake will be reduced from a few weeks to a few days. When this happens, satellite images could become a valuable tool for those planning the relief effort as the satellite images could show the scale and extent of devastation across a whole region.

Boreal forest fires

One of the regions where the impact of global warming will be greatest is in the high latitude forests of the northern hemisphere. In order to help us understand the effect of environmental change on these boreal forests, scientists based at the Climate and Land Surface Systems Interaction Centre (CLASSIC), in association with the Sukachev Institute of Forest and the Siberia Earth System Science Cluster, have been studying the relationship between environmental change and fire in Siberian forests. Fire is a cause of major environmental change in Siberia. For example 38,000 square kilometres of boreal forest were lost to fire in 2003. Fire frequency data from the MODIS satellite has been combined with rainfall and population density data for Siberia. This work to establish the factors that control of distribution of fire in Siberia has shown that fire in the boreal forests is influenced by regional rainfall anomalies, human population density and large scale climate patterns, such as the Arctic oscillation.

UK industry plays a major role in supporting the priorities of UK scientists through the development of technologies and instrumentations that can satisfy data requirements. Working within ESA, BNSC leads the two Global Monitoring for Environment and Security (GMES) Service Elements (GSE) – Respond (humanitarian aid) and Terrafirma (geohazard risk management). In addition, the UK is a member of the Disaster Management Charter (DMC), where the UK DMCii is helping to coordinate a constellation of international satellites that contribute to the voluntary system called upon in times of crisis. This is providing a very important international contribution, and the constellation is evolving and expanding to provide even more coverage. The UK played an important role in providing images to the civil authorities in the aftermath of the tsunami in 2004 and Hurricane Katrina in 2005.

An area in which the UK is particularly active is that of operational services for climate research and weather forecasting. Severe weather events impact on us all, and significant direct economic and social benefits can be associated with improved weather forecasting capabilities. These benefits contributed to many of the GEOSS SBAs, such as civil security, civil aviation, transport, health etc. Environmental satellites contribute substantially to the weather forecasting system and provide vital data for the weather prediction models. The UK Met Office leads in the area of operational forecasting through the exploitation of Earth observation data.

The UK is now contributing to the planning and implementation of a tsunami warning system for the Northeast Atlantic and Mediterranean. A multi-hazard approach is being adopted to make efficient use of the common infrastructure, and information needed to issue warnings of storm surges, extreme wave conditions and sea level rise. In a related initiative, the UK is leading an activity on developing guidelines that promote awareness and mitigation of marine-related hazards and risks in integrated coastal area management.

We hope that this article helps to paint a picture of the types of activities that the UK is involved in, which contribute to GEO/GEOSS. The UK also plays a proactive role in the Committee on Earth Observation Satellites (CEOS), which is currently positioning itself in becoming the Earth observation space coordinating body. There are many other activities within the UK that also contribute in other areas defined within the SBAs, and UK scientists and industrialists will continue to work in the international fora to support and develop new technology and scientific techniques that further our understanding of our Earth's processes and climate change.[1]

Photo: NERC

The power of nature, in this case a tsunami, cannot be underestimated

United States Group on Earth Observations

Gene Whitney, OSTP; Teresa Fryberger, NASA; Helen Wood, NOAA

On 31 July 2003, the United States hosted the first ever Earth Observation Summit in Washington, DC. This initiative attracted participation from more than 30 nations and 20 multilateral organizations and resulted in the intergovernmental ad hoc Group on Earth Observations (GEO) establishing the development of a ten-year implementation plan for the Global Earth Observation System of Systems (GEOSS).

Following this event, the United States government formed an ad hoc Interagency Working Group on Earth Observations (IWGEO) to develop the US component of GEOSS, an Integrated Earth Observation System (IEOS). In the four years since its establishment, IWGEO has evolved into a formal United States Group on Earth Observations (USGEO), a standing subcommittee of the Committee on Environment and Natural Resources (CENR) under the President's National Science and Technology Council (NSTC). The organization's vision statement runs: "Enable a healthy public, economy, and planet through an integrated comprehensive and sustained Earth observation system".

Today, USGEO is a results-oriented organization that comprises representatives from fifteen United States federal agencies and three White House Offices, with co-chairs from the White House Office of Science and Technology (OSTP), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA).

Progress and achievements

The vast range of missions of the US government agencies in the area of Earth observations requires a systematic approach to integration. To provide a framework for the integration of US Earth observations, USGEO developed the Strategic Plan for the US Integrated Earth Observation System, released in 2005. This strategic plan sets forth goals and requirements for US observing systems and contributions to GEOSS.

The plan is organized around nine societal benefit areas that collectively cut across all mission areas of the USGEO member agencies. These nine societal benefit areas, while not identical to the societal benefit areas developed by GEO, are closely aligned to them and link US efforts to international activities in GEOSS. USGEO has already made progress towards realizing the goals set forth in the national IEOS strategic plan. Significant accomplishments have been made in all societal benefit areas, including the development of plans for air quality, disaster reduction, integrated drought monitoring, and land characterization.

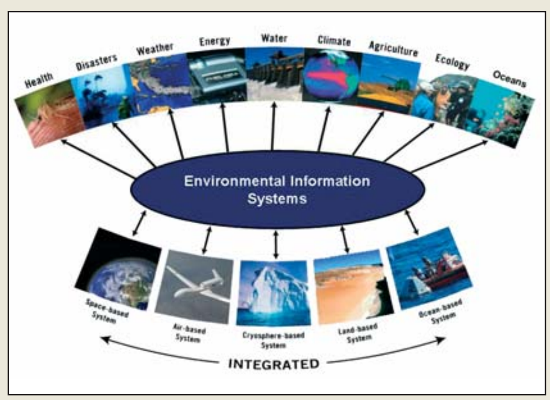
USGEO recognizes the importance of transitioning proven Earth observation systems and programs from research to implementation. The research and operational member agencies of USGEO, together with universities, private sector organizations, and international partners have collaborated to enhance

USGEO Membership

USGEO Co-Chairs: Dr. Gene Whitney (OSTP); Dr. Teresa Fryberger (NASA); Ms. Helen Wood (NOAA)

US Government Agencies and White House Offices

Societal benefit areas



- Improve weather forecasting
- Reduce loss of life and property from disasters
- Protect and monitor our ocean resource
- Understand, assess, predict, mitigate and adapt to climate variability and change
- Support sustainable agriculture and forestry and combat land degration
- Understand the effect of environmental factors on human health and well-being
- Develop the capacity to make ecological forecasts
- Protect and monitor water resources
- Monitor and manage energy resources

Photo: NOAA

The United States Group on Earth Observations aims to ensure a healthy public, economy, and planet through an integrated comprehensive and sustained Earth observation system

existing Earth observation models and systems, and to develop new ones. Such collaboration is key to achieving improved quality and availability of environmental data to benefit the world's economies and populations.

Fostering partnerships with external stakeholders and thereby engaging them in the work of advancing GEOSS and IEOS is a top priority of USGEO. To this end, USGEO has organized a variety of workshops, conferences and fora to develop and reinforce partnerships with government agencies, industry, academia, and non-governmental and international organizations. These activities have helped to bring Earth observations to the forefront of discussions on public health, agriculture, climate, data management and dissemination, to name a few.

International contributions

USGEO plans and coordinates US government engagement in, and support for, the work of GEO. USGEO participation strives particularly to promote widespread adoption of full and open data sharing policies and practices among GEO member countries. The organization also promotes addressing the capacity building needs of the developing countries, as they relate to Earth observations. USGEO experts serve on all GEO committees to support international progress in the implementation of GEOSS.

Current activities

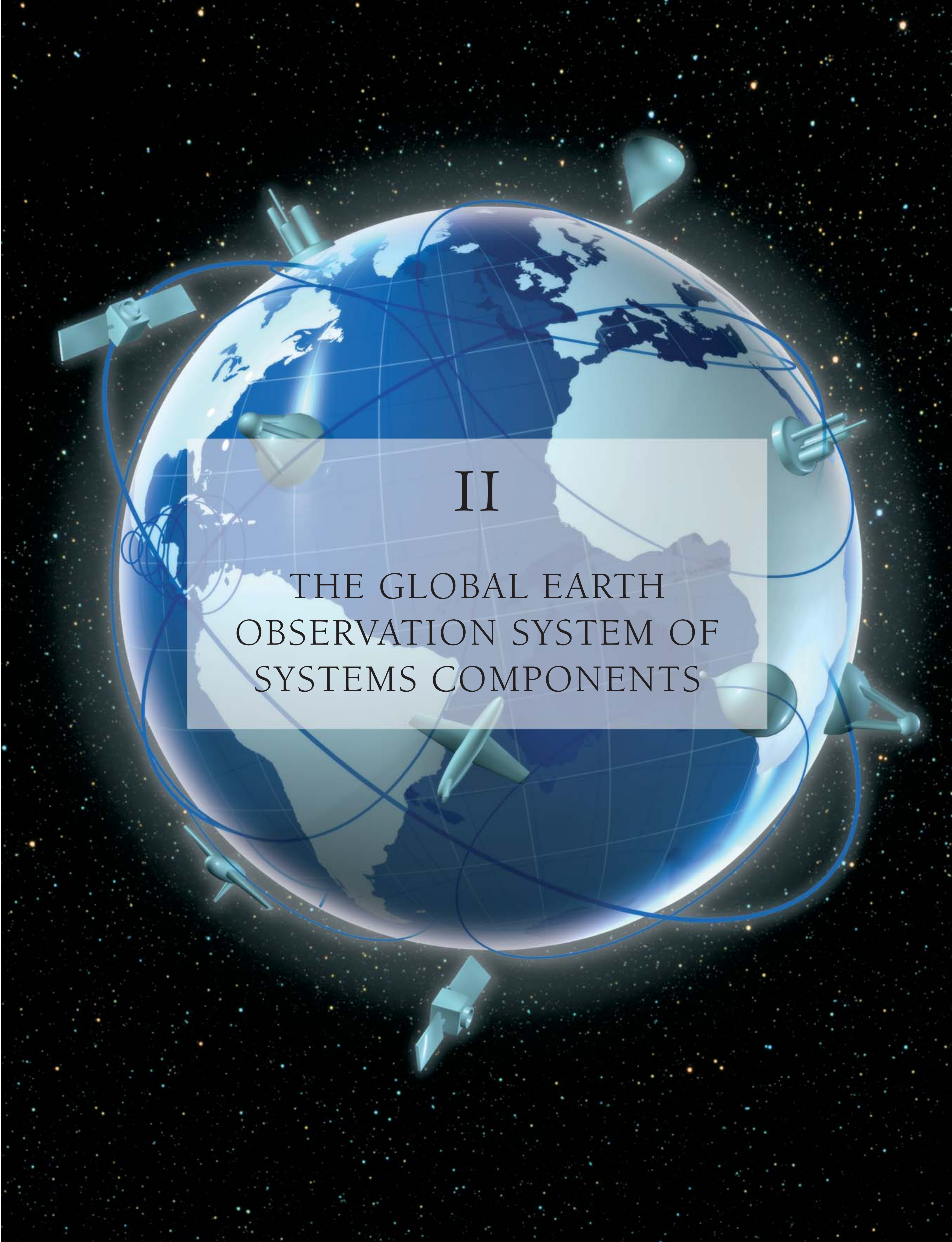
Capitalizing on the momentum created by demonstrated accomplishments and early successes, USGEO has embarked on two critical activities that are aimed at strengthening the national commitment to GEOSS and the US contribution, IEOS:

- Development of a US national civil Earth observation policy to ensure that Earth observation capabilities and data are available in a sustained and timely manner to further US scientific, economic, environmental protection and homeland security interests, and to enable effective domestic and international collaboration in Earth observation.
- Development of a comprehensive US Earth observation investment strategy that will assess national civil Earth observation needs and facilitate the integration of federal agency activities to meet those needs.

USGEO continues to focus on facilitating the use of Earth observations in models and decision support systems to improve decision-making and essential services federal agencies and others provide to the nation. Emphasis is also placed on cooperation with the international community, domestic governments, and other public and private organizations on Earth observation and science that are of mutual benefit.

US Early Achievement nominations

- Arctic Observing Network
- Establishment of a US national land imaging program
- GEONETCast a global environmental information delivery system
- Global space-based intercalibration system
- Large marine ecosystem
- Ocean surface topography
- SERVIR: An Earth observation, monitoring and visulization system
- Smithsonian Institution Global Earth Observatory Initiative (SIGEO)
- Standards-based, all-hazards, all-media public warning
- State of climate — A GEO achievement using Earth observations to monitor the global climate
- The North American drought monitor — A GEO achievement and the beginnings of a global drought early warning system
- USGEO program to improve air quality forecasts and desicions support for respiratory health



II

THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS COMPONENTS

Introduction

GEOSS: An emerging public infrastructure

We are entering a new era of global risks and opportunities where policy and management decisions must be based on the near-real-time environmental monitoring of the entire planetary system. So much is at stake: millions of people are vulnerable to natural disasters, desertification, food insecurity and emerging diseases; global problems such as climate change and biodiversity loss are worsening with each passing day; and too many opportunities for managing energy, water and other natural resources more effectively are being wasted.

Addressing these challenges will require interlinking existing and future Earth observation systems into one comprehensive 'system of systems' that will, more than ever before, provide 'the full picture' that today's decision makers so urgently need. This system is necessary because of the complexity of the Earth system itself and because of the growing demands that the dynamism of our modern civilization is placing on decision-makers. Their hunger for information about changes in the natural environment has evolved beyond the capabilities of what until now have been separate, single-purpose, stand-alone Earth observation systems.

This Global Earth Observation System of Systems is not only necessary, it is now possible as well. This is because investments in Earth observation instruments and technologies have reached a critical mass. The construction of new systems has increased dramatically over the past ten years and promises to continue rising steeply over the decade to come. The number of new Earth observation satellites alone that will be put into orbit may even double over the next decade.

But for this global public infrastructure to become a reality, a great deal of technical work will be required on developing compatible data standards and configuring diverse instruments and systems to communicate with one another. The challenge is to make widely different technologies, from remote-sensing satellites and ocean buoys to weather stations and wildlife-tracking radar and sonar systems, fully 'interoperable'. This will lead to important improvements in both data assembly and modelling.

For this to happen, the people and organizations involved in producing and disseminating data will need to collaborate more fully than ever before. These diverse groups have recently started to cooperate through the Group on Earth Observations. Their goal is nothing less than the construction of a Global Earth Observation System of Systems, or GEOSS.

Building upon existing partnerships, GEO's members and participating organizations are interlinking a large number of observing and processing systems and encouraging the development of new components. Ranging across the data processing cycle, from data collection to analysis to dissemination, the participating organizations are connecting up their systems while respecting and maintaining their own individual mandates.

Building synergies and sustainability

When an observing system operates in isolation, its data is limited by what its own instruments and components can gather. But when it is linked to other systems, its coverage expands accordingly. Today, rapid technical progress is making it easier to combine different types of data. For example, the broad spatial coverage that is one of the great advantages of satellites can be combined with the precision of in situ instruments located in the ocean or on the land. By coordinating and co-designing an integrated observation strategy, partner organizations can maximize the effectiveness of the collection, processing and dissemination of information.

Earth observation systems that serve multiple purposes also make it easier to remove redundancies, and thus generate cost savings. For example, validating the findings of land cover monitoring requires a distributed network of ground-level instruments. If these instruments can be co-located with existing weather stations the overhead costs of basic infrastructure can be reduced, and better datasets can be provided to each partner.

Observation systems often suffer from gaps and from a lack of continuity. Environmental changes take place on decadal time scales, so observation systems have to be maintained on similar scales. GEOSS will help to identify these gaps and mobilize the resources needed to ensure the long-term sustainability of observation systems.

Ocean monitoring provides an early example of what is needed. The global system of Argo ocean floats, which measures ocean temperature and salinity, is being supported by satellite altimetry instruments, which provide information on the heat trapped in the oceans and on currents. All of these data are essential for long-term meteorological forecasting, oceanographic studies, fishing management and disaster mitigation. The logistics and costs of deploying this system throughout the world's oceans and in space would have been daunting for a single nation, but the project has become feasible because it is being jointly undertaken by many countries for the common good. Ensuring the long-term sustainable operation of these systems will require even more of the kind of international cooperation that GEO can provide.

One dataset, many users; one user, many datasets

Many datasets are collected for a single purpose, but are in fact extremely useful for a variety of users. Land cover data may be gathered for climate models but would be equally useful for forecasting and abating the risks to people, infrastructure and the environment posed by severe weather events. Solar radiation data may be targeted to the energy sector but could also be useful for predicting future movements of threatened and endangered species. Unfortunately, these datasets may not be widely known by, and available to, the biodiversity community. Because the Earth system consists of a complex set of interactions, no single part of the system is unaffected by processes in other parts. Addressing and mitigating health problems such as meningitis outbreaks requires decision makers to understand desertification trends and weather conditions, and then to integrate this information with socio-economic variables such as housing and transport infrastructure. Flood monitoring requires a range of data from satellites as well as in situ observations on water runoff. It is crucial that observation systems and modelling processes merge different sources of data in order to account for these complex interactions, and GEOSS aims to achieve this.

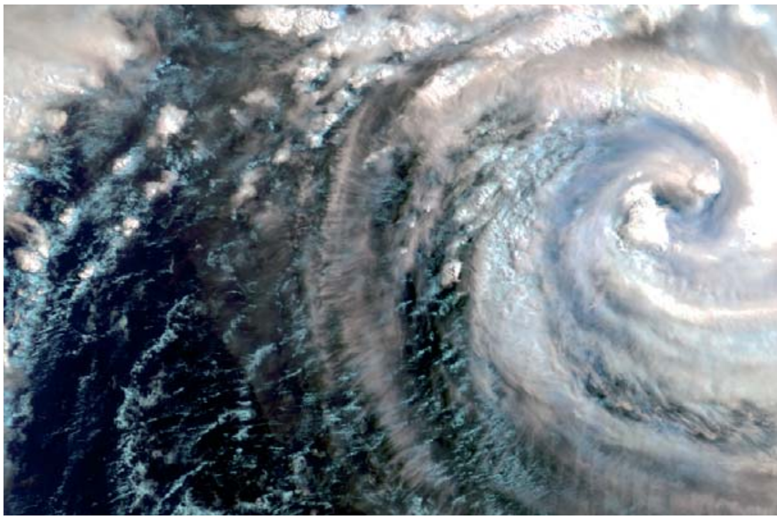
As modelling and analysis become more comprehensive and complex, more thematically diverse data becomes necessary. For example, vegetation models need climate data, climate models need data on vegetation distribution and attributes, and both need data about the terrain. Terrain data in turn must be transformed from elevation-only data to reflect slope, aspect and elevation.

The costs of integrating Earth observation data in this way should not be underestimated. Nevertheless, there is no need for any individual institution to bear the full costs, when distributed processing and resource sharing can provide overall savings to the larger community. In addition, GEO seeks to maximize the efficient use of limited resources by promoting more capacity building programmes and investments. By coordinating existing and planned capacity-building efforts and collectively identifying priorities, the GEO community can better position itself to attract resources that enable it to address human, institutional and infrastructural gaps in Earth observation capacity building.

The importance of architecture

The success of GEOSS will depend on data and information providers accepting and implementing a set of interoperability arrangements, including technical specifications for collecting, processing, storing and disseminating shared data, metadata and products. The interoperability of the GEOSS components will be based on non-proprietary standards, with preference given to formal international standards. It will focus on interfaces, defining only how system components connect to one another. This will minimize any potential impact on external, non-GEOSS systems that do not choose to reconfigure the hardware and software components of their architecture.

Three key data-sharing principles form the foundation of the GEOSS architecture. First, there must be a full and open exchange of data, metadata and products within GEOSS, accompanied by a simultaneous recognition of relevant international instruments and national policies and legislation. Second, all shared data, metadata and products will be made available with the minimum time delay, and at minimum cost. In order to encourage their use for research and education, all shared data, metadata and products should be supplied free of charge or at no more than the cost of reproduction.



Early warnings of disasters such as Hurricanes are only possible with accurate, timely data

The implementation of GEOSS will therefore advocate the increased sharing of data and tools for the modelling and analysis needed to transform data into useful information. GEOSS will facilitate data-management approaches that encompass a broad view of the observation-data lifecycle, from input through processing, archiving and dissemination, including reprocessing, analysis and visualization of large volumes and diverse types of data. With this architecture, GEOSS will establish international information sharing and dissemination policies, drawing on existing capabilities through appropriate technologies including, but not limited to, Internet-based services. It will provide a true system of systems, enabling users at all levels to access information and make informed, efficient decisions.

GEOSS: the first steps

The following articles clearly demonstrate that GEO has already achieved a great deal. They present a series of activities geared to developing the functional architecture that will make it technically possible to interlink the various components of GEOSS. These components include: data collection systems, such as remote sensing satellites and in situ monitors; information and dissemination systems, which will bring Earth observations to the end users in a format they can use; and prediction systems, which are particularly vital for decisions makers. The chapter concludes with several examples of how GEOSS will develop operational forecasting capabilities in the near future for disasters, droughts, ocean conditions and climate change.

More 'eyes in the skies' provide a full picture: a report from the Committee on Earth Observation Satellites (CEOS)

Barbara J. Ryan, US Geological Survey (2007 CEOS Chair)
Timothy S. Stryker, US Geological Survey
Rebecca L. Johnson, Science Applications International Corporation, contractor to the US Geological Survey

Since the United Nations Framework Convention on Climate Change entered into force in 1994, government recognition and public awareness of global change have increased substantially. And change is occurring rapidly — in the atmosphere, oceans, and across countless landscapes. Worldwide, climate patterns and other natural cycles and systems are being affected in complex and unprecedented ways. As societies grow and expand their already sizable imprint on the Earth, even greater changes lie ahead.

Understanding and addressing climate change requires a global view of Earth's natural systems. While ground-, sea- and aerial-based measurements and networks provide much essential climate information, only satellites making regular, long-term observations of the planet can give a complete, global perspective on the Earth system. Indeed, a detailed, global climate record that lends a view both to the past and the future is not possible without a major, sustained satellite component, one characterized by continuity of observations over time.

Human societies have an impact on the Earth

Government decision makers need the most complete picture possible of global climate change in order to assess its impacts and implications for their societies. Sound, scientifically based information ultimately enables the best decision making. Capturing a complete climate picture, however, is beyond the capability of any single country or handful of countries, no matter how technologically advanced. This task requires large-scale, broadly based international cooperation.

The Committee on Earth Observation Satellites (CEOS) endeavours to coordinate satellite missions worldwide and maximize the use of satellite data to provide a detailed and accurate view of the Earth system. Established in 1984, CEOS provides a broad framework for international coordination of space-related Earth-observation missions through cooperation of its member agencies. CEOS membership comprises all of the world's major civil space agencies, as well as various user organizations and stakeholders. By working together, CEOS members advance the coordination of current Earth-observing systems and the development of future systems that will not only fill observational gaps, but will possess new capabilities designed to answer fundamental questions about the Earth system.

In recent years, CEOS has refined its focus to directly implement the work and goals of the Group on Earth Observations (GEO). In 2005, the CEOS membership decided to realign its strategies and plans to deliver the space-based component of the Global Earth Observation System of Systems (GEOSS).

As one of the original contributing organizations of GEO, CEOS fostered space agencies' participation in the initial GEO 2006 work plan and contributed to tasks that directly addressed or cut across all of the nine GEOSS societal benefit areas (SBAs) relating to agriculture, biodiversity, climate, disasters, ecosystems, energy, health, water and weather. CEOS' involvement continues at a similar level for the current GEO work plan.

30 years of land surface change characterized by satellites

Satellite imagery reveals the progressive drying up of Africa's Lake Chad — bordered by Cameroon, Chad and Nigeria — between 1972 and 2001

Source: Department of the Interior/US Geological Survey

In 2006, CEOS provided a coordinated response on behalf of its member space agencies to the proposed requirements for the space-based component of the Global Climate Observing System (GCOS). The CEOS response was a comprehensive collection of actions aimed at fulfilling climate-observing needs in the atmosphere, ocean and terrestrial domains, as well as a number of crosscutting areas. CEOS provided the opportunity for space agencies to review the way in which multi-agency climate observations are prioritised, agreed, funded, implemented and monitored. CEOS also identified what can be achieved by better coordination of existing and future capabilities as well as specific improvements that require additional resources or mandates beyond the present capacity of member space agencies.

GEO focuses on nine Societal Benefit Areas

Better coordination is also the driving force behind CEOS' 'Virtual Constellations' initiative, a proposal to coordinate satellite missions across borders, allowing valuable contributions from a wide range of parties to build and sustain truly global observing systems for maximum societal benefit. The virtual constellations concept is of multiple satellites working in harmony as part of the GEOSS, to augment coverage, enhance system compatibility and increase data availability. Such an arrangement encourages international cooperation among space agencies while stimulating them to develop a coordinated response to space-based observation needs. It also fosters improved data management and dissemination worldwide.

A series of four prototype virtual constellations is currently under review by CEOS members and participating organizations, in consultation with their respective user communities. The focus of these virtual constellations is on land surface imaging, precipitation, ocean surface topography and atmospheric composition. They are designed to make key GEOSS observations, maintain continuity of observations, and identify and address potential gaps in data. They should also enable more effective and efficient resource allocation by CEOS members to a variety of observing systems.

The Virtual Constellations initiative capitalizes on the idea that many 'eyes' focused on the same problem are considerably better than just one. Coordinated operations of multiple missions would also provide more accurate, detailed and complete information on a variety of environmental phenomena. The better the information gathered about the Earth system, the better the chances of understanding its workings and its impact on life and society.

For example, a virtual constellation of land-imaging satellites would continually monitor the Earth's land surfaces, tracking changes to farmlands, coastlines, deserts and forests over time, and illuminating relatively long-term alterations to land cover, ecosystems and biodiversity. The same set of satellites could also track short-term

Rising sea levels worldwide will impact islands and coastal regions such as Mumbai, India

Source: European Space Agency

Torrential rains and flooding affected millions in Bangladesh in June 2007

threats linked to climate change, such as wildfires and floods, which can adversely affect human health, property and infrastructure, and natural ecosystems.

A virtual constellation of satellites monitoring atmospheric composition and behaviour would measure concentrations of various gases and aerosols above the Earth's surface; such measurements are critical to understanding global change. These satellites could also be used to monitor severe environmental phenomena worldwide. In 2006, for example, widespread fires and their smoke plumes in Africa were mapped by European and American satellites, while the height of the plumes was measured by a joint US-French satellite mission. Data gathered by these different satellites were combined and used to predict how the particulates in the smoke would disperse across land masses and oceans. This information was then used by authorities to prepare public warnings, increase the effectiveness of emergency responders and assess environmental impacts.

A virtual constellation of satellites monitoring precipitation would enable national authorities to track the seasonal progression of rainfall patterns, better understand the development, movement and impact of severe storms such as typhoons and hurricanes, and identify areas likely to experience intense, rapid flooding. Such a virtual constellation could improve forecast and warning services provided by national weather agencies to better protect lives and property.

Oceans cover more than three-quarters of the Earth's surface and play an integral part in its climate system. A virtual constellation of satellites focused on ocean dynamics would gather data critical to monitoring sea level rise and the threat it poses to coastal communities worldwide. Such a constellation would gather information about ocean temperature and chemistry, and possible changes in ocean currents. It would also be vital for use in tracking and predicting the behaviour of tropical storms that form over ocean waters with the potential to threaten coastal communities and ecosystems. And it would provide information essential to understanding the scope and pace of climate change.

The Earth system is complex and changing rapidly. Virtual constellations of satellites, unified in their focus through international coordination, have the potential to provide policy makers with vital, integrated and readily available information about natural hazards, climate change, and societies' impact on that system. Information that efficiently coordinated and effectively deployed satellites gather can also help to protect lives and property and assist decision makers in better managing and protecting the Earth's precious resources.

The concept of coordinated teams of satellites working together will hopefully lead to the implementation of real, physical constellations of satellites, flying in coordinated orbits to monitor, assess and forecast changes in the atmosphere, oceans and terrestrial environment. It is clear that a new period of integrative and collaborative effort has begun in the area of Earth-observing satellites and climate change research. With the continued support of CEOS to develop and deploy space assets as part of the GEOSS, the global Earth-observation community is effectively refocusing its efforts. The member agencies of CEOS are committed to this unprecedented effort to better coordinate observing systems and human expertise to provide government decision makers with a better understanding of the Earth system.

The Sensor Web: GEOSS's foundation layer

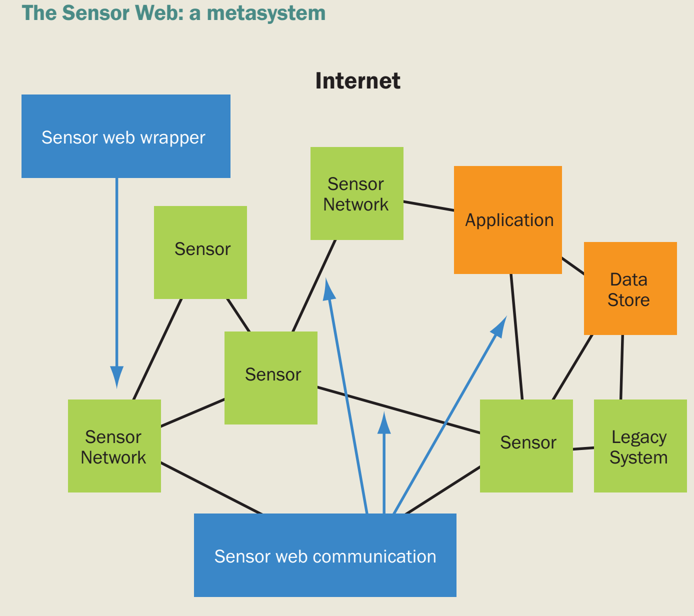
Ingo Simonis, GEO Spatial Research

The Global Earth Observing System of Systems (GEOSS) aims to continuously monitor the state of the Earth in order to increase knowledge and understanding of our planet and its processes. As a system of systems, GEOSS must integrate heterogeneous systems across institutional and political boundaries. Timely delivery of earth observation data is key to identifying potential threats, such as tornados, tsunamis, wild fires and algae blooms, that may affect humans or infrastructure facilities.

Stored sensor data is the basis for analysing gradual processes, such as increasing drought, water shortages or rising sea levels. The Sensor Web presents a paradigm in which the Internet is evolving into an active sensing macro instrument, capable of bringing sensory data from across the globe to the fingertips of any individual. Based on internationally adopted standards, the Sensor Web ensures interoperability among its various components. Its software components and services work interactively, without adaptations for arbitrary application domains.

The GEOSS Web portal, as well as community portals, provide access to data sets that have been processed and optimised to represent specific aspects of our planet relevant to Earth observation applications. Users can access large amounts of data sets in a convenient way, as graphs or visualized on a map. For example, you could follow caribou tracks to identify the correlation between their movements, annual variations in snow coverage and a potential climate change. You could follow veld fires in real time, analyse potential damage to commercial forestations or electrical power lines, and calculate fire spreading based on wind and topographical data. The origin of the data is often hidden from the user; namely, the Sensor Web, the foundation layer of the GEOSS.

The Sensor Web: a metasystem



Source: Ingo Simonis

The Sensor Web is a revolutionary concept for achieving a collaborative, coherent, consistent, and consolidated sensor data collection, fusion and distribution system. It is a new breed of Internet for monitoring spatio-temporal phenomena appearing in the physical environment in real time. Any kind of sensor, from a thermometer located at a fixed position to a highly complex hyper spectral sensor on board an Earth-orbiting satellite, will be available on a global level in the near future.

Sensors can remain at fixed locations (e.g. as part of weather stations), or move autonomously or by remote control in physical space (e.g. on board vehicles, aeroplanes or satellites). Once deployed, each sensor associates the phenomenon it detects with the location it currently populates. This information is either stored on the sensor for later access, or sent directly to aggregation systems. Retrieval and processing of sensor data, and the management of sensor devices, will soon be carried out by means of distributed software entities that interoperate via the Internet. Once the Sensor Web is widely used, millions of sensors will be connected to a large network and will be capable of producing georeferenced observation data. Every sensor provides a small mosaic stone that helps to generate a consolidated view of the world and get a better understanding of the past, present and future situation of our planet, as well as active processes and correlations.

The Sensor Web uses the underlying infrastructure of the Internet to connect sensors and sensor networks, sensor data processors and consumers. Consumers may access data directly from the sensor, or from a data centre. A fundamental design principle concerns the distributed organization of sensors and storage of observation data. Data is stored at, or close to its place of production. This mechanism avoids unnecessary data duplication and simplifies system maintenance.

Sensor providers can choose the level of access to their sensors and the kind of data provided to the Sensor Web. They remain responsible for their sensors and sensor networks, can continue to operate them in established modes, and can keep following proprietarily defined procedures and methodologies. Additional support for the standardized Web interfaces is the only requirement for connection to the Sensor Web.

Sensor Web is a meta-platform that integrates arbitrary sensors and sensor networks, each maintained and operated by individual institutions. Examples include the Australian Water Resources Network, the European Environment Information and Observation Network, and the South African Earth Observation Network. This reflects the existing legal, organizational and technical situation. Sensors and sensor systems are operated by various organizations with varying access constraints, as well as security, data quality and performance requirements. The architecture of the Sensor Web allows the integration of individual sensors and of complete sensor systems without the need for fundamental changes to the legacy systems.

Once connected to the Sensor Web, data sets may be used multiple times in applications never intended by the original system set-up. Traffic sensors initially deployed to avoid traffic jams by means of dynamic traffic control might be used to calculate the carbon dioxide ratios of highway sections in another application. Satellites with different sensors on board might be used in a variety of application domains that were not primarily targeted, simply because the interoperable interfaces allow users to task the satellite based on distinct requirements.

Consumers use the Internet to access distributed data sources by invoking Web services. The Web services interfaces must be standardized to achieve interoperability between all data, or sensor providers and consumers. Currently, the most prominent approach to standardizing Sensor Web interfaces is the Sensor Web Enablement Initiative run by the Open Geospatial Consortium (OGC), a not-for-profit, international, voluntary consensus standards organization that leads the development of standards for geospatial and location-based services.

The consortium unites more than 350 software vendors, research institutes and government agencies worldwide. In the context of the Sensor Web Enablement Initiative, a number of standards have been developed during the past seven years to provide a sound technological foundation on which to build the Sensor Web. The standards cover a number of requirements. First, sensors and sensor data have to be discoverable. Queries based on observed phenomena, temporal resolution, spatial extent, and quality levels, among other criteria, allow the filtering of the vast amounts of available data sources. The information obtained has to be understandable and processable by machines. This requires a high level of syntactical and semantic expressiveness. Sensors will be tasked to the specific needs of various user groups and will send alerts when a sensor measures a particular phenomenon.

Overall, the OGC has published seven standards: four Web service interface specifications and three data encoding and metadata languages. The sensor observation service retrieves sensor data, the sensor planning service tasks sensors and models, the sensor alert service pushes real-time information to the registered user, and the Web notification service delivers sensor information by means of various communication protocols. The sensor model language describes sensors, platforms and sensor data processing chains. Abstract models and XML-based implementations to encode sensor data are provided by the observation and measurement. The transducer mark-up language supports description and encoding of continuous data streams.

Although technical solutions for building the Sensor Web are available, there is a lack of consolidated effort to make all data sets discoverable and accessible. This is mainly due to the fact that the Sensor Web specifications enable access to sensors and observation data, but do not provide any catalogues, dictionaries or registries that facilitate discovery and exploitation. This was done intentionally. Other internationally adopted standards, provided by the International Organization for Standardization and the OGC, cover this field.

An operational geospatial IT solution spanning multiple data sources and disciplines, such as GEOSS, is needed to bridge the 'isolated' interoperability building blocks of Sensor Web, discovery and exploitation services. Thus, GEOSS will be key to the successful path of the Sensor Web and vice versa. GEOSS depends on a powerful sensor data infrastructure to obtain its major tasks, while providing several key components necessary to make the Sensor Web fully operational. The GEOSS Web portal implements a single point of entry either directly to the Sensor Web services and products, or via its linked community portals. In conjunction with the GEOSS clearinghouse, the GEOSS registry and community catalogue services, Sensor Web components will be explored for reuse in new applications built on top of the existing Sensor Web infrastructure. The following example illustrates how GEOSS empowers the set-up of new applications based on sensor data and made available by Sensor Web components.

The Advanced Fire Information System (AFIS) version two, is one of the early examples of a GEOSS application based on Sensor Web technology. Currently in an experimental phase, it integrates a growing number of data sources and sensor tasking components. Once completed, AFIS will be the ideal example of an application that makes use of a number of systems that were united in the GEOSS.

AFIS analyses veld fires in sub-Saharan Africa. Moderate-resolution imaging spectroradiometer satellite data from Aqua and Terra satellites is continuously parsed for hot pixels, which indicate potential veld fires. This hotspot data is provided by a sensor observation service instance located in South Africa. Hotspots located close to power lines, commercial forestations or urban areas trigger NASA's EO1 satellite automatically. The tasking uses a sensor planning service to upload the observation requests to the satellite. The Hyerperion and ALI sensors onboard EO1 produce vast amounts of data that is downlinked and further processed in the US, before it is sent to a data store located in Canada. This data store is façaded by a Web coverage service interface. Standardized by the OGC, the Web coverage service allows clients compliant to the standard to retrieve the data automatically.

The client application integrates additional data sets provided by sensor observation services, including current wind situation and topographical data sets, to calculate the spread of the fires. The client application sends alerts via the Web notification service in case the fires threaten valuable areas. All AFIS components can be explored in the GEOSS clearinghouse. Component interfaces are registered at the GEOSS registry. Since each is fully standards compliant, it can be used within other applications.

The Sensor Web, as a new Earth observation system, opens up a new avenue to fast assimilation of data from various sensors (both in situ and remote), as well as to accurate analysis and informed decision making. It provides the foundation layer for GEOSS, in the form of raw and processed sensor data that is the basis for the higher level information in Earth observations essential to understanding the current and future situation of planet.

GCOS, a system of systems for the global observation of climate

Gilles Sommeria, GCOS Secretariat; John W. Zillman, Chairman, GCOS Steering Committee and David Goodrich, Director, GCOS Secretariat

One of the most important roles to be fulfilled by a fully implemented GEOSS is provision of the Earth system observations needed for understanding, assessing, predicting, mitigating and adapting to natural climate variability and human-induced climate change. The GEOSS 10-year Implementation Plan identifies an extensive set of atmospheric, oceanic and terrestrial variables needed in support of the climate Societal Benefit Area (SBA). The Global Climate Observing System (GCOS), which is itself a 'system of systems' built on the climate-relevant parts of established observing systems of the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission of the UNESCO (IOC), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU), was designed to meet these needs and is thus an essential component of GEOSS. This article describes the origin and historical development of GCOS, summarizes its structure and concept of operation and explains its role as the climate component of GEOSS.

Historical background and main objectives of GCOS

GCOS was established in 1992 as a joint initiative of WMO, IOC, UNEP and ICSU, all now participating organisations in GEO, as a response to the growing need for international cooperation in the systematic observation of climate. It was designed as a 'system of systems', built on existing global observing systems and aimed at ensuring that data will collectively be improved or complemented in order to fulfil its objectives.

The major established observing systems that contribute to GCOS are the Global Observing System of the World Weather Watch, the Global Atmospheric Watch and related atmospheric constituent observing systems, the Global Ocean Observing System for physical chemical and biological measurements of the oceans, and the Global Terrestrial Observing System for land surface ecosystems, hydrosphere and cryosphere measurements.

The objectives of GCOS have not changed significantly since its establishment. As recalled and updated by the 2007 WMO Congress, they are to ensure that climate observing systems provide adequate data for:

- Climate system monitoring
- Climate change detection and attribution
- Research to improve understanding, modelling and prediction of the climate system
- Operational climate prediction on seasonal-to-inter-annual timescales
- Assessment of the impacts of, and vulnerability and adaptation to, natural climate variability and human-induced climate change
- Applications and services for sustainable economic development
- Requirements of the UNFCCC and other international conventions and agreements.

Main elements and achievements of GCOS

The first GCOS plan was published in 1995, and an Implementation Plan (IP) for the Global Observing System for Climate in support of the United Nations Framework Convention on Climate Change (UNFCCC) was published in 2004. The IP puts together a number of guidelines developed during the last ten years on the main variables to be observed, the so-called 'Essential Climate Variables' and on the observation strategies, which should follow the so-called 'GCOS Climate Monitoring Principles'. It provides guidance and defines priorities for advances in the observation of those variables on a five to ten year time-scale.

The main items covered include the improvement of key satellite and in situ networks, the generation of integrated global products for climate analysis, the enhancement of the participation of developing countries through system improvement and regional projects, supported by an international cooperation mechanism, and the necessary enhancement of the archival and access to climate data for all. The IP has found broad acceptance across a range of international bodies and national organizations and thus represents the current consensus document of the international community regarding the global observing system for climate, in support of the UNFCCC.

Major activities are going on with respect to the maintenance or improvement of observation networks and satellite observation, which are intended to serve a number of programs and activities representing a large range of users of climate information. This includes among others the research community represented by the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere-Programme (IGBP), the Intergovernmental Panel on Climate Change

Muir Glacier (Alaska) in August 1941 and 2004

The global monitoring of glaciers, under the World Glacier Monitoring Service, is one of the numerous types of observations undertaken through GCOS

Source: US National Snow and Ice Data Center, W. O. Field, B. F. Molnia

(IPCC), and a range of international programmes or projects that make use of climate information for societal or economic applications.

GCOS has more specifically conducted, with the funding of donor countries, a programme of renovation or establishment of new surface and upper air observing stations, complemented by technical support projects in developing regions of the world. The two main atmospheric GCOS networks are the GCOS Surface Network (GSN) and the GCOS Upper Air Network (GUAN). Other networks of importance for climate monitoring, dedicated for example to the measurement of atmospheric constituents, surface radiative measurements, and hydrology related variables have been formally associated with GCOS, and benefited from GCOS support and expertise. The programme has also greatly supported the development of the research based ocean observing system, including the Argo profiling float network (comprising approximately 3000 floating stations worldwide), with the goal of a transition into a fully operational network.

With respect to space observation, a close consultation has been developed with space agencies, under the Committee on Earth Observation Satellites (CEOS) and the Coordination Group for Meteorological Satellites (CGMS), and in coordination with the WMO Space Programme, in order to encourage the development of the space component of GCOS, along the lines of the IP. A specific document prepared by GCOS entitled Systematic Observation Requirements for Satellite-Based Products for Climate has been presented to the UNFCCC and published in 2006, serving as a basis for the preparation of a coordinated plan by space agencies.

Action on national and regional levels is central to the improvement of global observations for climate. The GCOS Regional Workshop Programme, supported by the Global Environmental Facility and United Nations Development Programme has since 2000, through the development of regional action plans and follow-up activities in ten regions worldwide, identified national and regional needs and deficiencies for climate data, including needs for assessing climate impacts, conducting vulnerability analyses, and undertaking adaptation studies. It also has a great impact on capacity building in developing countries.

In order to facilitate implementation of network improvements specifically in Africa, a meeting was organized by GCOS in Addis Ababa, Ethiopia in April 2006, with the meteorological community, the communities of users of climate information, and potential donors. It lead to an agreement to launch a ten-year programme called 'Climate for Development in Africa' (ClimDev Africa), that would focus on improving climate information in support of achieving the Millennium Development Goals.

It received the initial support of the African Union Commission, the UN Economic Commission for Africa and the UK's Department for International Development, and a number of countries and agencies have declared their intention to join. Following these endorsements, ClimDev Africa is intended to be a fully integrated, user-driven programme that addresses not only needs for improved climate observations as expressed in the GCOS regional action plans, but also needs for climate services, climate risk management, and associated policy development and implementation.

GCOS as a component of GEOSS

The GCOS community has been closely involved in the development of GEOSS since the beginning, and actively participated in the first Earth Observation Summit in Washington DC in July 2003. GEOSS basically extends the GCOS concept of a 'system of systems' to a wide range of societal benefit areas (SBA), which require timely, high quality long-term global information as a basis for sound decision making, and in order to better serve societal needs. The main thrusts of the climate SBA, 'understanding, assessing, predicting, mitigating and adapting to climate variability and change", are in great part reflected in the thrusts of GCOS, and it is natural to consider GCOS as the climate component of GEOSS. However, as mentioned in GEOSS 10-year Implementation Plan: 'the climate has impacts in each of the other eight SBAs', and GCOS is designed to provide climate-related information to basically all of them. Within GEOSS, the GCOS implementation process can also serve as an example for other SBAs and a contribution to cross-cutting activities.

Within the climate SBA, the IP serves as a backbone for the definition of GEO tasks and GCOS is working in collaboration with a number of other participating organisations and agencies to undertake them. Three main priorities emerge.

The first is the optimal use of past and current climate data, through better processing and reanalysis techniques using advanced models. This is the object of a 'climate task' co-lead with WCRP and CEOS, which includes efforts of National Meteorological and Hydrological Services to rescue and reprocess historical data, the development of a reprocessing strategy adapted to climate information requirements for both space and in situ data and the coordination of those activities between providers, and the coordination of reanalyses of recent climate by modelling centres.

The second is the maintenance and development of the global climate observing capacity from in situ and space-based platforms within the atmosphere, the oceans and over land and ice. This is the object of several 'climate tasks' developed jointly by data providers and coordination agencies, making use of GCOS specifications. The third, and last GCOS priority, is the progress in climate predictive capacity as a result of improved observations, handling and assimilation of observations, and breakthroughs in modelling capabilities.

Climate observations, as coordinated under GCOS, serve most GEO SBAs, since geophysical observations required for both climate monitoring and climate research are being used in many application areas outside climate. This is reflected in the 10-year Implementation Plan and a study on this topic is under way as part of GEO tasks. For example, precipitation (frequency, intensity, quantity and type) is a key variable for all SBAs. It varies considerably in space and time and requires a high-density network to observe its variability and extremes on regional scales. Analysis of precipitation variability and change is crucial for the assessment of the impact of climate on the natural environment and many human activities reflected in GEO SBAs. Changes in timing of precipitation, such as seasonality, can have implications for water supplies and agriculture.

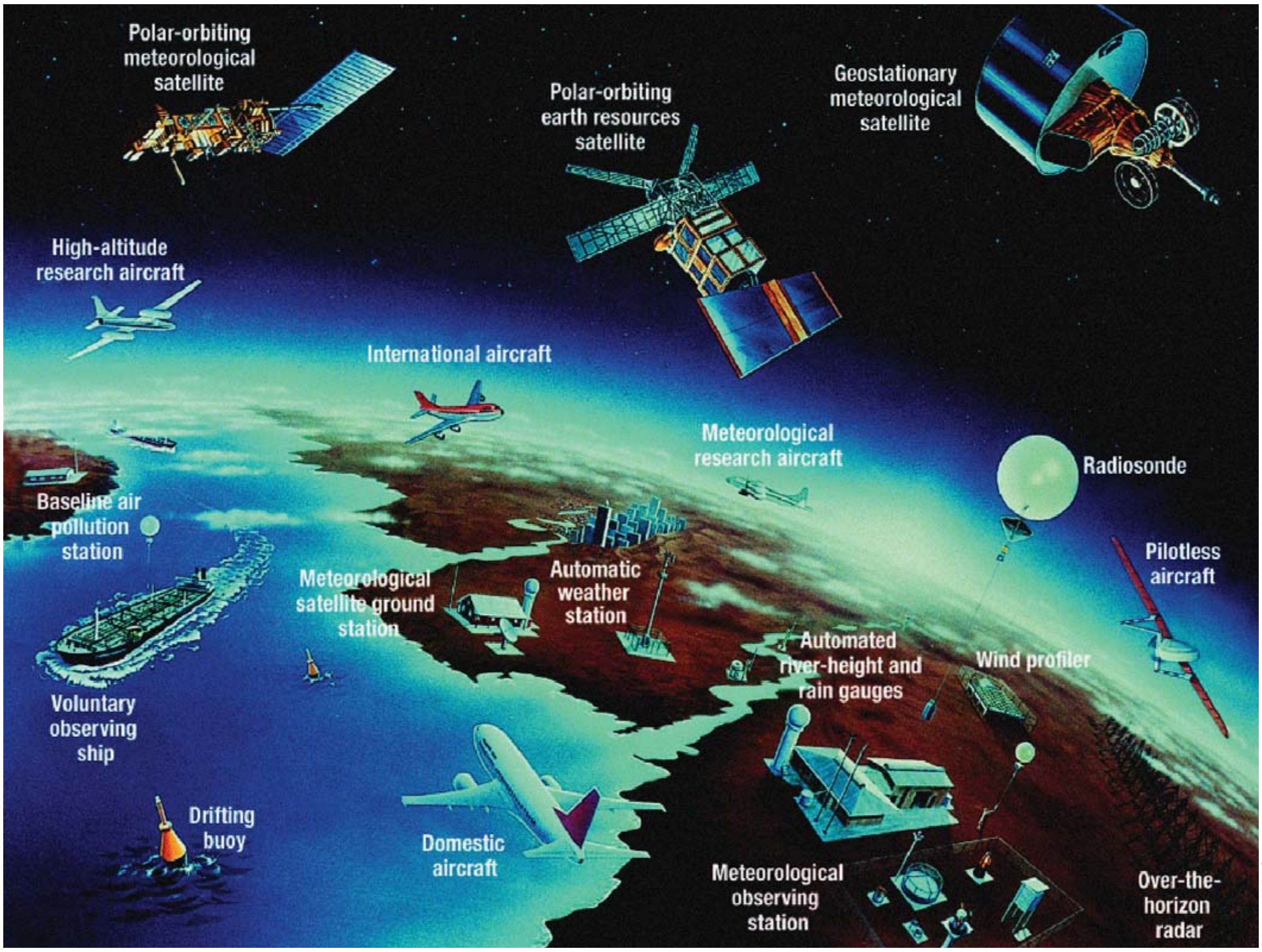


Photo: WMO

GCOS was established as a 'system of systems', built on existing global observing systems and aimed at ensuring that data will collectively be improved or complemented in order to fulfil its objectives

In particular, knowledge of surface precipitation (rainfall, snowfall) is important for the assessment of global water resources and for a better understanding of the interaction between the energy and water cycle, as well as for the assessment of climate impact on ecosystems. Changes in precipitation regimes in relation with climate change impact on vegetation, biodiversity, desertification (duration of droughts, shift of climate zones), water resources, river runoff and floods (intensity and duration of extreme events), snow cover and ice sheet balance.

The occurrence and human consequences of natural disasters are also dependent on precipitation regimes or amounts. The occurrence of some illnesses, especially those carried by insects, is also affected by precipitation parameters. A similar type of analysis can be done for other so-called 'essential climate variables', such as land and sea-surface temperature, or wind speed. Other variables required for climate monitoring can be considered as primarily required for another SBA: it is for example the case for land cover, which is a basic variable for bio-diversity, or river discharge, which is central to the water SBA. In a more general sense, strategies developed by GCOS for collecting, handling, sharing and making use of large quantities of geophysical data, can serve as an example for GEO in its other domains of interest.

Among the cross-cutting activities of GEO, it is worth mentioning the commitment of GCOS to the use of climate information for capacity building and development in the various regions of the world. This commitment is reflected in the following recommendation in the G8 Gleneagles Plan of Action prepared in 2005 for Climate Change, Clean Energy and Sustainable Development: "[The G8] support efforts to help developing countries and regions obtain full benefit from GEOSS, including from GCOS such as placement of observational systems to fill data gaps, development of in-country and regional capacity for analyzing and interpreting observational data, and development of decision-support systems and tools relevant to local needs."

The latest example of this commitment relates to the ClimDev Africa initiative mentioned earlier. The programme would be implemented as a partnership between the providers of climate information (principally the National Meteorological and Hydrological Services) and users of climate information. Outputs will include: strengthened climate observation networks and improved data management; new and improved climate services for a variety of user needs; incorporation of climate risk management practices in development planning; and raised awareness and enhanced political engagement among African national decision-makers concerning the importance of addressing climate change-related issues.

The expected outcomes associated with programme implementation will include improved food security and opportunities for agricultural growth, better protection from malaria and other climate sensitive diseases, better management of water resources, better management of disaster risks, improved environmental sustainability, and more judicious use of energy resources. This ten-year programme is expected to be formally launched in the near future after a short design phase is completed.

Photo: WMO

The Global Atmospheric Watch surface stations for meteorology and atmospheric composition, such as the Ushuaïa station in Argentina, form an important part of the GCOS network

Going forward with GCOS

The importance of climate issues for society has clearly been demonstrated in the last few years. The IPCC fourth assessment report published this year recognizes more than ever before the importance of on-going climate change, and the role of human activity in the evolution of climate. It also provides new information on trends of climate variability and probability of occurrence of climate extremes. The impact of climate characteristics on the environment and on human activities is also assessed in more detail, providing stronger evidence on the role of climate information in a number of domains, including those defined in the societal benefit areas of GEO. There is also a growing interest in the development of mitigation and adaptation strategies to climate change, which also require access to global climate data inserted in advanced assimilation-modelling systems.

GCOS is contributing actively to the development of GEOSS in meeting the needs of the climate SBA, as provider of climate data for the other SBAs, and as a driver for a number of cross-cutting activities, namely data management, capacity building and support for development in various regions of the world. Several actions in which GCOS is heavily involved have been identified as 'GEO early achievements'. This is the case for the development of the ARGO oceanic observation network (as an example of an advanced climate observing in situ network), for the constellation concept developed by space agencies in response to the GCOS IP, and for the ClimDev Africa initiative designed to make use of climate information in support of economic development in Africa.

The implementation of GCOS requires major investments which may be facilitated by the international consensus underlying GEOSS. It is also expected that the GEOSS framework will help develop the interaction between the various communities in need of global climate data and develop synergies of mutual benefit.

Argo — a global ocean observing system for the 21st century

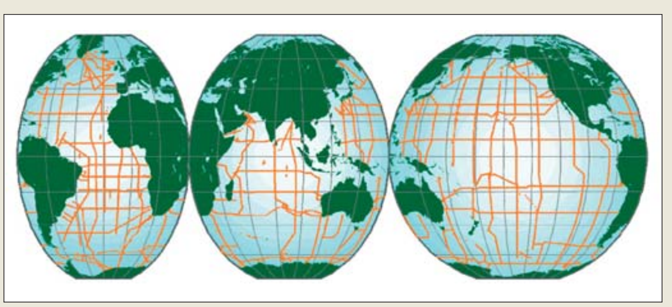
Howard Freeland, Institute of Ocean Sciences/Fisheries and Oceans Canada;
Dean Roemmich, Scripps Institute of Oceanography;
John Gould, National Oceanography Centre,
and Mathieu Belbéoch, Argo Technical Coordinator

Argo is an innovative ocean monitoring programme that is entirely different from anything undertaken previously in the oceans of the world. To understand how different it is from earlier approaches, it is instructive to compare it with the only previous attempt to observe the climate state of the oceans.

The World Ocean Circulation Experiment (WOCE) was first suggested in the late 1970s, and following a decade of planning, it became reality with an intensive field programme between 1990 and 1997. During that period, scientists from 25 nations collaborated in a top-to-bottom survey of the world's ice-free oceans.

During WOCE, research vessels carrying large science teams occupied more than 20,000 sampling stations, measuring temperature, salinity, velocity, dissolved oxygen, nutrients and geochemical tracers. The ship-time alone, 25 ship-years spread across the international research fleet, cost about USD200 million. The WOCE survey was of enormous scientific value, not least in providing a baseline against which change can be measured. But in being tied to the research fleet, it had intrinsic limitations. There were large unobserved areas between the survey lines. Not only were there gaps in spatial coverage, but the long time required to complete the global survey also posed problems. This 'snapshot' of the oceans extended over seven years during which there were seasonal changes but also, more importantly, climate shifts came and went. There were strong interannual changes due to El Niño and other climate phenomena and so this snapshot raises serious issues of representation. Finally, and perhaps most significantly, the high cost of research vessel surveys allows only a subset of the WOCE lines to be resampled approximately every decade, giving limited information on global scale climate variability.

Survey lines occupied during the field programme phase of WOCE



This 'snapshot' technique had intrinsic limitations, with large unobserved areas between survey lines, gaps in spatial coverage and a long timescale that did not necessarily observe climate shifts and interannual changes. Thus, it raised serious issues of representation

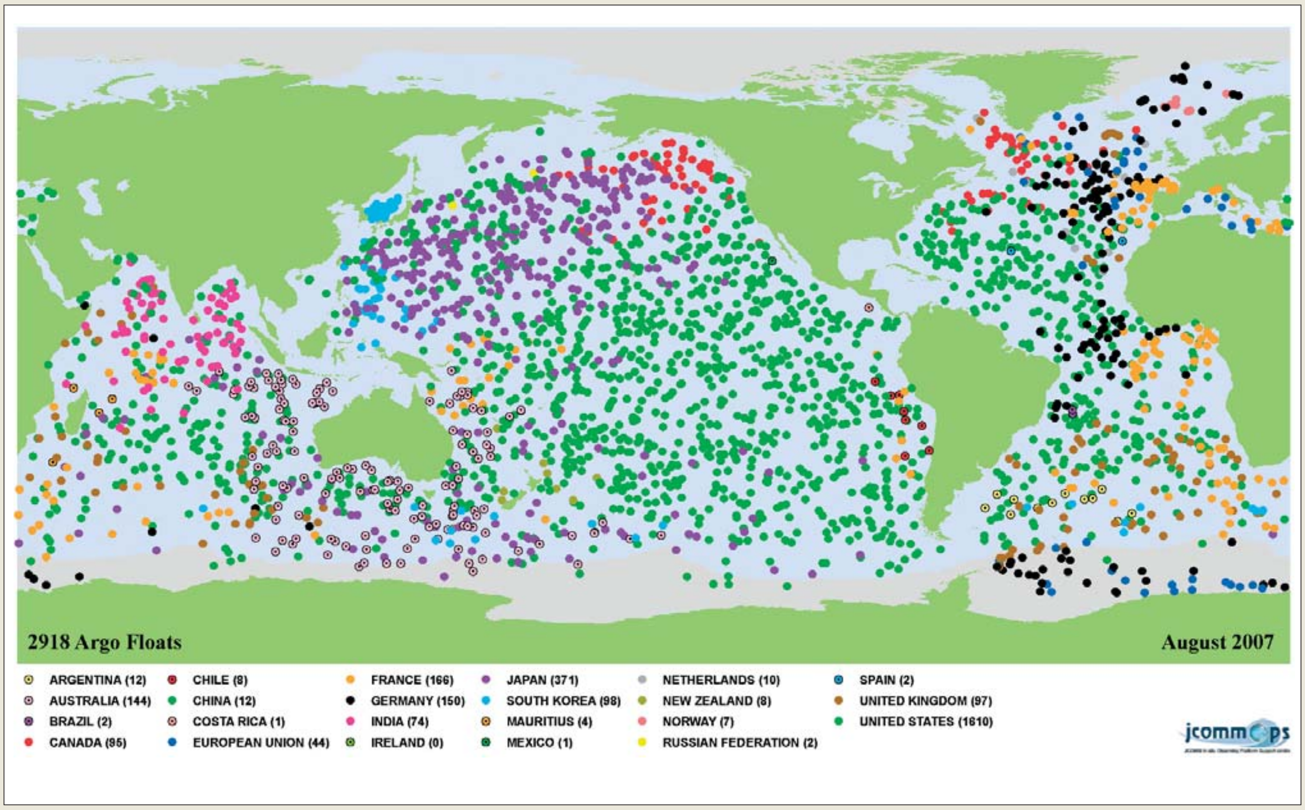
Source: WOCE Hydrographic Program Office

A technological breakthrough was needed to enable regular sampling of the ocean's interior, and the seeds of that breakthrough sprouted early in the WOCE survey itself. As a part of WOCE, free-drifting buoys were developed to measure ocean circulation patterns at about 1 km depth. These instruments rose to the sea-surface on a monthly basis to have their positions determined by satellite, and then sank again to their drifting depth. As the technology matured, temperature sensors were added to the buoys, and then salinity. By the late 1990s it became apparent that a revolutionary new way of doing oceanography had been developed.

In 1998, the Argo Prospectus was circulated, outlining this new method. Scientists of all nations were invited to participate in the deployment of a global array of 3,000 robotic drifting buoys. These would drift in deep water; have lifetimes of four-to-five years and supply profiles of ocean properties every ten days. By collecting over 100,000 profiles per year of temperature and salinity and drift measurements of ocean circulation, Argo would be able to track the physical state of the oceans. So in only a decade, the time required to obtain a snapshot of the climate state of the oceans had been reduced from seven years to just ten days!

The Argo plan was enthusiastically received, being quickly endorsed by the World Climate Research Programme's Climate Variability and Predictability (CLIVAR) study, the Global Ocean Data Assimilation

The distribution of floats in the Argo array, August 2007



As of mid-2007, 26 nations were deploying floats in support of Argo.
The initial objective of a global array of instruments at about 3° spacing had been achieved

Source: Argo Information Centre — Mathieu Belbéoch

Experiment (GODAE), and the Global Ocean Observing System (GOOS). The strong consensus for a global Argo array was promoted by national agencies as well as by scientists around the world, and plans to begin deploying Argo floats developed rapidly. Initial deployments began in 2000, with regional arrays expanding and technological hurdles being overcome in 2001-2003. By 2004 deployments were on a global scale and the target rate of around 800 floats per year was achieved. As of mid-2007 there are 26 nations deploying floats in support of Argo, and the initial objective of a global array of instruments at about 3° spacing has been reached.

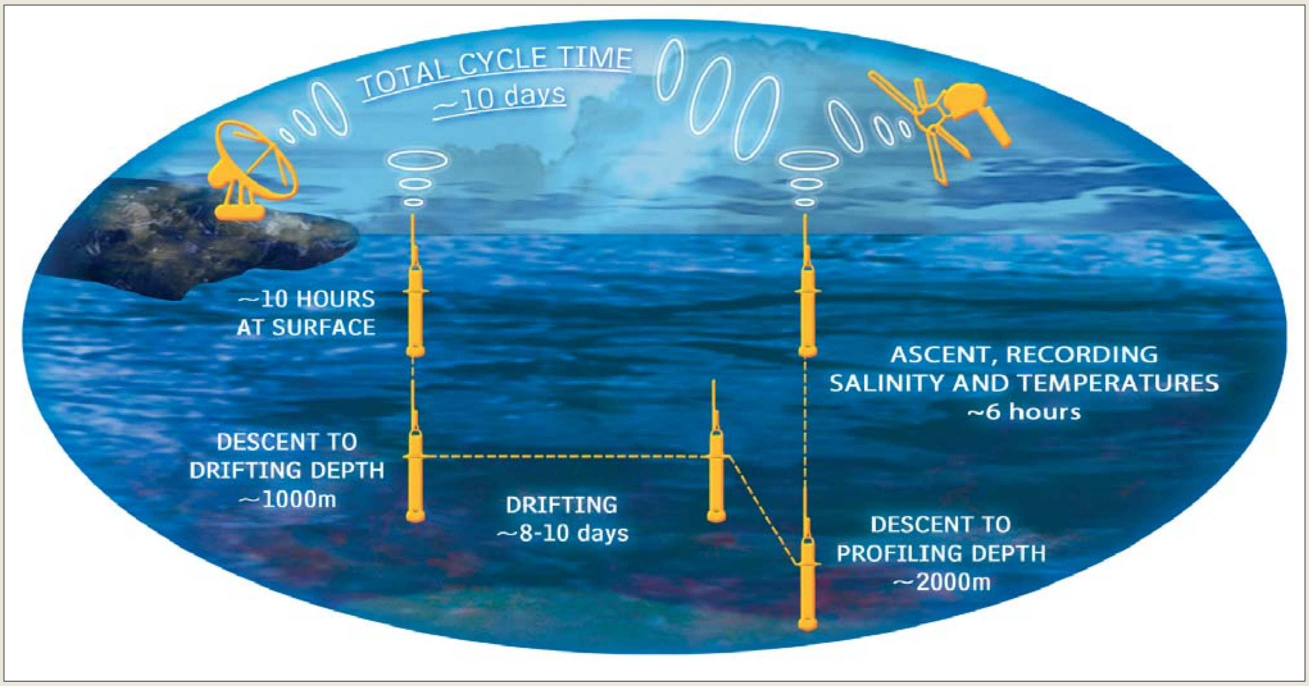
How do Argo floats work?

Argo floats are made in several countries, and while there are differences in design, the basic concept does not vary. A float is launched at the sea surface from a research vessel, commercial ship or aeroplane. The float sinks to about 1,000 metres depth, and drifts with ocean currents for ten days. After this interval, the float dives to about 2,000 metres, and then ascends to the sea surface, measuring temperature and salinity on the way up. At the sea surface, the data are transmitted to a satellite and relayed to a ground station and data centre. Meanwhile, the float again sinks to 1,000 metres to start a new ten-day cycle. To achieve this ascent and descent, floats change their buoyancy using a high-pressure pump that moves mineral oil into an external rubber bladder for ascent, or draws it back inside the instrument for descent.

Argo data are subjected to automated quality checks and made publicly available within about 24 hours of collection at two Global Data Assembly Centers (GDACs). Operational centres and other users may acquire this near real-time data either from GDAC via the Internet or from the World Meteorological Organization's Global Telecommunications System. A research-quality version of the data is prepared by expert examination of all float data, using internationally agreed protocols, and is similarly available from the GDACs. The Argo Information Centre maintains a searchable database of all float positions, and serves the programme in many different ways by facilitating communication and exchange between national Argo programmes and users.

While the basic Argo float collects temperature and salinity profiles in the upper 2 km of the oceans, technological advances will broaden the use and applications of Argo in the future. Argo floats can carry additional sensors for dissolved oxygen and other ocean properties. Several approaches are being tested to allow sampling under seasonal ice cover. The present 2,000-metre depth limitation could be extended with modifications to the pressure hull and pumping system. Finally, a sophisticated new version of the instrument (the glider) with wings, a streamlined hull and active

A typical duty cycle for an Argo float

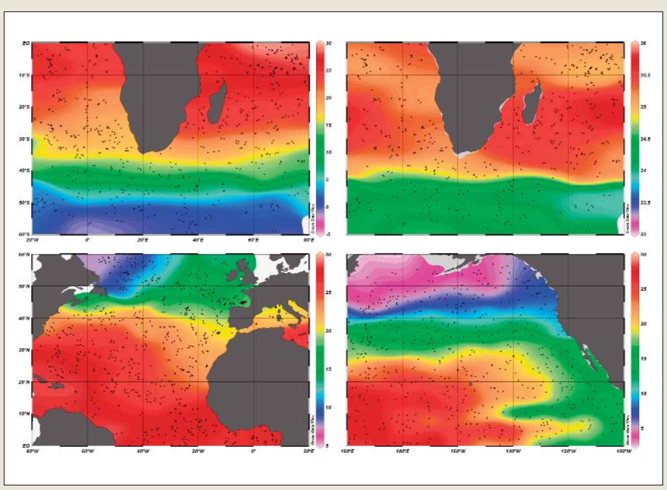


An Argo float is launched on the sea surface. It sinks to around 1,000 metres depth and then drifts with ocean currents for ten days before diving to around 2,000 metres. It then ascends to the sea surface, measuring temperature and salinity on the way up, before repeating the process

Source: Argo Information Centre – Mathieu Belbéoch

ballasting, 'glides' along programmed track lines to collect data with much higher spatial resolution than conventional Argo floats, near ocean boundaries or other special regions.

Distribution of ocean properties



Plots of the distribution of some ocean properties using data acquired during the last ten days of July 2007. Clockwise from top left the plots show sea surface temperature surrounding southern Africa, salinity at a depth of 200 metres, temperature at 100 metres in the North Pacific and sea surface temperature again, this time in the North Atlantic

Source: Howard Freeland (using Ocean DataView)

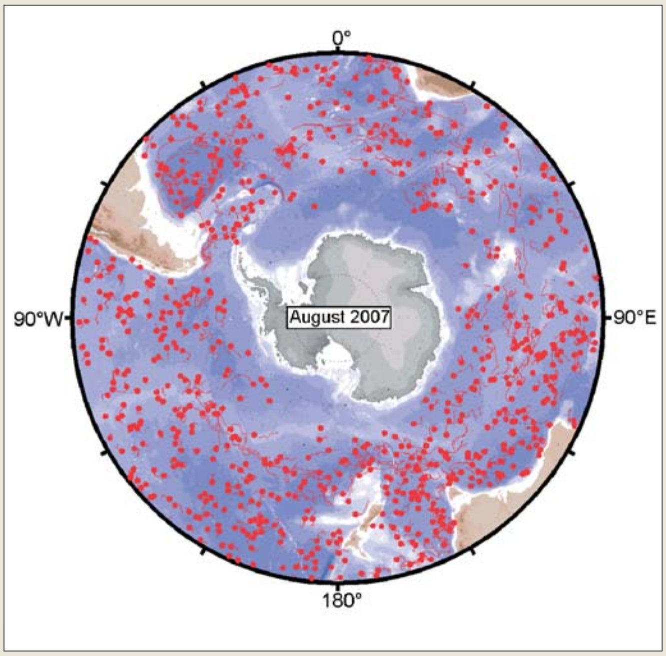
The international essence of the Argo programme

The creation of the Argo array has involved a degree of international collaboration that is unprecedented in oceanography. The goal of achieving global coverage requires that national Argo programmes put their regional priorities second to the global objective. Two-thirds of the ocean is in the southern hemisphere while most Argo floats are provided by northern hemisphere nations. The international Argo Steering Team (AST) coordinates the national efforts, working on the basis of consensus among partners to encourage and ensure nearly uniform coverage of the global oceans.

The AST is also responsible for uniform standards of data quality, in terms of float hardware and data processing, and uniform data formatting. The latter functions are overseen by the AST's Data Management Team. All Argo national programmes adhere strictly to Argo's policy of free and unfettered exchange of data. Argo is carried out for the benefit of all nations, not for individual participants. Similarly, all nations can contribute to Argo, if not by providing floats and data management services, then by facilitating float deployments and helping to analyse and gain value from Argo data. Through collaboration, the national origins of floats become irrelevant and the Argo array becomes an asset for all mankind.

The benefits of the collaborative international approach are demonstrated in the image above, which shows, maps of recent ocean conditions in several regions. The data to make these plots were gathered during the last ten days

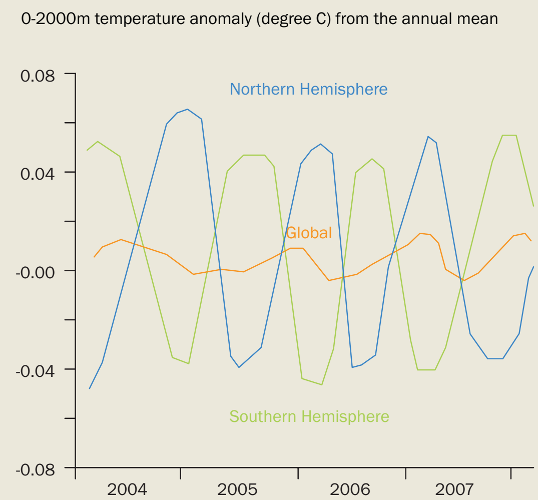
Distribution of floats in the Southern Ocean, August 2007



Some of the blank areas close to Antarctica contain floats, but at the time of this image these are under winter ice cover. They and will reappear in austral spring

Source: Howard Freeland

Argo floats observe the pulse of the oceans



Time-series of 0-2,000 metre temperature, degrees Celsius anomaly from the annual mean, for the northern (blue) and southern (red) hemisphere oceans and the global ocean (black), from Argo data. Each line is plotted as the anomaly from a three-year, 2004-2006 mean value

Source: Dean Roemmich

of July 2007 and downloaded directly from the US Global Data Centre via the Internet, in time for their inclusion in this article, which was written during August 2007. The data were plotted using Ocean Data View, which is publicly available software. This capability places the power to map present ocean conditions right where it belongs, at the fingertips of local scientists, government agencies, interested students or public users anywhere in the world.

This is a blue planet whose surface area is dominated by oceans. Between the equator and 60°S, 84 per cent of the globe is ocean, including the most remote and inaccessible regions of the world. The Argo programme committed at an early stage to sample the northern and southern hemispheres equally, and progress continues toward that objective. Already, Argo's dataset in the critical but remote region of the Southern Ocean greatly exceeds, in number and coverage, the total of all previous Southern Ocean observations.

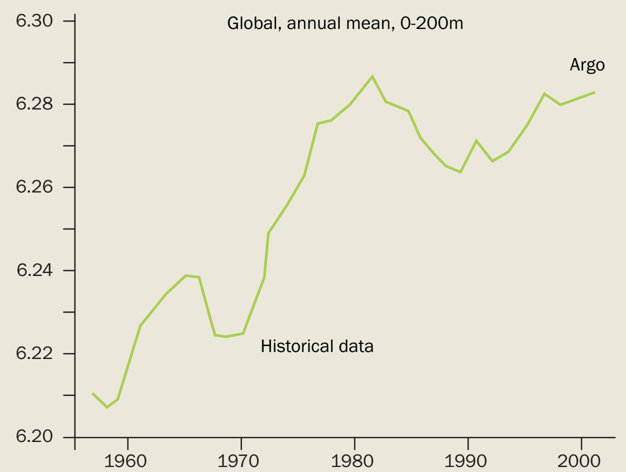
The future of Argo

The future of Argo depends on demonstrating the value of systematically repeated observation of the global oceans. Already, at least 14 operational centres in the US, Europe, Asia and Australia are ingesting Argo data into ocean data assimilation and forecast models to improve estimates of the state of the ocean and to initialize seasonal and interannual predictions. Scientists from all over the world have used Argo data in more than 100 research publications in the past few years. Nevertheless, since a primary objective of Argo is the ocean's role in climate, its value can be realized only when the array has been sustained over climate-relevant timescales. While Argo already observes seasonal variability on global scales, it will take a decade to show its power in observing interannual variability.

Fortunately, many of Argo's capabilities are simple and straightforward – for example, a monthly time-series can be produced, showing the ocean's temperature, averaged from the sea surface to 2,000 metres, globally as well as separately in the northern and southern hemisphere. This is the seasonal 'heartbeat' of the oceans, showing that the annual and the interannual variability in temperature are greater in the northern hemisphere, but that the southern hemisphere, by virtue of its larger ocean area, controls the April maximum in global mean temperature.

While the ocean's annual mean temperature has been fairly constant over the past three years, this was not the case over the past 50 years, with ocean warming accounting for more than 80 per cent of the total heat absorbed by the climate system (air, sea, land and ice). When the global mean ocean temperature from Argo is compared to earlier estimates made from much sparser datasets by S. Levitus and colleagues, the surface layer of the oceans is thought to have warmed by about 0.4°C over the 50-year period, with the 0-2,000 metre average warming by about .07°C. Unfortunately, the sparseness of pre-Argo data, particularly in the Southern Ocean, means that the pace of change is highly uncertain; the actual warming could have been twice the estimated rate. This is critical information for the testing and verification of climate models. For the future, Argo eliminates the uncertainty that has been experienced due to under-sampling.

Global annual mean ocean temperature, 0-2,000 metres



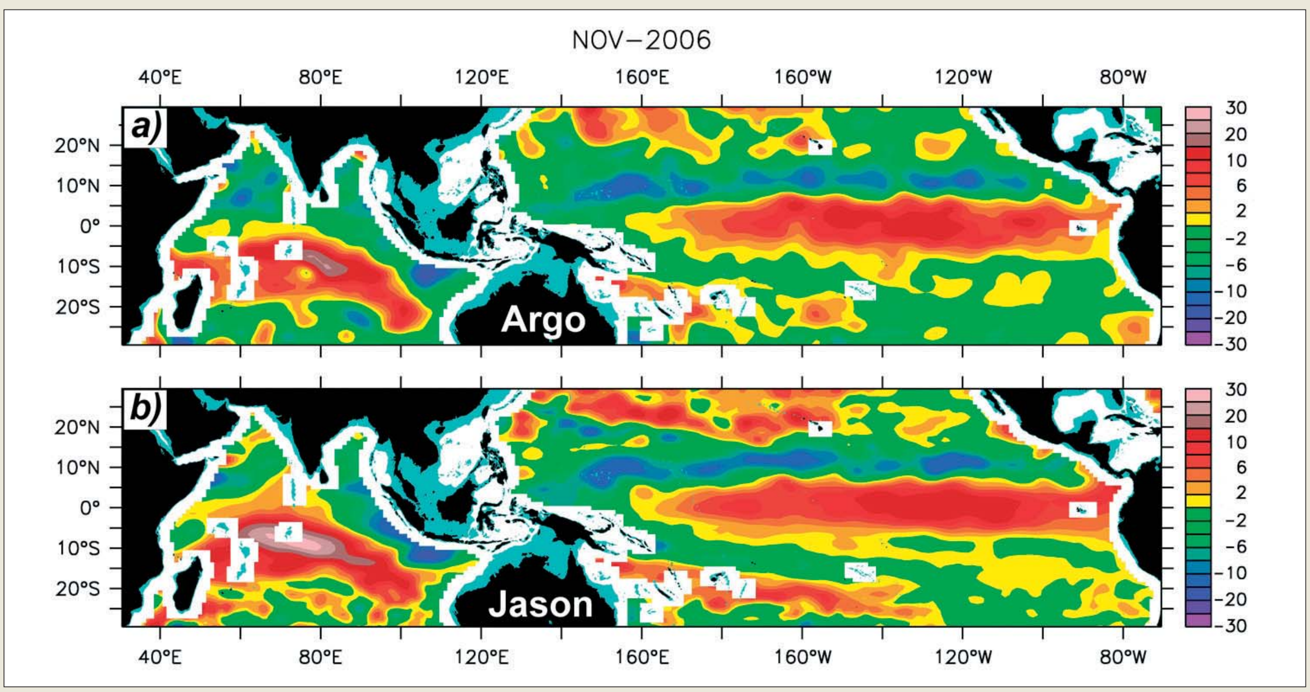
Historical (pre-Argo) data and Argo data showing the global annual mean ocean temperature at 0-2,000 metres

Source: Dean Roemmich

Argo was designed specifically to exploit the complementary relationship between satellite measurements of sea surface height (SSH) and subsurface profile measurements of temperature, salinity and velocity. Indeed, the name Argo was chosen to underline the float programme's synergy with the Jason satellite altimeter. On seasonal and longer timescales, SSH changes measured by Jason are largely due to temperature and salinity changes in the water column, measured by Argo. SSH during the El Niño event of late 2006 (centimetres difference from the 2004-2006 mean) measured by Jason and the part of SSH due to ocean temperature and salinity changes measured by Argo show a striking similarity, demonstrating that these key observing systems are operating in tandem to capture large-scale phenomena. Differences between the two sets of measurements can be exploited to determine previously inaccessible features of ocean change.

The Argo array, while still growing in coverage and capabilities, is moving into a pre-operational phase that requires the array to be sustained for a ten-year period, while its value in various applications is assessed. This will allow time for the operational agencies and the scientific researchers of the world to learn how to use the new dataset, understand its synergy with other observing system elements and its role in both new and existing applications. The societal need for climate observations to monitor the state of the planet and give early warning of significant change creates a responsibility to implement and sustain measurement systems that are matched to the global scope of the climate problem.

Argo and Jason offer complementary views of the oceans



Sea surface height anomaly in November 2006 (cm, relative to a three-year mean 2004-2006) estimated from Argo profile data (a) and from satellite altimetry (b). High values in the eastern equatorial Pacific indicate El Niño conditions

Source: Dean Roemmich

The blue planet — observations of the global ocean

D. James Baker, Tom Gross and
Howard S. J. Roe, Intergovernmental Oceanographic Commission of UNESCO and
Partnership for Observation of the Global Ocean; the GOOS writing team[1]

We depend on the oceans more than at any time in history, yet we know less about this watery part of Earth — the blue planet — than we do about the surface of the moon. The oceans have an important influence on our climate, are a source of critical resources, are essential to global transportation, and form the largest and mostly unexplored ecosystem on the planet. The actual numbers reveal that the impact of the oceans on our daily life is far reaching: the oceans cover 71 per cent of Earth's surface and hold 97 per cent of the available water; 38 per cent of the world population lives in coastal regions at risk; more than 90 per cent of goods are transported by sea; the global value of marine markets is over USD1.5 trillion, excluding fisheries; in the USA alone the current value of fisheries is USD60 billion; and offshore oil and gas accounts for 20 per cent of current production.

And our society is at risk from the oceans. Flooding and wave damage from storms, tsunamis and sea-level rise can devastate life and property in coastal regions. Even over the interior of continents, climate and weather are affected by changes in the currents and heat content of the ocean. El Niño and La Niña, closely linked to temperature changes in the tropical Pacific ocean, cause drought and floods around the globe – the 1997/8 El Niño killed 2,000 people and cost USD30 billion in insured losses alone. Australian agriculture loses USD1 billion when the seas to the north cool less than one degree Celsius, as often happens during El Niño. Future impacts will be even greater. As populations grow and as climate changes, the ocean is presenting increased risks to society. Current estimates show that improved weather and climate prediction using better ocean information could save USD1 billion per major climate event. A full system for ocean observing and forecasting is necessary for protection and mitigation of these risks.

Managing living resources also requires understanding and predicting ocean conditions. Fisheries and aquaculture are a major source of food but over-fishing, habitat destruction, climate change, pollution and aquaculture itself adversely impact both food species and the underlying ecosystem. Shifts in populations of marine life are occurring, coral reefs are bleaching, and increased carbon dioxide in the atmosphere is creating a more acid ocean with potentially catastrophic effects on ocean life. Most marine pollution originates on land — from industry, agricultural runoff, construction and habitat destruction. Warmer seawater now carries deadly diseases such as cholera, and eutrophication of coastal areas caused by pollution may lead to toxic algal blooms. All of these processes must be monitored so that society can deal with them in an informed, cost-effective and timely way.

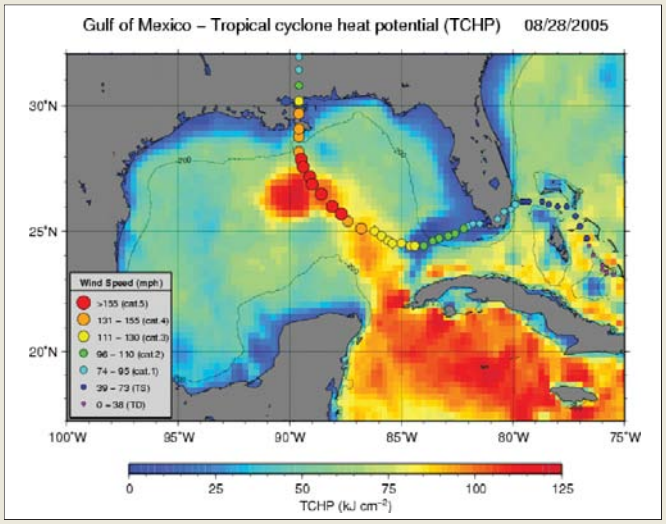
Finally, the entire world depends upon energy taken from the sea. The sea floor is tapped for hydrocarbon and mineral resources. Waves, tides, offshore winds, and ocean temperature differences are sources of renewable energy. The global value of renewable energy is estimated to be close to USD1 trillion by 2010. But ocean conditions strongly affect our ability to harvest these resources; offshore oil and gas operations are often disrupted by unexpected strong ocean currents, waves and tropical storms fueled by ocean heat which can also shut down renewable activities.

For all of these reasons, more than two decades ago ocean scientists, engineers and users began to plan and build a Global Ocean Observing System (GOOS) for rapid detection and timely prediction of changes in oceanic and coastal environments that impact our social and economic well-being. And today many of the components of the system are providing critical and fundamental information for society. Just as radiosondes, barometers, and satellites are essential for weather forecasting, the GOOS global *in situ* system of floats and moorings and the constellation of satellite-based instruments are proving to be essential for a range of forecasts and warning systems for the oceans. A fully implemented GOOS is thus a core component of the Global Earth Observing System of Systems (GEOSS).

The Global Ocean Observing System

The goal is to build a permanent and sustained global system covering deep ocean basins, coasts and estuaries for observations and modelling, leading to the provision of information and services. The instruments fly on satellites, are installed on research and commercial vessels, are carried by drifting and moored systems on and in the ocean, and are deployed on the sea floor. The initial specifications for the open ocean component of GOOS described a system that includes a network of 3,000 Argo profilers 1,500 drifting buoys, moored buoys such as the array for El Niño forecasting in the tropical Pacific, sea level stations and satellite resources, all tied together with data archives, modelling, and products.

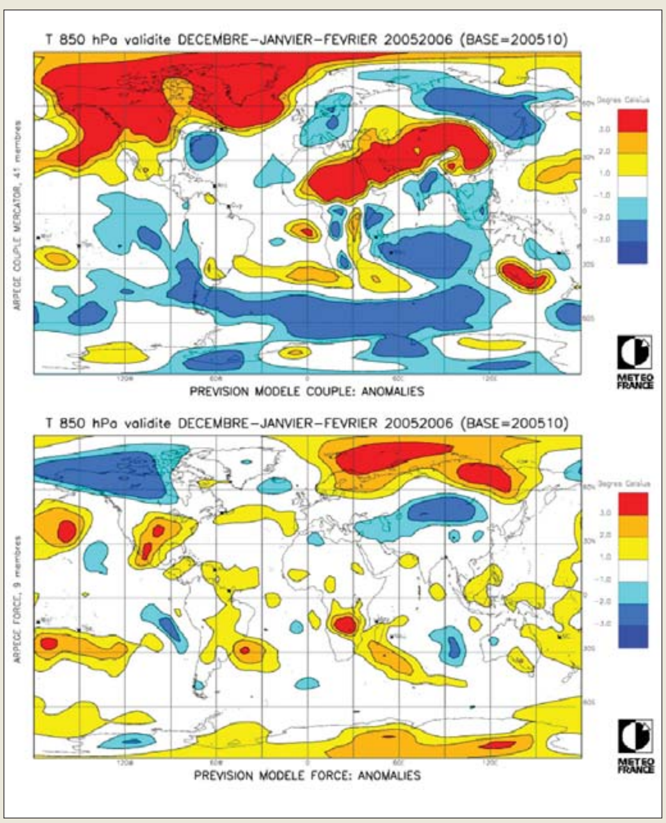
Observations of ocean heat content critical to storm forecasts



Tropical Cyclone Heat Potential associated with Hurricanes Katrina and Rita; the hurricanes grow in intensity as they pass over warm water

Source: NOAA/AOML

Climate forecasts depend upon changing ocean conditions



Composite figure showing the winter forecast for 2005-2006 with a coupled ocean atmosphere model initialized with (upper) and without (lower) the Mercator ocean analyses; the cold anomaly over Europe is missed without the ocean information

Source: Meteo France

Today, nearly 60 per cent of that initial specification has been completed, and an overall strategy and implementation plan for Coastal GOOS has been approved by the GOOS member states.

Increasingly, these instruments record biological, chemical and geological data and variability in addition to physical variables such as temperature, salinity and surface weather. A fully implemented GOOS will efficiently link observations and models for mitigation of environmental damage, improvement of predictions of drought and flood in support of agriculture, fire-fighting, water resource management and human health; management of marine and coastal ecosystems and resources; protection of life and property on coasts and at sea; and facilitation of scientific research.

The primary international coordination for GOOS is provided by the Intergovernmental Oceanographic Commission (IOC) of UNESCO working together with the World Meteorological Organization (WMO), the United Nations Environment Program (UNEP) and the International Council for Science (ICSU). The design and implementation of the open ocean component of GOOS is overseen by panels of experts, member states and participating organizations cooperating through the joint WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM). The Partnership for Observation of the Global Ocean (POGO) links much of the ocean research community with GOOS, providing ocean observations and active participation by the world's fleet of deep sea research vessels. The coastal aspects of GOOS are implemented through member states and participating organizations operating independently or cooperating through GOOS Regional Alliances.

How GOOS contributes to GEOSS

The current implementation of GOOS has components in place which are routinely used for warnings and forecasts of great benefit to society. Below are several examples, from forecasting disasters to sea level measurements to coastal coordination, all of which show the value of an integrated global system.

Forecasting disasters

Major storms and destructive waves are a particular concern to coastal communities. GOOS data gives communities basic information that they need for forecasts of these increasing dangers. Tsunamis are one important example, and GOOS has contributed to the development of a tsunami warning system. Another example is hurricanes: the image below shows how oceanic hurricanes draw their energy from the underlying warm ocean surface. Better forecasts of ocean temperature from the satellites and buoys in the GOOS observational system are providing better estimates of storm generation and intensity. These in turn are allowing communities to prepare for oncoming storms and to mitigate damage. Investments in the system provide a good return – for example, a recent study in the UK showed a roughly twenty to one benefit/cost ratio for the information provided from oceanographic satellites.

Forecasting seasonal weather patterns

GOOS enables more accurate seasonal climate forecasts and improved strategies for better land and ocean harvests. Cost benefits to the USA from better forecasts of El Niño and effects on Australia were given earlier. A different example is the European seasonal forecasts that were made for the winter of 2005-2006. The coupled ocean-atmosphere models of several meteorological agencies, initialized with data from the ocean observing system, predicted an enhanced risk of a colder than average winter over Europe. Using their model and additional statistical links between patterns in North Atlantic heat anomalies and European winter, the UK Met Office issued a public statement warning of a two in three chance of a colder than average winter for northern Europe. At the end of the winter surveys showed that more than 71 per cent of people in the UK were aware of the forecast, and that more than 13 per cent actually acted on the forecast. In the event much of Europe did experience a colder-than-average winter. Retrospective forecasts with the Météo-France model show that use of ocean observations is essential to achieve a successful model forecast of the cold winter.

Satellite-based sea level measurements

The oceans absorb more than 80 per cent of the excess heat from global warming, making the rise of sea level a sensitive indicator of climate change. The 15-year data set collected by satellite altimeters, when merged with those from Argo floats and other measurements of ocean heat content, satellite measurements of gravity over the ocean and coastal sea-level gauges, provide the first accurate global observations of the trends of sea-level change. These trends reveal that the rate of sea level rise has increased from 1.7 to 3.1 mm/year. In addition, the altimetry data shows for the first time basin-scale decadal variability in the oceans, including El Nino-Southern Oscillation and its impact on seasonal floods and droughts, and longer-term changes such as the North Atlantic Oscillation. The information on sea level is of critical importance for coastal countries and is vital to the very existence of many small island states.

Photo: Paulo Arlino, www.pmel.noaa.gov/pirata

Research ship in the background, monitoring buoy in front

Coastal GOOS and the GEO Coastal Zone Community of Practice

The coastal zone is a dynamic region where the terrestrial, oceanic, atmospheric, and human domains converge. It supports the greatest concentrations of resources and people, with the most rapid increase in population density, on the planet. Consequently, coastal ecosystems are experiencing unprecedented changes from habitat alteration and loss, oxygen depletion, harmful algal blooms and increasing public health risks, coastal erosion and greater susceptibility to flooding. The resulting conflicts between commerce, recreation, development, sustenance, and conservation are becoming increasingly contentious, politically charged, and expensive. Resolving these conflicts in an informed, timely and cost-effective fashion depends on significant improvements in our ability to detect and predict changes in coastal ecosystems. Coastal GOOS is working toward the sustained provision of data and information necessary for this purpose.

Coastal GOOS is developing regionally on many fronts. Examples contributing to the development of GOOS for detecting and predicting changes in water quality include harmful algal blooms, the use of synoptic satellite ocean colour imagery, long-term time series provided by the continuous plankton recorder (CPR), and the development of in situ sensors that can measure bio-optical properties, dissolved oxygen and nutrients in real time.

Together with GRAs, GEO has established a Coastal Zone Community of Practice (CZCP) to help coordinate the development of coastal GOOS, the coastal component of the Global Terrestrial Observing System, and other coastal observing programmes to achieve the benefits of GEOSS and provide data and information needed by coastal managers, decision-makers and other users. This integrated land-sea observing approach is especially important given the extent to which land-based sources of pollution impact the coastal zone, and conversely the impacts of storm surge and sea level rise on land.

Issues for the future

GOOS is the ocean component of GEOSS. Completing the implementation of GOOS will provide the improved ocean information required for society to better manage and mitigate the impacts of climate change, natural disasters and human activity. It will further reduce the human health risks associated with contact with marine waters and seafood consumption and will enhance the

Photo: NASA, earthobservatory.nasa.gov/Newsroom/NewImages/

The Mississippi River discharges sediments into coastal waters as shown in this satellite image (5 March 2001). The discharge also transports anthropogenic nutrients stimulating the growth of phytoplankton, which fuel oxygen depletion in bottom waters and the development of the 'dead zone' in the Gulf of Mexico

capacity of marine and estuarine ecosystems to support products and services valued by society.

Despite the progress that has been made, we do not yet have a fully implemented and sustained system. We still have inadequate warning and response mechanisms, and fisheries continue to decline while environmental degradation of the oceans increases. Our existing observing systems are inadequate; modelling and prediction capabilities need improvement and delivery to users expanded. There are gaps in satellite and in situ coverage, and data sharing issues loom, especially for developing countries. Resources for routine maintenance of both *in situ* and remote sensing observing systems have not been allocated and should be better coordinated internationally. Finally, funding commitments are inadequate and mostly short-term. Society must address all of these issues.

GEO and GEOSS can help GOOS in three ways:

- By achieving significant new government and private industry commitments for implementing and sustaining long-term observations of the ocean
- By promoting the sharing of data by all countries
- By raising public awareness.

Terrestrial, oceanic, and space-borne satellite observing systems require international coordination, cross-calibration and validation, and agreements on observing protocols. Responsibilities for global coverage, especially for remote, data-sparse regions of high societal impact, for example in the Southern Ocean, must be shared and coordinated. Technology development must be fostered and integrated to preserve the integrity of the observing systems while increasing efficiencies and coverage. Data, products and models for forecasting high impact events, long-term change, and the resultant complex interactions with society must be developed.

Clearly, much remains to be done, but GEOSS provides the framework to make significant progress on these critical environmental and societal issues. The participants in GOOS will work with GEOSS to ensure the integration of existing and future observational networks in open ocean and coastal environments and to promote new technology and sustainability of in situ and remote observing arrays. Perhaps most importantly, the member countries of GOOS must join with their GEO partners and organizations, such as the World Meteorological Organization and the Intergovernmental Oceanographic Commission, to ensure implementation of the necessary observing systems, sustained funding and timely, open access to shared data and products across the globe.

Why the world needs a Global Ocean Observing System

Keith Alverson, Chief of Ocean Observations and Services, IOC/UNESCO

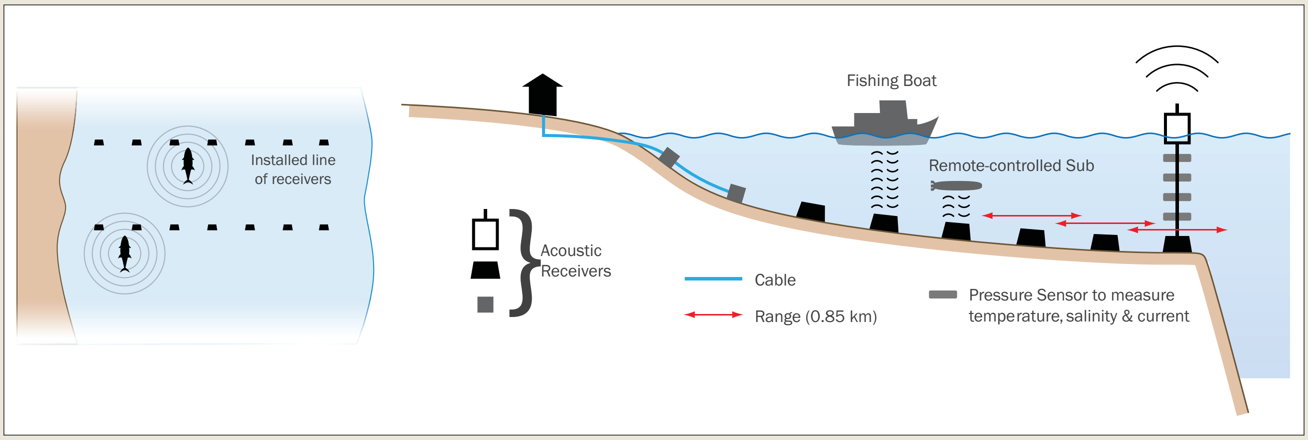
Ocean observations received plenty of media attention recently when a manned submersible planted a titanium flag on the sea floor at the North Pole.[1] Meanwhile, around the globe powerful monsoon rains and floods killed hundreds and displaced tens of millions more across Bangladesh and North India.[2] The Arctic summer sea ice retreat surpassed all previous records, even with another month of summer melt still to come.[3] Pacific coral reefs were found to have declined 20 per cent in the past two decades, far faster than they were expected to.[4] Due to weak La Niña tendencies in the tropical pacific, US Government forecasters slightly reduced their Atlantic seasonal hurricane forecast, though they still await an above average season, with up to nine hurricanes and 16 tropical storms expected.[5] A 7.5 magnitude submarine earthquake struck near the Island of Java but was located too deep in the earth to generate a destructive tsunami in the Indian Ocean.[6] The Australian Bureau of Meteorology confirmed that 12-month rainfall deficiencies had expanded and intensified over large areas of the country and are likely to remain for some time.[7] And lastly, the first span was welded into place for a new USD14 million bridge across the Grand Canal in Venice,[8] a city protected by the construction of a USD2.6 billion system of floodgates that may still leave the city vulnerable to future sea level rise.

This list may at first seem like nothing more than an eclectic smorgasbord of media coverage from early August 2007, but in fact each one of these stories highlights the importance of ocean observations, and together they clearly demonstrate the need for such observations to be brought together in a global system. That all these events occurred so close together is no doubt a coincidence. That they testify to the societal benefits of the global ocean observing system is not.

Although ocean observations were not mentioned directly in any of these stories, the societal and economic impacts that make them of interest to the public, and hence news agencies, are provided by the Global Ocean Observing System (GOOS). Exploitation of submarine resources, prediction of monsoon onset and intensity, monitoring of arctic ice dynamics, prediction of point of landfall and degree of intensification of tropical storms, provision of tsunami warnings, understanding of patterns of protracted drought, and protection of coastal infrastructure are all services that can only be maintained due to the ready availability of sustained and coordinated ocean observations.

One of the reasons ocean observations aren't mentioned in the mainstream press is that they are, by design, rela-

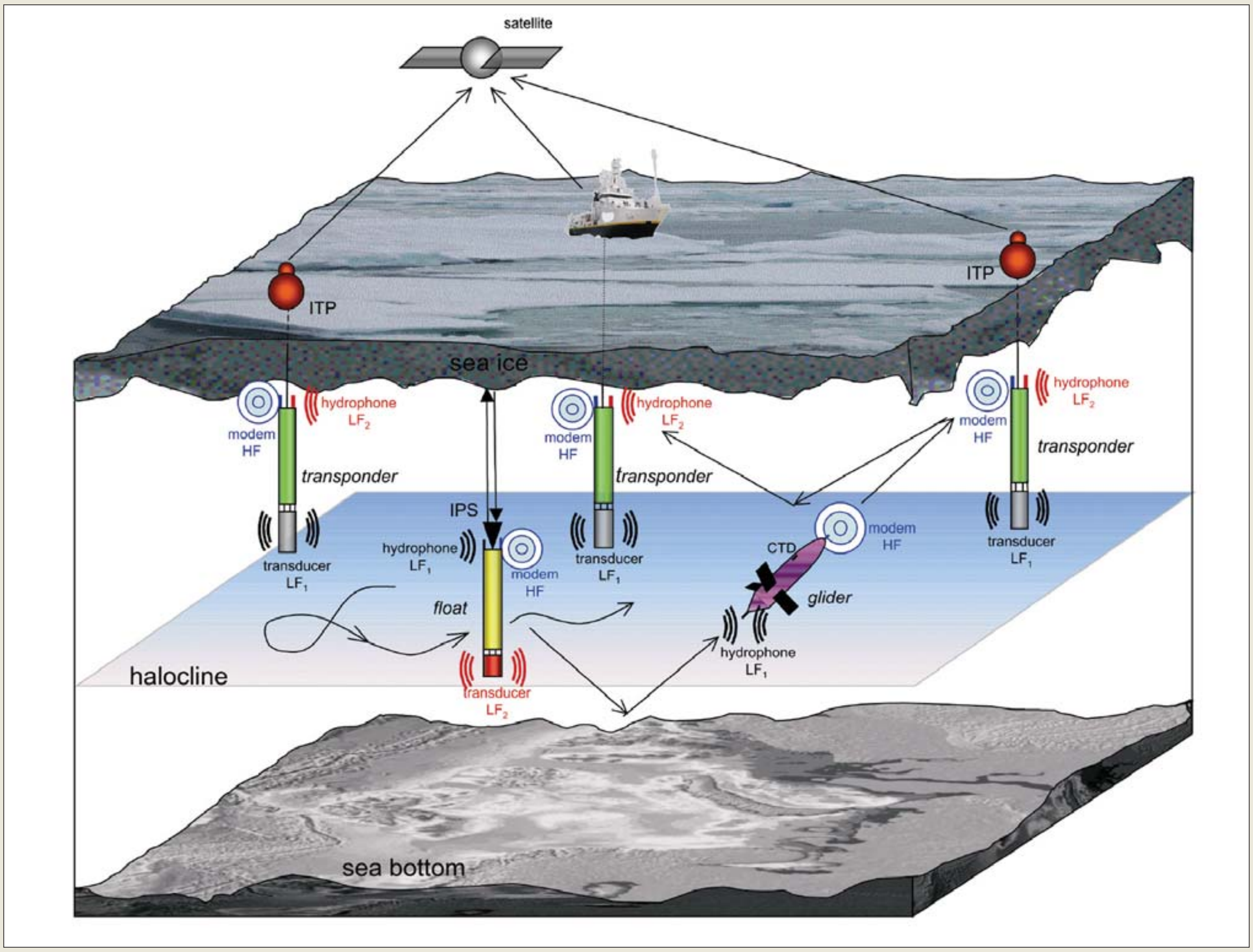
Ocean Tracking Network



The Ocean Tracking Network (www.oceantrackingnetwork.org) is a global initiative that comprehensively monitors ocean conditions and the response of marine life to changes in these conditions

Source: www.oceantracking.net

An ocean observing scheme for the Arctic Ocean



The ocean-observing scheme for the Arctic Ocean currently being implemented by the DAMOCLES Integrated Project of EC-FP6. An extensive system of floats and gliders explore the upper ocean, communicating their data to satellites and receiving measurement-control and navigation information via a net of ice-tethered platforms

Source: Summerhayes et al, Observing the Polar Oceans During the International Polar Year and Beyond, WMO bulletin 56(4) 2007

tively boring. In order to serve such a diverse array of users and products, operational observing system components are designed to be inexpensive, simple, reliable and to adhere to common standards and protocols. Hardly headline material. As with levees in New Orleans and highway bridges in Minnesota, for example, the ocean observing system is designed to unobtrusively provide public services that generally only receive attention when they fail.

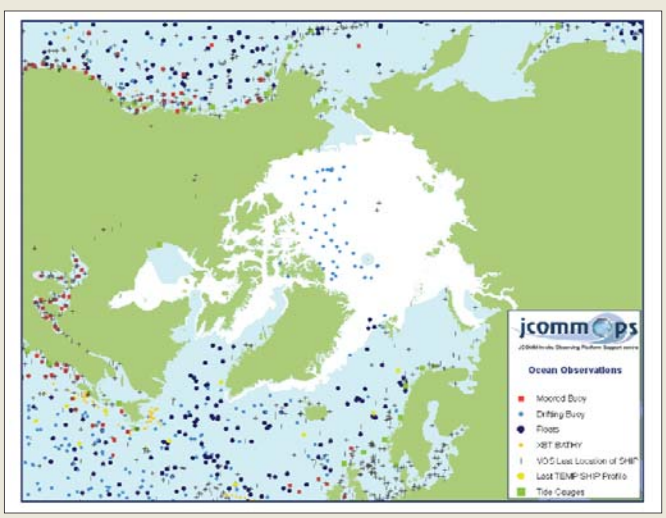
What are these low profile observing system components? As described in the article *The blue planet — observations of the global ocean* by Baker et al in this book, a network of buoys, moorings, floats, tide gauges and XBT hydrographic lines that make up the planned in situ open ocean module is in place. However, the network has to date reached just over 50 per cent of its design specifications, and current and projected future levels of national contributions are clearly insufficient to finish the task. Furthermore, although plans for a coastal module for the GOOS have been agreed, they have yet to develop substantially as a global system, but in many cases continue to exist as a menagerie of disparate national efforts. Full implementation of GOOS, including both the open ocean and coastal modules, will require substantial new commitments from member states and much stronger intergovernmental mechanisms to ensure they are sustained.[9]

Putting aside the importance of simplicity as a means to ensure reliability and sustainability, it is clear that pressure will always exist to fill gaps and improve accuracy. Indeed, many exciting new technologies are being developed as pilot projects for potential future inclusion in GOOS and, as with any new technology, there will no doubt be myriad exciting spin-offs from these innovations. One example is the recently approved GOOS pilot project, the ocean tracking network (OTN), which simultaneously monitors ocean conditions and marine life response to these conditions by tagging sea creatures with tiny transmitters. These transmitters allow the movement of sea creatures to be tracked for over 20 years by receivers placed at one-kilometre intervals along the ocean floor, across continental shelves. The OTN has been kick-started with a USD35 million grant from the Canadian Foundation for Innovation and is bringing together international scientists, industry and government in an effort that could potentially add a biological monitoring component to the ocean observing system for the first time.

Another gap in the system occurs in polar regions, underneath the sea ice. An ocean observing scheme for the Arctic Ocean, for example, is being implemented by the European Commission 6th Framework Program-funded project DAMOCLES, which includes an extensive system of floats and gliders exploring the upper ocean, receiving navigation information and communicating their data to satellite via a net of ice-tethered platforms. One hope is that International Polar Year 2007-2009 (a scientific programme) will help provide the impetus to maintain such observations into the future as an arctic component of the sustained global ocean observing system. The prospect of filling gaps in our observational capabilities with novel research and technologies developed in pilot projects such as OTN and DAMOCLES is extremely exciting.

The value of ocean observations is dramatically increased if they are brought together as components in a coordinated global system that serves multiple users.[10] For example, the GLOSS tide gauge array provides real-time data vital for tsunami warning systems, but this infrequent use does not alone provide sufficient support to maintain the network. It is because local sea level data are also of use for more quotidian purposes, such as offshore development, routine marine transport planning and coastal zone management, and because these data are combinable with other observations, such as satellite remote sensing altimetry measurements for calibration and validation, that the tide gauge system is sustainable. Can even more benefit be extracted from ocean observations by integrating them still more broadly within a comprehensive system encompassing all earth observations? In the hope that such integration may add value, GOOS has accepted responsibility as the ocean component of the Global Earth Observing System of Systems (GEOSS) and is a founding participating organization in the Group on Earth Observations (GEO).

The existing near real time Arctic Ocean Observing System



Near real time GOOS data availability in the Arctic on 23 July 2007 from the Observing Platform Support Center (JCOMM-ops) of the Joint IOC/WMO Commission on Oceanography and Marine Meteorology

Source: www.jcommops.org

The GEO has provided unprecedented political interest in the observation of the Earth. Thanks to GEO, earth observations were discussed by heads of state at the G8 summit meetings in Gleneagles in 2005 and Heiligendamm in 2007, and a third ministerial level GEO meeting is to be held in Cape Town in November 2007. GEOSS is intended to build on, and add value to, existing observation systems by coordinating their efforts, addressing critical gaps, supporting their interoperability, sharing information, reaching a common understanding of user requirements, and improving delivery of information to users. This is certainly bold and exciting vision from the top, but how is it working down in the trenches for the sub-sub-sub-systems that are actually collecting and disseminating data?

For example, what specific added value would be derived from sharing protocols for interoperability between, say, fish population movement observations off the Pacific Coast of North America, and glacial mass balance observations in the European Alps? Both are important, supported by strong communities of scientists and have clear societal benefits, but spending too much time, money and effort coordinating them is probably an imbalance of effort and reward.

In fact it is certainly possible to ‘overestimate the potential of synergies’ as Dieter Zetsche, chief executive of DaimlerChrysler, stated after announcing the USD15 billion loss associated with the sale of Chrysler, less than a decade after its merger with Daimler-Benz. The GEOSS experiment is several years old now and, as was the case at Daimler-Chrysler, finding specific, tangible, quantifiable benefits that owe their existence to this new layer of coordination, as opposed to constituent observing systems that were already in place, is not an easy task.

The ocean community potentially has an enormous amount to gain from the advent of GEOSS, but to do so we must keep a steady aim on the goal of delivering an actual earth observing system for society. If not, it would be all too easy to lose our way in a plethora of trivial tasks, only to be forced to cut our losses. Furthermore, oceanographers must remain vigilant to ensure that this new high-level political exposure and coordination with non-oceanic observing systems is indeed adding new value to our existing efforts.

For fifteen years GOOS has been meeting important needs of the global society. New technologies are being incorporated and gaps in the system are being filled. However, existing intergovernmental mechanisms have enabled surprisingly little progress toward a truly global system with long-term funding commitments. Monitoring and stewardship of the global oceans is a global responsibility, and GOOS is working with its sponsors in the United Nations, the Intergovernmental Oceanographic Commission (IOC) of UNESCO, UNEP and WMO, the International Council for Science (ICSU), GEO and the many individual nations that support these groups, to ensure that our responsibilities are met.

Toward a global biodiversity observation network

Bruno A. Walther and Anne Larigauderie, DIVERSITAS, Muséum National d'Histoire Naturelle; Neville Ash, UNEP-WCMC; Gary N. Geller, NASA Ecological Forecasting Program; Norbert Jürgens, University of Hamburg; Meredith A. Lane, Global Biodiversity Information Facility Secretariat

Understanding, monitoring and conserving biodiversity is one of the nine societal benefit areas of GEOSS because biodiversity, or the variety of life on earth, makes up and sustains all life processes of the biosphere. Therefore, biodiversity contributes both utilitarian values, such as ecosystem goods and services, as well as intrinsic values, such as aesthetic enjoyment and a sense of identity, to human well-being.

Current scientific evidence overwhelmingly demonstrates a continued decline in the status of biodiversity, because it is almost invariably impacted negatively by unsustainable human resource consumption. Such declining trends lead to reduced benefits for people and increasingly limited opportunities for development and livelihood options in the short and long term, as well as increasing occurrences of sudden negative changes in the world's ecosystems and life processes. Further understanding of biodiversity change is therefore critical if decision-makers at all scales, as well as the public, are to be informed about the global scale of biodiversity degradation, and the consequences of such degradation on ecosystem services and human well-being.

A wide range of user groups began a process to express their needs for biodiversity observation data at a GEOSS-DIVERSITAS workshop in 2006. Those present included users of natural resources (e.g. agriculture, forestry, fisheries), the health sector (e.g. infectious diseases, emerging pathogens, allergy forecasts), the genetics sector (e.g. bio safety aspects, genetically manipulated organisms, genetic diversity of cultivars), the conservation planning community (e.g. species and ecosystems change, conservation management) and several international treaties (e.g. CBD, CCD, CMS, Ramsar).

As a result of the workshop, the GEO Biodiversity Observation Network was established as a global partnership to collect, manage, analyse and report on the status and trends of the world's biodiversity. The network will provide a scientifically robust framework for global biodiversity monitoring and define a strategy to reach network goals and objectives. In broad strokes, these objectives are:

- Bring together biodiversity data and information from many different provider communities (e.g. museums, remote sensing, intensive plot-type monitoring systems) and existing networks of such communities
- Ascertain data requirements of user groups, develop new analytical tools, and facilitate interoperability among information system components and the interconnectivity of databases
- Establish a global biodiversity observation mechanism and data clearinghouse, supervized by an independent advisory board and supported by adequate long-term international funding.
- Review and prioritize research spatially and topically by identifying 1) gaps in methodological, taxonomic, regional or ecosystematic knowledge, and 2) those ecosystems particularly important for the supply of ecosystem services.
- Assess biodiversity at both the species and ecosystems level, and thereby identify priorities for global conservation, such as unique or highly diverse ecosystems, those supporting migratory, endemic or globally threatened species, and then use this information to guide global conservation priorities
- Generate regular reports of global biodiversity trends, including not only species and ecosystem trends, but also associated ecosystem goods and services vital to human well-being, as well as associated threats and drivers of biodiversity change, such as habitat conversion, climate change, pollution etc.
- Communicate the importance of 'biodiversity change' to human well-being so that the status of 'biodiversity change' in the public discourse is elevated to that currently held on climate change.
- Design decision support systems that integrate monitoring with ecological modelling and forecasting; these can then be used to generate future biodiversity scenarios which will provide essential information for the sustainable use and management of biodiversity, including analysis, prediction, early warning, conservation planning, policy making, and management effectiveness evaluation
- Make these data, tools, analytical products and reports available through the GEOSS web portal.

Another important strategic goal of the GEO Biodiversity Observation Network is to increase capacity to monitor biodiversity, especially in developing countries because these countries host most of global biodiversity (e.g. in the so-called biodiversity hotspots), but often lack the resources to adequate monitoring. Therefore, the

Network places great emphasis on the establishment of a shared but distributed architecture of data provision, processing and delivery of information open to everyone. For example, we envision that each partner institution will form a data node within the network, so that each node may share its individual databases with the network to the extent the partner wishes.

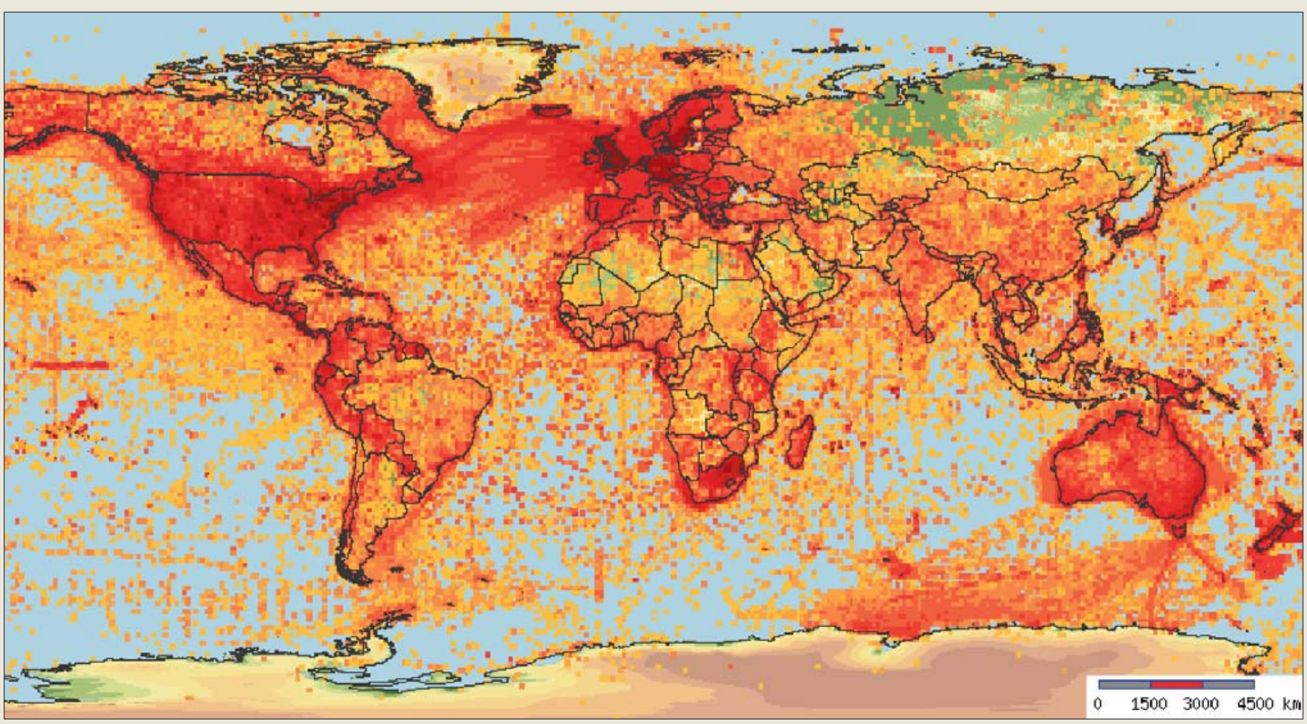
Toward these goals, several demonstration projects are currently being developed on biodiversity and climate change, protected areas characterization and monitoring, the use of geospatial data to improve threatened and endangered species assessments, and a monitoring system for invasive species. For example, one of the network partners, the Ecological Forecasting Program at NASA, is developing the Ecological Model Web, which is an open-ended system to improve ecological forecasting abilities. The Model Web brings together various computer models and databases dealing with a broad scope of physical, chemical, biological and ecological processes and making them interoperable via a distributed network of web services. Model interoperability is often limited by both technical and non-technical barriers, thus severely limiting their potential uses and users. Following the GEOSS architecture, the Model Web will try to remove such barriers so that global access to sophisticated ecological modelling and forecasting becomes a reality. A demonstration system is currently being developed that will test the viability of the concept as well as provide a core onto which further components can be added.

In a similar vein, the World Data Center for Biodiversity and Ecology (WDCBE)[1] is supporting the data and information requirements for some of the world's global biodiversity and ecological issues. It is building the framework and partnerships for housing integrated, updated and accessible global biodiversity, ecology and geophysical data for use by the scientific and conservation community. Its work toward the GEO Biodiversity Observation Network includes, for example, the distribution of data and results from the Millennium Ecosystem Assessment. Likewise, the USGS, NBII, and other governmental and non-governmental institutions are pursuing: (1) development of web-enabled capabilities (tools) to improve the efficiency of digital data input and resulting accuracies; (2) Integration and improved accessibility of key global data sets; (3) Creation of long-term data sharing and analysis partnerships with leading international biodiversity and ecological informatics and conservation organizations.

For this purpose, various global biodiversity and associated geophysical datasets are being created. Combined datasets allow for the creation and analysis of valued-added products and analyses. The following tools are being developed, tested, and deployed:

- The Global Integrated Trends Analysis Network (GITAN) is developing a Global Data Toolset (GDT)[2] which is an operational and easy-to-use online polygon data entry tool to facilitate an organization's ability to engage its network in the entry and/or validation of digital data (e.g. protected areas, species distributions, Important Bird Areas).

Geographic distribution of density of species occurrence records



The Global Biodiversity Information Facility (GBIF) currently mediates approximately 135 million records of species occurrences through its data portal (http://data.gbif.org). Such historical biodiversity data is needed in many fields of biodiversity research, for example, in establishing baselines for measurement and monitoring of biodiversity change

- Rapid Land Cover/Ecosystem Mapping Tool: an online tool to manually interpret satellite imagery for mapping land cover.
- Integrated Taxonomic Information System (ITIS): a taxonomic crosswalk to operationally compare, integrate and apply global biodiversity data sets.
- TerraLook[3] expands and broadens the remote sensing user community by providing a user-selectable collection of satellite images from three epochs (circa 1975, 1990 and 2000).

The world's natural history museums are a rich, and by far the main source of historical biodiversity data that are needed in many fields of biodiversity research. These data can provide a snapshot of biodiversity prior to the time when modern biodiversity monitoring systems were put in place.

The Global Biodiversity Information Facility (GBIF) is promoting the digitization and availability of such data, as well as datasets created by citizen scientists. GBIF has developed an information architecture that enables interoperability among datasets of this type, which is extensible to observational data and other datasets that contain scientific names. GBIF currently manages approximately 135 million records of species occurrences. These primary biodiversity data records can serve both science and society in many ways because they can be utilized in many different analyses. GBIF's information infrastructure can also serve as a basis and example for the development of the information infrastructure that will be needed for the GEO Biodiversity Observation Network. The GBIF Data Portal is already interoperable with the GEO Web Portal, and the WDCBE is providing tools that help to validate such historical data, and incorporate it into analyses conducted using its other tools.

The GEO Biodiversity Observation Network will also build on the work and outputs of the 2010 Biodiversity Indicators Partnership (2010 BIP), which was established in direct response to the need for global biodiversity indicators to track progress toward the 2010 biodiversity target[4] in order 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth.' The 2010 BIP brings together the numerous organizations and agencies working on developing and communicating biodiversity indicators in support of the 2010 target, and will facilitate the regular delivery of global biodiversity indicators into the CBD and other relevant fora in order to help track progress toward the 2010 target. The 2010 BIP will thus play a crucial role in advancing the data and processes for monitoring global biodiversity change within the context of the GEO Biodiversity Observation Network.

DIVERSITAS and NASA are leading the early planning stages for the GEO Biodiversity Observation Network. For this purpose, DIVERSITAS has assembled an expert group of monitoring and modelling scientists under its bioDISCOVERY Core Project, which will develop a scientific framework to improve global biodiversity monitoring. This expert group of leading scientists will develop the underpinning scientific research and advice on strategic goals for the Network. Furthermore, since not everything can be monitored, an increased interaction with field experiments and ecological model development will be sought that will help fill the knowledge gaps left by incomplete monitoring. Finally, the expert group will work on how results from long-term monitoring need to be analysed and presented so as to be useful to data users; e.g. value judgments going into summary and interpretation need to be clarified and explicitly stated. This is especially important for the development of global biodiversity indicators, as they will be one of the main means by which information is delivered to decision-makers and the public. Monitoring results will be interpreted in an ecosystem context — that is to say that efforts will be made to compare the current state of an ecosystem to its potential capacity. For example, an ecological assessment might not just report the measured state of a depleted fishery over the last five years, but also use ecological modelling to estimate the possible population levels of the fishery if sustainable fishing regimes had been adopted, so that monitoring results are embedded in the context of management options of the respective ecosystem. Combined with economic calculations, not just the *actual*, but also the *potential* productivity of an ecosystem's services could be estimated, and thus give stakeholders and decision-makers robust and rational arguments for weighing alternative policy options.

The ongoing activities generated by the GEO Biodiversity Observation Network have already helped to improve data access, sharing, and use, and to establish fora for crosscutting development and interdisciplinary collaboration within the biodiversity community, thus advancing biodiversity science and its applications. In the near future, the biodiversity science community, through the GEO framework, will increase capacity building, especially in developing nations, to fill monitoring gaps; develop more tools for policy making to be used in decision-making, especially in the light of improved resource management of marine, freshwater and terrestrial biodiversity resources and ecosystem services; and develop cross-links with other GEOSS societal benefit areas, e.g. land use change, coastal zones, water management and health; and further integrate monitoring activities and modelling exercises.

The GEO Biodiversity Observation Network

The GEO Biodiversity Observation Network (www.bioobservation.net) is made up of many relevant programmes and networks, for example:BIOTA-AFRICA, Birdlife International, CBD, Census of Marine Life, CEOS, CI, DIVERSITAS, GBIF, GTOS, ILTER, IUCN, NASA, NBII, The Nature Conservancy, UNESCO-MAB, US Geological Survey, WMO and 2010 BIP, to name just a few, plus a host of other of governmental, non-governmental, private and academic institutions, organizations and programmes.

For further information:
2010 BIP (www.twentyten.net)
CBD (www.cbd.int)
DIVERSITAS (www.diversitas-international.org)
GBIF (www.gbif.org)

The Network is open to any other relevant entity or institution that wishes to contribute to and benefit from the consortium of the whole.

Smithsonian Institution Global Earth Observatories

Ira Rubinoff, Smithsonian Institution, Office of the Undersecretary for Science;
Eldredge Bermingham and Charles Lydeard, Smithsonian Tropical Research Institute;
Stuart J. Davies, Smithsonian Tropical Research Institute and Arnold Arboretum, Harvard University

The Smithsonian Tropical Research Institute (STRI) is a US organization dedicated to advancing fundamental scientific discovery and understanding of biological diversity in the tropics and its contribution to human welfare. STRI plays a critical role for the US Government and the Smithsonian by maintaining world-class research facilities in Panama. Last year more than 1,000 resident and visiting scientists accessed diverse tropical environments, including rain forest and coral reef ecosystems at the facility. STRI serves as official custodian for the Barro Colorado Nature Monument (BCNM) in Panama under the terms of the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, which was ratified by the US Senate in April 1941. The BCNM is the only mainland tropical reserve under US stewardship.

More than 25 years ago STRI established a large-scale forest research plot on 50 hectares (approximately 120 acres) of lowland tropical forest on Barro Colorado Island (BCI), a fully protected tropical forest within the BCNM. Within the plot, every free-standing tree with a diameter at breast height of at least one centimetre was tagged, measured, mapped and identified to species. Beginning in 1980 the plot has been censused every five years, with the sixth census completed in 2006.

Over the years, re-censuses have revealed that tropical forest populations are incredibly dynamic and responsive to climate change. For example, in only one census interval of five years, more than 40 per cent of the tree species in the plot changed by more than ten per cent in total abundance. This was apparently in response to a severe El Niño drought that elevated death rates up to 20 times those of non-drought years. The large-scale and standard forest census methods developed on BCI proved to be a powerful approach to studying the dynamics of tropical forests. By 1990, scientists around the world had replicated the STRI methods, and a global network of research plots emerged.

The network was initially named the Center for Tropical Forest Science (CTFS), and although administered by STRI, individual forest plots are led and managed in each country by one or more partner institutions (see Appendix). For example, the Indian Institute of Science manages the forest dynamics plot in Mudumalai, India, and the National Institute of Research of the Amazônia is the custodian of the CTFS plot in the Central Amazon. In addition, CTFS in Asia is coordinated through a partnership with the Arnold Arboretum of Harvard University.

CTFS coordinates research activities using standardized methods on forest plots ranging from 2 — 52 hectares that now include 20 sites in 15 tropical countries in Latin America, Africa and Asia. The CTFS plots involve hundreds of scientists from more than two dozen institutions. Over the past 25 years, the CTFS network has created the first actuarial table for tropical trees around the world, thus providing a basis for determining quantitatively how trees and forest ecosystems are responding to the Earth's changing climate. This international collaboration is now monitoring the growth and survival of 3.5 million trees in over 6,500 species, which constitutes over 12 per cent of all known tropical tree species. The CTFS system has now matured to the point where there is a tremendous and unique opportunity to expand the programme into a truly interdisciplinary research endeavour that will enable the world's scientists to investigate key indicators of global environmental health.

STRI is now in the process of transforming its network of tropical forest plots into the Smithsonian Institution Global Earth Observatories (SIGEO). Although tremendous advances in our understanding of tropical diversity and dynamics have been gained from 25 years of research across the network of tropical forest plots, CTFS and its system of global earth observatories is poised to make an even larger contribution through monitoring the effects of anthropogenic increases in atmospheric CO_2, nitrogen and general air pollution at local, regional and global scales.

The global earth observatories will provide baseline data to help solve real-world problems through real-time dissemination of critical data and cutting-edge science. It is worth noting that the network is extremely well utilized by independent university-associated faculty and network partners, thus SIGEO leverages huge intellectual horsepower. Over 200 scientists have published over 1,000 scientific articles from the CTFS data sets, attesting to the broad usability and benefits of the network.

Photo: Marcos A. Guerra

Researchers measuring trees at Barro Colorado Island, Panama

The Smithsonian Institution is uniquely positioned to conduct interdisciplinary research on complex biological systems at a global scale. It will do this by expanding and deepening its collaborative ventures among units including the National Zoological Park's (NZP) Conservation and Research Center (CRC), the National Air and Space Museum (NASM), the National Museum of Natural History (NMNH), the Smithsonian Astrophysical Observatory (SAO), the Smithsonian Environmental Research Center (SERC) and STRI.

SIGEO will contribute to fulfilling the strategic plan of the US Climate Change Science Program (CCSP) and addressing a proposed CCSP priority of reducing scientific uncertainty about potential effects of climatic change on ecosystems. Furthermore, the Intergovernmental Panel on Climate Change (IPCC) Working Group II assessment report has shown the great need for better observational data on climate change impacts, and has particularly pointed out the need for systematic and comprehensive observations that SIGEO will provide.

Finally, the Smithsonian is reaching out to build or strengthen collaborations with government agencies of the United States including the US Environmental Protection Agency (US EPA), US Geological Survey (USGS), US Department of Agriculture (USDA) Forest Service, National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). Such efforts are focused particularly on the intergovernmental Group on Earth Observations (GEO) and the implementation of the Global Earth Observation System of Systems (GEOSS). The Smithsonian Institution is interested in expanding the opportunities for collaboration and partnerships among agencies to maximize the increase and diffusion of knowledge.

The Smithsonian will transform the CTFS network of tropical forest plots into a system of SIGEO in three primary ways.

Global carbon research programme

Human activities have caused a 15 per cent increase in atmospheric carbon dioxide in the past 40 years and are set to increase atmospheric CO_2 levels even more dramatically in the coming decades. This increase, coupled with equally dramatic increases in other greenhouse gases, is having a profound effect on global climate, and on terrestrial and oceanic ecosystems. Regrettably, there is a tremendous gap in our understanding of the role of forests in the global carbon budget, and insufficient evidence on whether temperate and tropical forests behave differently under changing global conditions.

SIGEO plots provide in situ measures of above- and below-ground carbon and how it is changing in response to rising CO_2. A recent publication by CTFS scientists using data from two forest plots with measurements for over 20 years (BCI, Panama and Pasoh, Malaysia) has shown that despite increased carbon fertilization, growth rates of tropical forest trees has decreased. This decrease is perhaps a response to global warming. Rigorously generated, long-term data from a global network of plots will provide critical empirical data for modelling carbon dynamics in the future. It will also provide direct measurement of whether efforts to reduce carbon emissions are effective.

Branching out into the temperate zone

Because of differences in seasonality, albedo and other climate factors, tropical and temperate forests are anticipated to behave differently with regard to changes in atmospheric carbon dioxide levels and changing temperatures. Currently no temperate-zone plots follow the same methodology as the tropical plots but the SIGEO initiative will take advantage of long-term forest plot-associated research at the CRC of the Smithsonian NZP and the SERC to quickly establish a series of large-scale temperate plots that will permit direct comparison to the tropical plot network.

Partnerships in temperate China and Europe are being developed to help expand these temperate-tropical comparisons to a global scale. HSBC has recently formed a partnership with the Smithsonian Institution and the Earthwatch Institute to establish a regional training centre on climate change at SERC.

Scientists at SERC and CRC have a rich and productive history of conducting long-term environmental studies such as measuring the effects of atmospheric CO_2 on plant and soil microbial communities, biodiversity monitoring and assessment, landscape ecology, and the biology of migratory birds.

Expanding the monitoring programme: looking beyond the trees

Scientists from CRC, the NMNH, and STRI will significantly improve assessment of the impact of global change on biodiversity through focused surveys of vertebrates, invertebrates and microbes across the global earth observatories. Standard methods for measuring and monitoring biodiversity of different groups of organisms will be developed and distributed.

The use of identical sampling methods has been a central tenet of the CTFS programme and allows for maximal combinability and comparability of the data. In addition, this research will be coupled with training workshops to build professional capacity in developing countries to maintain biodiversity monitoring programmes. It is hoped that this, in turn, will lead towards wise decision-making for sustainable management of natural resources. The Monitoring and Assessment of Biodiversity (MAB) Program at CRC and STRI have considerable experience in fostering the growth of professional capacity.

Furthermore, NMNH scientists will work with STRI scientists to DNA barcode selected taxonomic groups such as trees, invertebrates, nematodes and microbes. The Smithsonian Institution is the host of the Consortium for the Barcode of Life, an international initiative devoted to developing DNA barcoding as a global standard in taxonomy. Many if not most of the plants, invertebrates, nematodes and microbes in the tropics are formally undescribed species, including some of the tree species that have been mapped and measured on the plots. Coupling the formal taxonomy with DNA barcoding will provide an extremely useful database for future researchers interested in genetics, systematics, and bioprospecting.

Finally, scientists from the NASM and the Smithsonian Astrophysical Observatory (SAO) will work to link data on the ground (plots) to regional and global predictions through space-based assessments. For example, SAO has pioneered the measurement of formaldehyde (HCHO) from space, its use as the main proxy for volatile organic compound (VOC) emissions, and the development of a climatology of emissions. Isoprene is emitted by heat-stressed trees and is thus a direct indicator of global heat stress on forests. NASM in turn, will use remote sensing technology to extend ground-based measurements of carbon dynamics to broader scales.

CTFS has successfully melded observation, data analysis, models, and basic and social research to enable scientists and policymakers to better understand global environmental issues. The expanded methodology and objectives of SIGEO will provide the necessary platform to supply critical scientific data to address the needs of society into the future. In the environmental sciences, CTFS stands as one of the premier international partnerships, and SIGEO aims to integrate the SI network of forest dynamics plots with the GEOSS to further advance the progress of science across borders. CTFS and SIGEO promote large-scale environmental monitoring, and maintain enormous banks of data and metadata that galvanize advanced data networks and sophisticated analyses from forest plots to outer space.

SIGEO sites

Twenty-two established SIGEO sites in black (blue dots) and 12 candidate sites in blue (red dots). CRC and SERC are also shown

Source: Lina Gonzalez, Smithsonian Tropical Research Institute (STRI)

European geological surveys and GEOSS — observing the Earth beneath our feet: why does it matter?

Patrice Christmann, Secretary-General, EuroGeoSurveys

While the atmosphere and the Earth's surface are accessible to direct observation including by remote sensing techniques, the observation of the Earth's subsurface, its related resources and hazards require the use of complementary observation techniques. Many of these are of an indirect nature, such as the cartography of the various physical properties of the subsurface (geophysics).

Geology is all about understanding, mapping and modeling the Earth's subsurface nature, structure and dynamics, and its related resources and hazards. It is also the forensic science needed to understand our Earth's long and turbulent past. The resulting spatial data, information and knowledge are needed to better address societal issues of today and tomorrow such as climate change, sustainable use of natural resources, land-use planning, management and storage of waste, mitigation of the impacts of natural hazards of geological origin, identifying public health issues and many more.

An ever-growing number of Earth observation techniques is available to geologists to produce the information required by the wide range of end users of geological information, ranging from the macro scale, such as the use of remotely sensed data and/or direct in situ observations and mapping, to the nano scale, such as isotopic geochemistry needed to determine the age of rock formations, or electronic microprobe studies of mineral grains to develop the technologies best suited for the efficient recovery of the valuable metals content from an ore body. Geological data describing the nature, structure and ages of superficial formations and bedrock formations is in most cases a fundamental geographic data layer necessary, in combination with other data layers, to produce the information required by end users.

In addition to technologies, considerable human skills are necessary to select the right data sources and to steer/implement the data acquisition process, which in many cases requires direct observation in the field, and afterwards to do the combinatorial processing and modelling of heterogeneous Earth observation datasets. Processing and modelling by experienced scientists is necessary to turn raw Earth observation data, which is meaningless to most end users, into the geographic information required to address end users' concerns. The whole process is steered by specific end uses, each requiring the use of different data sources and processing/modelling techniques. For instance, the process involved in developing geographic information necessary to mitigate the potential impacts of landslides is very different from the process involved in generating information to guide mineral exploration or sustainable groundwater management. Therefore, geological surveys are institutions populated by scientists from a wide range of complementary disciplines, working together to deliver high-quality geographic information to end users.

Understanding and mapping the subsurface and providing the derived geographic information to end users is essential to the global economy and to social well-being. The underground is home to many resources that are essential to life: energy (fossil and the clean, renewable, dependable geothermal energy), groundwater (the main source of drinking water supply in many countries) and minerals (the main material flow across the world economy).

Subsurface also means space to develop a wide range of infrastructures, and storage for gas, waste or water. Geology also has a strong incidence on the nature and fertility of soils. The chemical elements in rocks determine the chemical composition of the groundwater they host, of soils derived from their weathering and, from this, the chemical elements found in our food and drinking water. Excess or deficit of certain of these elements can significantly impact health.

The subsurface and its dynamics are also the source of many natural hazards. Some, such as earthquakes, landslides or volcanic eruptions are spectacular and hence are easily perceived by public authorities. Some are more subtle and difficult to notice before their economic and social impacts become visible: among these are land heave and subsidence, gaseous emanations (radon gas emanations are considered in various epidemiological studies as an important source of lung cancer), caving-in of man-made or natural cavities, and shrinkage and swelling of clay-rich soils (costing billions of euros to insurance companies compensating the resulting damage to buildings).

Access to and sustainable use of natural resources of geological origin, and mitigation of the impacts of natural disasters of geological origin, will be issues of growing importance — the Earth's population is set to reach nine billion in 2050, and the populations of highly-populated yet developing countries aspire to enjoy the same lifestyles as those from richer areas. EuroGeoSurveys and its members recognize the Global Earth Observation System of Systems (GEOSS) as an essential global initiative, supported by all the diverse and complementary components of the global Earth observation community, to guide policy-making and governance development at all levels, from individual to global, to address the challenging issues faced by humanity.

European geological surveys and GEOSS

EuroGeoSurveys and its members, within the limits of their available resources, are committed to contribute to the development of GEOSS, considering that the availability, multilingual accessibility and interoperability of public geographic data and information, and the progressive development of a global spatial data infrastructure (GSDI) based on the interoperability concept. These are essential to sustainable development. The development of interoperability is needed not only for end users to access and combine datasets produced by all public digital data/information suppliers describing a same data theme, wherever these suppliers are located. It is also needed for cross-thematic combinatory processing of different thematic digital data/information, for instance for the production of natural risk zoning maps or groundwater resources protection.

In support of the development of GEOSS, EuroGeoSurveys and its members contribute to a number of GEOSS relevant developments and directly participate in existing GEOSS tasks.

GeoSciML

Within the International Union of Geological Sciences (IUGS), a member of the International Council of Scientific Unions (ICSU), an international working group on geological spatial data and information interoperability has been operating since 2003 to actively develop the geological sciences specific extension (GeoSciML) to the Geography Markup Language (GML). This is an essential step in developing schematic and semantic interoperability of digital geology related national/regional digital information systems, and of these information systems with the other environmental information systems that form part of GEOSS. EuroGeoSurveys supports the development of this GEOSS-relevant international standard for digital geological data interoperability, based on Open Geospatial Consortium standards, and several EuroGeoSurveys members actively contribute to this.[1]

The European Spatial Data Infrastructure

On 15 May 2007, the European Spatial Data Infrastructure (INSPIRE) directive[2] was published in the *Official Journal of the European Union*, establishing an infrastructure for spatial information in the European Community. The directive fully recognized the importance of accessible, shared spatial data and information in support of the formulation and implementation of environment-related policies and the need to address the problems regarding the availability, quality, organization, accessibility and sharing of spatial information common to a large number of policy and information themes, experienced across various levels of public authority. INSPIRE's reach covers 34 spatial data themes, including geology; natural hazards; water resources; energy and mineral resources, as well as soils-related digital spatial information. EuroGeoSurveys is among the formally registered European Spatial Data Interest Communities (SDIC), having supported the INSPIRE legislative process from its beginning. Its experts actively participate in the drafting teams that are currently working under the coordination and supervision of the European Commission to develop the INSPIRE Implementing Rules. These will set legally binding rules on metadata; technical arrangements for the interoperability and, where practicable, harmonization of spatial data sets and services; network services, and data sharing and reuse.

The experience gained in these activities is complementary to the development of GeoSciML and relevant to the geolog-specific development of interoperability in the GEOSS framework.

The International Year of Planet Earth and OneGeology

On 5 January 2006 the United Nations General Assembly proclaimed the year 2008 to be the United Nations International Year of Planet Earth (IYPE). IYPE activities will span the three years 2007–2009. Its purpose is to foster understanding of and interest in the solid Earth, and to enhance the attention given to a wide range of societal issues close to GEOSS societal benefit areas:

- Reduce risks for society caused by natural and human-induced hazards
- Reduce health problems by improving understanding of the medical aspects of Earth science
- Discover new natural resources and make them available in a sustainable manner
- Build safer structures and expand urban areas, utilizing natural subsurface conditions
- Determine the non-human factors in climatic change
- Enhance understanding of the occurrence of natural resources so as to contribute to efforts to reduce political tension
- Detect deep and poorly accessible groundwater resources
- Improve understanding of the evolution of life
- Increase interest in Earth sciences in society at large
- Encourage more young people to study Earth sciences in university.

EuroGeoSurveys contributes to support the IYPE and some of its related activities, in particular the OneGeology project launched by the British Geological Survey (BGS) in March 2007. OneGeology aims to create a public, freely accessible, dynamic digital geological map of the world at about 1:1,000,000 scale as a distributed web service. Depending on the situation in individual countries, the geological maps will initially be made available as raster images or a vector-based geographical information system (GIS) layers. The plan is to make the resulting digital coverage available through Google Earth and other dynamic map browsers. Geological surveys from over 60 countries currently contribute to this project, whereby European geological surveys consider developing a pan-European vector-based digital geological layer based on

GeoSciML and INSPIRE principles to make a significant contribution to the implementation of the directive — that is, developing systems and protocols to better enable the discovery, viewing, downloading and sharing of core European spatial geological data and to demonstrate best practice examples of the delivery and application of geological spatial data in the public and private sectors. This initiative is a further practical contribution of the European geological surveys to GEOSS.[3]

Mitigating the impacts of geohazards

A wide range of natural hazards is related to local geological conditions. Some are very spectacular, and widely known (e.g. earthquakes, landslides or volcanic eruption) but many are of a less visible, insidious nature such as radon gas emanations or land heave and subsidence. These nevertheless affect lives and economic assets.

Thanks to the support of the European Space Agency, the IGOS-P Geohazards Executive Bureau is managed by BRGM, the French geological survey and a EuroGeoSurveys member. It intends to respond to scientific and operational geospatial information needs for the prediction and monitoring of geophysical hazards, namely earthquakes, volcanoes and land instability. The Executive Bureau coordinates the efforts of a wide international partnership, bringing together well over 200 experts from a broad range of organizations, from data suppliers to end users. Gathering a wide community of practice, it plays an important role in supporting GEOSS, contributing to the GEOSS clearinghouse through its GeoHazData system and to a number of GEOSS tasks:

- DI-06-07 ‘Multi-hazard Zonation and Maps’
- DI-06-03 ‘Integration of InSAR Technology’
- DI-06-02 ‘Seismographic Networks Improvement and Coordination’.

Contributions to further GEOSS tasks are proposed.

Energy environmental impact monitoring

TNO, the Dutch member of EuroGeoSurveys, leads the task EN-07-02, promoting the development of Earth observation systems for the monitoring and prediction of environmental impact from energy resource exploration, extraction, transportation and/or exploitation. It brings to bear the wide experience of TNO and some other European geological surveys in CO_2 capture and its sequestration in depleted gas or oil reservoirs and other geological formations.

The African-EU Georesources Observation System

Africa, the largest single component of the African Caribbean Pacific (ACP) group of states, despite its huge potential for development through both human and resources of geological origin (georesources), suffers in many places from poverty and underdevelopment. The sustainable use of its resources is a key issue, not only for development of the African countries, but also for the world’s future. The sustainable use of its georesources requires knowledge based on data, information and expertise. Thus, the availability, traceability, accessibility and processing using GIS technologies of heterogeneous data from multiple sources are essential, as explained above. Such processing requires qualified and experienced personnel and the definition of strategies for capacity building and training. In view of this situation, a recognized need has emerged for a shared, distributed, Internet-linked georesources observation system based on open standards and interoperability developments, as a contribution to the sustainable development of African countries. Twenty-two partners, including nine from Africa, tabled an EU Coordination Action Proposal, which is the preparatory phase needed to develop the partnership and design the African-European Georesources Observation System (AEGOS). The system will be capable of hosting and providing access to Africa’s georesources spatial information, including groundwater, energy and mineral resources. The project is expected to start near the end of 2007.

The Geochemical Atlas of Europe

On a voluntary basis, without any external financial support, the European geological surveys developed the first ever continent-wide cartography of the distribution of over 60 chemical elements in soils and surface water, using common sampling and analytical procedures across Europe. The result is the European Geochemical Atlas. Although this is a small-scale cartography, the atlas presents the first ever overview of the pan-European distribution of such elements as arsenic or selenium in soils and surface water. The methodology and continent-wide data delivered by this project are of relevance to GEOSS both in terms of methodology for the production of continent-wide thematic geological data and in terms of contribution to the GEOSS ‘health’ societal benefit area.[4]

The collective experience in research is documented in the list of about 200 European Research projects, most supported by the fifth and sixth EU Research Framework programmes (covering the period 1998 — 2006).[5]

End-users of geological spatial data, information and knowledge

EU, national, regional and local authorities in charge of:

- Civil protection
- Land-use planning
- Environmental protection
- Resources management
- Competitiveness and industrial policy
- Health
- Defence
- Police and security

Engineering companies
Real-estate and construction companies
Insurance companies
Investors
Industry, including oil, gas, mining etc.
Tourism sector
Heritage conservation
Consultants
Landowners
Farmers
Research & Academia
Data suppliers
Civil society, NGOs
General public
Media

Source: Patrice Christmann

NSF's observing systems: platforms for large-scale environmental research

Arden Bement, Jr., Director; James Collins, Assistant Director for Biological Sciences; Jeannette Wing, Assistant Director for Computer and Information Sciences and Engineering; Richard Buckius, Assistant Director for Engineering; Jarvis Moyers, Acting Assistant Director for Geosciences; David Lightfoot, Assistant Director for Social, Behavioral and Economic Sciences; Daniel Atkins, Director, Office of Cyberinfrastructure; Karl Erb, Director, Office of Polar Programs; Kathie Olsen, Deputy Director, US National Science Foundation

In April of 2001, in the hottest, driest parts of southern California and Arizona, it appeared to snow. But in fact the white haze was dust. A swirling storm from Mongolia had carried dust from the Gobi Desert and deposited it across almost half the mainland United States. Although it wasn't the only such storm to reach the US, the particles of April 2001 were the first Asian dust visible to the naked eye on another continent.

Asia's dust storms are growing in number and extent. Among the reasons for this is spreading drought, which is, in part, the result of global climate change. Heavy snows once fell over Central Asia in winter, keeping soils damp through the spring. Now, winters with little snow allow soils to dry out and be easily carried aloft by spring winds.

Overgrazing by sheep and goats that belong to the formerly nomadic peoples of Central Asia has also exacerbated the situation. Today the region is reminiscent of the 1930s Dust Bowl in the United States.

This past April, scientists aboard HIAPER, the US National Science Foundation (NSF)'s High-Performance Instrumented Airborne Platform for Environmental Research, flew across the Pacific ocean alongside the Asian dust storm. HIAPER is a Gulfstream V aircraft modified for environmental research.

The dust plumes registered as the largest such events on Earth. They affected clouds and weather across thousands of miles and also interacted with the Sun to increase the effects of greenhouse gases, in turn playing a role in climate change. Having observed these effects the natural question for the scientists was: could the dust affect North American ecosystems as it settled onto forests and fields, lakes and rivers?

Earth and its systems are changing rapidly as a result of the global effects of climate change. To adapt to such change we must study how the interrelated geosphere, atmosphere, hydrosphere, and biosphere interact with each other and with people. As our quest to understand planetary change also accelerates, finding new ways of observing the environment increases in importance. HIAPER is just one of those new ways.

Blanketing the globe with interconnected land, ocean, and atmosphere environmental observatories is the goal of the intergovernmental Group on Earth Observations (GEO). GEO is leading an international effort to build a Global Earth Observation System of Systems (GEOSS), key to the accurate prediction of environmental changes across the planet.

Research is a fundamental component of this effort. By supporting environmental observing systems for basic research, NSF is taking the first step toward an understanding of Earth's workings. The agency's network of observation platforms will crisscross the nation and the world, and connect with other countries' systems, sending data to scientists, students, and the public around the globe. The observatories address all nine of the GEO societal benefit areas: climate, disasters, agriculture, biodiversity, ecosystems, health, weather, water, and energy.

Through NSF-supported observing systems such as HIAPER, the National Ecological Observatory Network, Ocean Observatories Initiative, EarthScope, and the Arctic Observing Network, scientists seek to answer questions such as: What forces connect the biosphere, geosphere, hydrosphere, and atmosphere at regional to continental scales? How will life in the sea and on land, including humans, respond to and alter climate change? How will global trade affect the spread of invasive species? How are climate and ocean circulation linked? How does Earth's carbon cycle influence global patterns of precipitation?

Many US federal agencies support environmental observation systems for specific missions, such as predicting weather or tracking pollutants. National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA) and a constellation of agencies keep an eye on Earth conditions through satellites and ground-based sensors.

NSF-sponsored observing platforms emphasize connectedness with these systems by providing scientists with a means of understanding the underlying dynamics of each of Earth's complex systems. That knowledge is then used by other federal agencies.

NSF-funded observing networks support these agencies' missions and improve our ability to understand coupled biological and physical systems in ways that will allow us to forecast disasters like the December, 2004, Indian Ocean tsunami and 2005 US hurricanes. This predictive power can help prevent loss of life and improve our ability to manage resources in a sustainable way.

The first NSF environmental observing networks

Among the earliest environmental observing efforts to receive NSF support was the Long-Term Ecological Research (LTER) network. It was established in 1980 at six locations with the aim of enhancing our understanding of long-term patterns and processes in ecosystems. Now 26 LTER sites span the range of global ecosystems, from dry valleys in Antarctica to tundra in Alaska, from coral reefs in Tahiti to forests in New Hampshire. Long-term ecological research has given insight into the most basic of Earth's functions, such as how ecosystems with greater plant biodiversity are better able to withstand and recover from droughts, insect pests, and disease outbreaks.

Most LTER sites originally focused on 'pristine' environments, which is to say those with no or minimal human interference. However, it was decided that finding out how people interact with these natural settings is growing in importance. As a result, two urban LTER sites, in Baltimore, Maryland and Phoenix, Arizona as well as a row crop agricultural site in Michigan were set up.

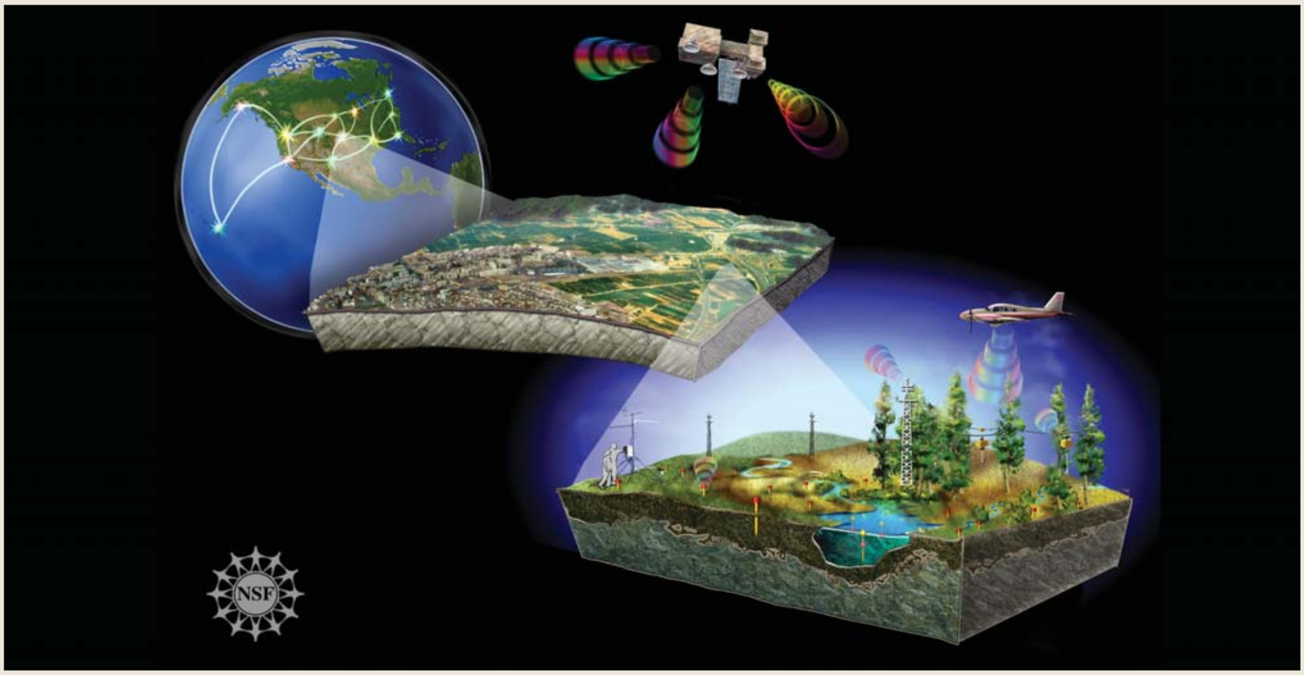
Eight years after the initial LTER sites, marine scientists created an LTER equivalent in the oceans. In 1988, two long-term open ocean observing stations began operation: the Hawaii Ocean Time-series (HOT) and Bermuda Atlantic Time-series Study (BATS) sites. Data from HOT and BATS continue to provide information about the effects of global warming and greenhouse gases on the seas. LTER, HOT, BATS and other ongoing environmental observing programs have led the way for new NSF observing networks for research.

NSF-supported environmental observing systems for the land

Among the most recent NSF Earth observing projects, the National Ecological Observatory Network (NEON) is an initiative to develop North American continent-spanning, land-based research infrastructure for ecological observations and experiments. NEON will provide data for research on processes at all spatial scales, time scales, and levels of biological organization, from regions, to local ecosystems, to microbes. It will also give scientists new ways of answering questions such as: How important is biodiversity in being able to predict human impacts on ecosystems? How do large-scale processes such as El Niño affect regional drought and carbon cycles?

Fixed sensors and towers, mobile suites of instruments, rapid deployment systems placed on vehicles, and airborne observation capabilities will give NEON scientists the basic information to develop and validate models that can be used to predict the effects of climate change. Effects including increased droughts and wildfires, the spread of invasive species, and infectious disease outbreaks.

NSF National Ecological Observatory Network (NEON): Opening new horizons in the science of large-scale ecology



NSF research is a key component in the creation of a Global Earth Observation System of Systems

Source: National Science Foundation/National Ecological Observatory Network

Society needs 'ecosystem forecasts' in the same way it depends on weather forecasts. For example, viruses like Hantavirus, carried by mice, infect humans through exposure to rodent droppings. Ecological observing systems can help track where and when mice carrying this virus may appear and put humans at risk.

The quality of ecosystem forecasts will improve with an understanding of how the Earth system operates. Resource managers make decisions that affect ecosystems for decades. Good forecasts of the consequences of these choices will lead to better-informed management of our coasts, rivers and lakes, forests, and agricultural lands.

NSF-supported land-based observatories also measure environmental parameters near areas prone to earthquakes and volcanic eruptions. For example, the US EarthScope, a vast network of geologic sensors, tracks the motions of Earth's surface, records seismic waves, and provides scientists with a way to recover rock samples from deep beneath the Earth where earthquakes originate.

Last year, EarthScope instruments installed on the flanks of the Augustine Volcano in Alaska revealed a steady increase in earthquakes beneath the volcano. EarthScope recorded Augustine's eventual eruption, as well as an ash plume that extended more than 40,000 feet high, forcing jets to alter their routes as they travelled to and from Asia. Only with permanent observing stations, like EarthScope, can scientists monitor a volcano's 'breathing' as it shrinks and swells with the movement of magma inside.

Through a related system, NSF's Network for Earthquake Engineering Simulation (NEES), engineers and scientists are performing research on the effects of earthquakes on people, soils, buildings, and infrastructure like bridges. NEES facilities are a network through which real-time simulations of earthquakes can be conducted and their consequences to society observed.

NSF-supported environmental observing systems for the seas

While NEON, EarthScope and NEES are land-based projects; NSF's Ocean Observatories Initiative (OOI) will gather continuous observations from near-shore and remote areas of the seas, providing the basis for a new understanding of the ocean. OOI will allow scientists to probe the depths, and give them access to long-term measurements of the ocean and the seafloor.

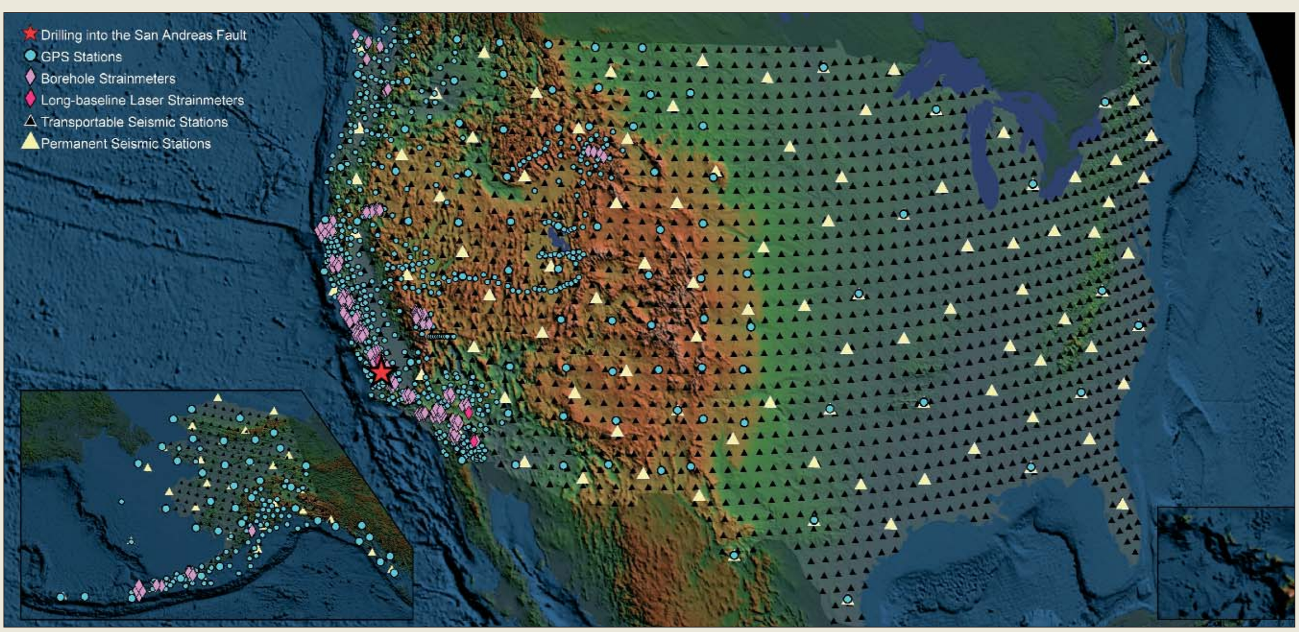
High-tech ocean observatories supported by NSF, located in places like the depths of California's Monterey Bay, will give insight into issues such as how nutrients like nitrogen make their way from near-shore areas to the deep-sea and back again.

A network of global, regional, and coastal ocean observatories, OOI will be linked to the internet via seafloor cables and satellites. Through OOI, marine scientists will address questions such as: How does climate change impact ocean ecosystems, including declining fisheries and increasing harmful algal blooms? And how can ocean-bottom seismic readings give us early warnings of the undersea earthquakes that precede tsunamis?

NSF-supported environmental observing systems for the polar regions

Global warming is having a speedy and significant impact on the polar regions. Arctic sea ice cover reached a record minimum in September, 2007, and ice sheets and glaciers are melting with great speed. Waters flowing through melt channels, or moulins, in

The US EarthScope Network



EarthScope is a vast network of geologic sensors that track the motions of Earth's surface, record seismic waves, and provide scientists with a way to recover rock samples from deep beneath the Earth

Source: EarthScope

Greenland's glaciers have become steady downspouts. The melting of ice sheets and glaciers raises sea level, which will eventually affect low-lying coastal areas around the globe, and perhaps alter the flow of major ocean currents.

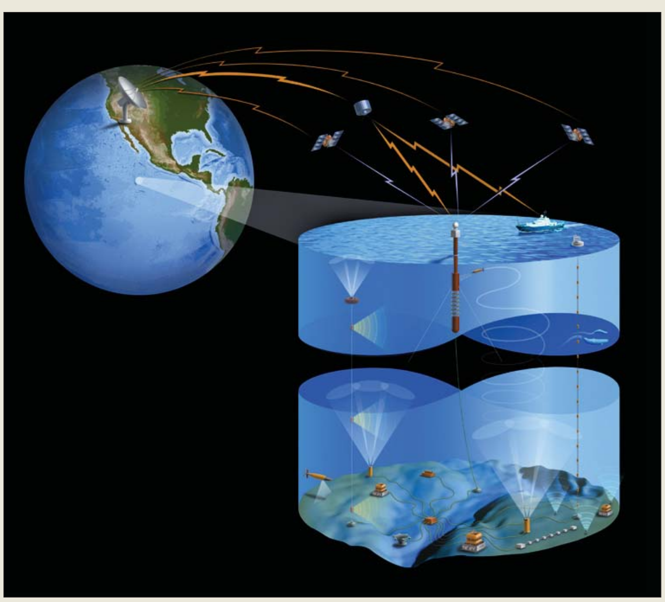
To improve our knowledge of environmental change in the Arctic and the understanding of its consequences, NSF is taking the lead in helping to develop an Arctic Observing Network (AON). In parallel with AON, NSF is contributing to POLENET, an international observing effort for, as its title suggests, both the Arctic and Antarctic. In Greenland, for example, the deployment of a network of POLENET global positioning system sensors will allow scientists to 'weigh' the continent's ice sheet and detect changes in its mass, changes that may well affect global sea level.

AON and POLENET are major US contributions to the International Polar Year (IPY 2007-2009), the largest scientific study to date of the Arctic and Antarctic. The project involves thousands of scientists from more than 60 countries. It is the fourth such polar year, following those in 1882-3, 1932-3, and 1957-8 (the International Geophysical Year). In the context of the sensitivity of Earth's poles to accelerating climate change, it's also perhaps the most important IPY so far.

Connecting it all: environmental observatories, data and people

The development of cyberinfrastructure (digital information and communication capabilities), and continued research in computer and information science, are integral to environmental observing capabilities. The explosion of real-time data calls for near real-time analysis and distribution if those data are to be most useful, especially in saving lives during hurricanes or earthquakes, or predicting likely outbreaks of infectious diseases. How we manage a constant flow of data is essential to the effectiveness of environmental observatories.

The Ocean Observatories Initiative



NSF's OOI will gather continuous observations from near-shore and remote areas of the seas

Source: Scripps Institution of Oceanography/Ocean Observatories Initiative

"To maximize the benefit of these investments, the development of extended observing systems must be coordinated with research on environmental cyberinfrastructure," states the 2005 NSF report, *Complex Environmental Systems: Pathways to the Future.* "Environmental cyberinfrastructure supports not only integrated access to data flowing from these observing systems, but also the wealth of environmental data held in existing databases."

The relevance of this information to the daily lives of citizens underscores the importance of basic research. Earth observatories offer unique opportunities to improve education at all levels. They also engage the public in an effort that is global and at the same time, personal.

"Coupled with continuing improvements in microprocessor speeds, converging advances in networking, software, visualization, data systems, and collaboration platforms are changing the way research and education are accomplished," states the 2007 NSF report, *Cyberinfrastructure Vision for 21st Century Discovery.* "Cyberinfrastructure-enhanced discovery and learning is especially exciting because of the opportunities it affords for broadened participation and wider diversity among individual, geographical, and institutional dimensions." The NSF-supported education projects with national and international reach have now begun to take advantage of all these possibilities.

From Manhattan to Bangladesh, sea-level rise will eventually affect everyone who lives along the world's coasts. Whether on a rice farm in Asia or a wheat farm in America, climate change is already affecting the fields and agriculture. In malaria-prone African countries, or out of Africa where climate is warming and malaria-carrying mosquitoes may now take up residence, new infectious diseases are on the way.

We are at a critical point in understanding the relationship between human systems and the rest of Earth's systems. The global population is now more than six billion people. In the next hundred years, that number may reach ten billion.

In the 21st century, we will make the choices that affect the most basic relationships between humans and the planet on which we live. How will we accommodate our needs, while maintaining the functions of the natural systems on which the future of the globe, and with it our existence, depend?

The challenge will be met, in large part, through basic research: By developing an understanding of the interplay of Earth's complex systems and how people function in and perceive the world they inhabit. This information will be used to predict what will happen in the years and decades ahead. In order to adapt to a changing world, and to mitigate changes that are already occurring, such knowledge is critical.

Solutions will come through the use of many eyes in the sky and ears on the ground: the network of networks of research environmental observing systems.[1]

New marine observing systems around Africa

Geoff Brundrit and Stewart Bernard, GOOS Africa;
Mika Odido, ODINAfrica and Lucy Scott, ACEP

New capabilities in marine observing and information systems are being brought into use on the coasts and in the oceans around Africa. These initiatives are pan-African in extent, covering many countries and all the regions of Africa. They are being developed in support of the Global Earth Observation System of Systems (GEOSS) vision of a future in which decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observation and information. At the same time there is intensive promotion of the scientific and technological capacity needed to take advantage of the new capabilities.

Further advances are planned, to be undertaken within ocean partnerships established by Africans for Africans. Key players within these partnerships are IOC/UNESCO's Global Ocean Observing System in Africa (GOOS AFRICA); the IOC/IODE's Ocean Data and Information Network in Africa (ODINAfrica), and the pan-African Large Marine Ecosystem (LME) and related programmes of the Global Environment Facility. Good progress was made with this cooperative planning at the pan-African LME/GOOS Africa Leadership Workshop on Operational Oceanography and Remote Sensing, held in Cape Town in November 2006.

The three case studies below illustrate the new capabilities and future prospects in marine observing and information systems that are being brought into use on the coasts and in the oceans around Africa.

ODINAfrica sea level monitoring

ODINAfrica, in collaboration with various partners, has embarked on an initiative to develop a network of sea level stations, providing data in near-real time, and addressing the key oceanographic phenomena along the African coastline. A survey of the status of the network undertaken in 2005 revealed the existence of at least 40 operational stations spread unevenly along the African coastline and island states. Long stretches of the coastline did not have operational tide gauges.

Since 2005, ODINAfrica has installed new tide gauges in Congo, Djibouti, Ghana and Mauritania. Additional stations have been installed or upgraded by the University of Hawaii Sea Level Centre (UHSLC) in Kenya, Mauritius, Seychelles, Tanzania, and by the Global Sea Level Observing System (GLOSS) in Mozambique and South Africa. Other countries where new gauges will be installed in 2007 include Cameroon, Egypt, Madagascar, Morocco, and Senegal.

ODINAFRICA Sea Level Data Facility (www.sealevelstation.net)
ODINAFRICA has collaborated with the Flanders Marine Institute (VLIZ) and the Pacific Tsunami Warning Centre (PTWC) to develop a sea level data facility. The facility receives real-time sea level data directly from the Global Telecommunication System (GTS). It provides information on the status of sea level stations, real-time data display and station metadata. The facility enables fast remedial action if a station fails by providing information (online, by e-mail and SMS), and also provides back-up to the centres monitoring tsunamis and other marine related hazards.

The Global Tide Stations Web Service (GTSWS) pilot project contributes to the ODINAfrica Sea Level data facility by providing up-to data metadata for the stations which are essential to ensure correct decoding and display of data.

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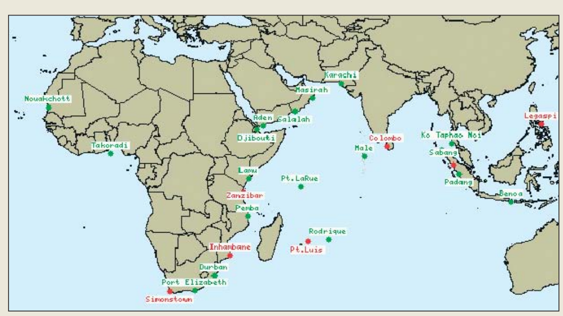
Tide gauge being installed at Noukchott, Mauritania

ODINAfrica, is working with various partners to develop a network of sea level stations, providing data in near-real time, and addressing the key oceanographic phenomena along the African coastline

Station status map



This station status map shows operational stations in green, with non-operational stations in red

GOOS-AFRICA remote sensing pilot projects

The GOOS AFRICA remote sensing pilot projects are designed to promote specific disciplines in remote sensing science; to promote the African implementation of international projects, and to provide the means of disseminating the large data volumes needed in regions with poor communications infrastructure.

Sustainable capacity development is an important aspect of the pilot projects, which aim to increase the numbers of skilled remote sensing scientists and technologists in Africa. Bilko-Africa is a pilot project specifically designed to enhance these remote sensing skills through exposure to applications with high priority in Africa. The intention is to provide for long-term use of these skills through synergy with national policy-makers and funding vehicles such as the large marine ecosystem programmes.

Discipline- or sensor-specific pilot projects include MSG-Africa, which develops coastal applications based on high frequency sea surface temperature data from the geostationary MeteoSat Second Generation satellites; and Alticore-Africa, which will develop the multi-scale observation and forecasting of waves and sea-state using altimetry and in situ platforms.

The Chlorophyll Ocean Global Integrated Network (ChloroGIN) is a GOOS/GEO demonstration project that provides international partners with operational measurements of chlorophyll and supporting variables using both satellite and in situ platforms in an ecosystem-based approach. ChloroGIN-Africa will provide sub-Saharan African countries with remotely sensed ocean colour and sea surface temperature products, and the ability to construct in situ time series of ocean chlorophyll measurements. A range of products from the MODIS and MERIS sensors provide information on phytoplankton biomass, primary productivity and turbidity, among others, and these are used in applications ranging from ecosystem analysis through resource management, to the detection of harmful algal blooms. Dissemination of data through C-band communications satellites is promoted through GEONETCast-Africa, a regional implementation of the GEONETCast system, which will greatly improve the ability to transfer large data streams into and through Africa. For example, it will also ensure the satellite-based dissemination of ChloroGIN-Africa products to users in Senegal, Ghana, Namibia, South Africa and Tanzania. Capacity development is core to ChloroGIN; and multi-national training programmes, post-graduate student placements and collaborative research cruises ensure that expertise is broadly developed across the continent.

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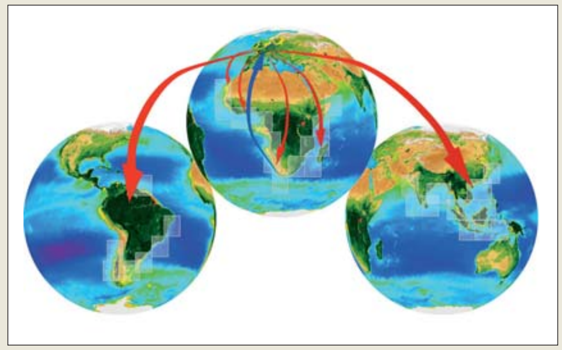
ChloroGIN-Africa



ChloroGIN-Africa is supported by data providers (shown here via blue arrows) and users (red arrows) through GEONETCast-Africa

In the future, GOOS Africa will seek to consolidate its in situ and remotely sensed observing systems and to close the gaps in its end-to-end user approach, so that a completely integrated observing and forecasting system is fully in operation. The encouragement of industry and business partners and the establishment of a multi-user environment will place the implementation of the system on a secure financial footing. In this way GOOS Africa, in cooperation with its partners, will also make a meaningful contribution to the implementation of the GOOS Coastal Network in Africa. This will operate through measuring, managing and analysing locally obtained high-resolution observations from a network of strategically placed sentinel and reference stations. The application of emerging technologies in computing and communication will see the establishment of modelling platforms and the routine generation of forecasting products for decision makers in the extended user community.

ODINAfrica will seek to position itself to service the greater demands placed on data acquisition and communication through the drive for ocean based services and industry sustaining the increasing population in Africa. It aims to become the pan African geo-spatial clearing house for coastal and ocean data and information, moving increasingly into digital communication, the development of user specific tool-boxes, and the design of high level interactive integrated products. These will focus on the establishment of an enhanced sea level network, on GIS-based atlases relevant to integrated coastal management, and on the development of scenarios of vulnerability to impacts of extreme events and climate change along the coast of Africa.

Sustained benefits from the efforts illustrated in these case studies cannot be realized without the simultaneous empowerment of African scientists and their national institutions. Such sustainable capacity development forms an integral part of all initiatives that seek to enhance the capabilities for earth observation in Africa: human capital; scientific and technological expertise; operational infrastructure; and mechanisms to maximize societal benefit must all be developed cohesively.

Such cohesion will be seen in the focus on marine observation and information systems, emphasizing an integrated approach to common needs and priorities within Africa as a whole. Africa must draw profitably on experiences gained elsewhere, but with adaptation to local systems and regional priorities and capabilities. Relevant, do-able, and cost-effective observing systems, utilizing and developing African science and technology, can also play a vital role as technological demonstrators in public and school-oriented science education.

Scientific and technical training must be supplemented by the long-term provision of the necessary equipment and the opportunity to practice newly acquired skills. Such efforts have been visible in the successes achieved by the ODINAfrica and GOOS Africa initiatives. The operation of the African sea level monitoring network has required extensive training in the

ODINAfrica African Marine Atlas

The delivery of accurate and reliable spatial data to marine and coastal managers and decision makers across Africa is essential for the sustainable management of natural resources in a rapidly changing environment. The African Marine Atlas is the first continental-scale marine and coastal data atlas for the African continent. Its purpose is to increase access to marine data, and capacity to use those data, in national institutions in the 25 coastal countries of Africa. The Atlas project seeks to address requirements for data at multiple scales, from the continental and large marine ecosystem scale, to national and local project scale. A variety of user requirements for a wide range of local applications will be addressed by serving multi-scale, multi-application data.

The African Marine Atlas project has brought great benefits to participating national institutions and to Africa as a whole, by encouraging scientists to work together, learn new techniques and build teams that will continue to collaborate in the future. Participants were drawn from Benin, Ghana, Kenya, Mauritania, Mauritius, Mozambique, Namibia, Senegal, Seychelles, South Africa, Tanzania and the USA, as well as two regional programmes; the African Coelacanth Ecosystem Programme (ACEP) and the United Nations Environment Programme (UNEP).

Based on an extensive survey of coastal and marine data needs, the Atlas team published a comprehensive library of over 800 datasets from hundreds of sources in the first of its web-based products, in February 2007. The data range from biogeographic data records from species of commercial or conservation interest, to monthly and seasonal climatologies of remotely sensed data and model products. Data and metadata are served together, in commonly used text and geographic information systems (GIS) formats.

Future directions for the African Marine Atlas will be toward developing high-resolution pilot sites in each country to demonstrate its applicability at local level for specific management challenges or use cases. At a higher level, integration with other African data serving projects and near-real-time observing systems through GOOS-Africa to GEOSS will be addressed, as well as ensuring that the Atlas system meets standards for interoperability between web atlases and interactive data servers at a global scale.

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The African Marine Atlas Team

The Atlas team has already published a comprehensive library of over 800 datasets from hundreds of sources in the first of its web-based products

use of the new equipment for the observation, processing and rapid dissemination of sea level information. The network now forms the backbone of the Africa-wide early warning system for tsunamis and other marine related hazards. There are now over 25 operational national ocean data centres in Africa, and a network of institutional libraries to disseminate marine and coastal information relevant for effective coastal planning. The innovative use of marine and coastal remote sensing is benefiting from both basic and advanced technical training, and enabling its application in the sustainable use of marine living resources, the protection of water resources and safety at sea.

Capacity building must take on an ‘operational’ profile, enabling nations to implement the marine services required by society, whilst maintaining the vital links to science, technical infrastructure and international cooperation. It must be based on identified priorities, as well as the utilization of shared observation and data resources, and shared technical and scientific service tools. Not all of these background conditions are adequately present today. However, experience from existing oceanographic services, the availability of freely exchangeable data and sophisticated numerical models, and the expanding use of Internet technology provide the prospect of rapid implementation of the necessary systems. The capacity building activities must find a balance between front-running high technology and the realism needed for robust, sustained marine observing and information systems. The aim must be to make the nations of Africa optimally self-sufficient in using these systems to protect the economic needs of society in the coastal ocean.

Observing systems for the Pacific Islands region — unique challenges for a unique environment

Paul Eastwood, Marc Overmars, Cristelle Pratt, Komal Raman, Peter Sinclair, Llyod Smith, Arthur Webb and Linda Yuen, Secretariat of the Pacific Islands Applied Geoscience Commission; Dean Solofa, Secretariat of the Pacific Regional Environment Programme

The Pacific Ocean, the largest water body on Earth, covers some 170 million square kilometres, spans climatic extremes from the poles to the equator, and exerts a major influence over global climate processes. Contained within the western tropical zone of the Pacific lies the Pacific Islands region, comprising some 20 small island developing states (SIDS). Many of these are composed entirely of small islands, some with combined total land areas of just a few tens of square kilometres, yet these same countries can control vast ocean Exclusive Economic Zones (EEZs) covering several million square kilometres.

For centuries the Pacific Ocean has strongly influenced the lives of the island communities scattered throughout the region, creating a rich, diverse and unique array of island heritages. Dependence on the resources of the Pacific, particularly the islands' fringing reefs, has underpinned subsistence lifestyles since humans first settled. Throughout much of this period, Pacific communities have managed to coexist in relative harmony with their environment. Indeed, some of the last remaining examples of how humans can live in sustainable relationships with coral reef ecosystems still remain in the region today. However, in more recent times pressures have increased as development, swelling populations and rapidly growing urban centres have resulted in previously unknown levels of environmental stress.

Photo: Marc Overmars

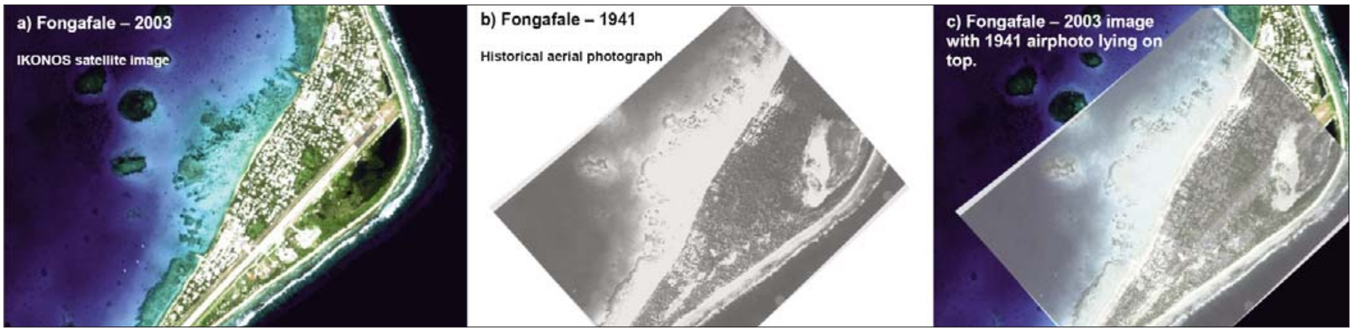
South Tarawa atoll, Kiribati

As competition for limited resources has increased, so have levels of vulnerability, particularly for the numerous atoll and small island communities that dominate the region. Pacific Island communities are also under threat from the projected effects of climate warming, which include an increased likelihood of coastal inundations, extreme weather events, coral bleaching with knock-on effects to reef fish resources and aquatic ecosystem structure, and a reduction in freshwater supply on small islands.[1,2] Given that many island communities in the Pacific are reliant on coastal natural resources through subsistence lifestyles, the threats posed by global-scale climate change are a major cause for concern.

In order to better understand the localised effects of global climate change, manage resources in a sustainable manner and develop strategies for mitigating the threat of environmental hazards, routine and comprehensive observations of the climate, seas, and freshwater resources are needed. However, developing such observational capacity in the Pacific Islands region poses some major logistical challenges, as most Pacific Island nations lack the resources and technical infrastructure to implement robust and sustained observation systems.

Improving observational capacity in the Pacific and other regions of the world is one of the main drivers behind the development of regional implementation programmes of global observing systems, such as the Global Ocean Observing System (GOOS), the Global Climate Observing System (GCOS), and the World Hydrological Cycle Observing System (WHYCOS).

All of these programmes have sub-components in the Pacific Islands region, namely Pacific Islands GOOS (PI-GOOS), Pacific Islands GCOS (PI-GCOS), and the Pacific component of WHYCOS (Pacific HYCOS). The central objective of all three of these regional programmes is to address the observational needs and unique capacity issues that exist among Pacific Island nations, and in doing so improve observational capacity and baseline information delivery at the national, regional, and global level.



Source: Webb, A. P. (2006)

Georectified contemporary and historical imagery for Fongafale islet, Tuvalu

Pacific Islands Global Climate Observing System

Established in 2000 at a regional GCOS workshop in Samoa, the creation of PI-GCOS reflects the recognition by Pacific Island countries that long-term, high quality observations of the region's climate are essential for improving forecasting capability and our understanding of both regional and global climate change. PI-GCOS is hosted by the Secretariat of the Pacific Regional Environmental Programme (SPREP) from its offices in Apia, Samoa. The primary objective of PI-GCOS is to improve the quantity and quality of climate and weather observations for the Pacific Islands region. This is achieved by assisting National Meteorological Services (NMS) to develop and strengthen the capacity of their observational networks. The data generated from enhanced observation platforms can then be used to develop improved and accurate climate and weather information, services and products to local communities.

Climate observations collected in the region include: long-term routine weather observations; specialized and general research observations; and proxy environmental climate data, designed to extend climatology time series in more remote regions to periods before weather instruments were available. In order to build the observational networks to collect these diverse data, capacity building efforts are directed at the following key areas: short- to long-term climate forecasting capability; communication links; training of climate personnel; and developing climate information services with stakeholders in key government and private sectors such as agriculture, water and tourism. Developing the data collection network is a central objective of the PI-GCOS programme and a cornerstone of enhancing capacity for weather and climate observations in the Pacific Islands region.

Photo: SPREP

Installation of tipping-bucket rain gauge on Funafuti, Tuvalu

Pacific Islands Global Ocean Observing System

Initiated in 1998, PI-GOOS is a regional alliance hosted by the Secretariat of the Pacific Islands Applied Geoscience Commission (SOPAC) from its offices in Suva, Fiji. As a global programme, GOOS aims to develop a permanent system of observations, modelling and analysis of coastal and ocean variables. Within this broad scope, regional alliances provide an effective mechanism for tailoring the GOOS programme to meet the specific needs of diverse communities around the world.

Given the scale and importance of the Pacific Ocean and the small size of many of the island nations scattered across the region, the drivers and needs for coastal and ocean observations are understandably quite different from those of other regions, such as Europe and Africa. One of the major differences is in the way in which ocean observations are collected. The Pacific Ocean is a major driving force for global climate process and therefore has received considerable attention from oceanographers and marine meteorologists for many years.

The number of observation and monitoring platforms that have been deployed in the Pacific is vast and growing, particularly through initiatives such as Argo (www.argo.net), a programme designed to increase global coverage of temperature and salinity measurements via systematic deployment of 3,000 profiling floats. Programmes such as Argo and ones similar are in all cases implemented by nations bordering the Pacific and farther afield. Involvement from Pacific Island nations in whose waters the observations are being collected is invariably limited to providing official permission for instruments to be deployed within their EEZ.

The PI-GOOS programme therefore aims to bridge the divide between data collectors and Pacific Island nations in two ways. First, by helping to build national observational capacity where needed, such as for mariculture sites where data on water quality are critical to successful operations. Second, by ensuring that the data and products being generated by the large-scale coastal and open ocean observation programmes are readily available in accessible formats and can be understood by a broad range of users from across the Pacific Islands region.

Currently PI-GOOS is undertaking a number of initiatives to help build capacity and bridge the data divide, such as compiling a catalogue of ocean observing systems and a digital marine atlas of the Pacific Islands region. Given the potential impact of climate change on coastal communities, support is also being given to locate and acquire historical aerial photographs of Pacific Island coastlines. This would allow a better understanding of the evolution of shorelines and coastal environments in the context of climate change and local management practices. Actions such as these, supported by awareness raising and education programmes, will help PI-GOOS achieve its long term vision of assisting development in Pacific Island nations via improved uptake and use of data and information from oceanic and coastal observing systems.

Pacific Hydrological Cycle Observing System

Pacific HYCOS is one of the regional components of WHYCOS, a World Meteorological Organization (WMO) initiative aiming at improving basic hydrological observation activities, strengthening capacity and international cooperation, and promoting availability and exchange of data.

The programme is hosted by SOPAC at its headquarters in Suva, Fiji, and will be implemented over a three-year period (2006-2009). At its core, Pacific HYCOS aims to improve the assessment, management and protection of small island states' freshwater resources through the provision of appropriate collection and management systems for water resources data. Access to better data and information on the status of water resources has the potential to feed into and improve local, regional and national planning efforts, economic development, and environmental and public health issues.

The current programme covers 14 Pacific Island countries and includes some of the most fragile communities in the world in terms of water resources. This fragility is due to their small size, lack of natural storage, competing land use, and vulnerability to natural and anthropogenic hazards, including drought, cyclones and urban pollution. One of the key objectives of the programme is to strengthen the technical capacity of National Hydrological Services (NHS) in these countries, in relation to water resources assessment and management. This will be achieved through targeted measures in the following critical areas: water resources assessment in major rivers; water resources databases; flood forecasting; drought forecasting; and groundwater and surface water quality monitoring and assessment.

Photo: Marc Overmars

River gauging, Espiritu Santo, Vanuatu

As one of its functions, the Pacific HYCOS programme continues the Pacific Dialogue on Water and Climate,[3] an initiative with the aim of improving capacity for water resources management by establishing a platform through which policymakers and water resource managers have better access to and make better use of information generated by climatologists and meteorologists. One of the tools promoted under Pacific HYCOS is the production of the Island Climate Update bulletin, which is published monthly by the National Institute of Water and Atmospheric Research (NIWA) in collaboration with SOPAC, SPREP, and NMSs. The bulletin's primary goal is to assist Pacific Island countries in making informed planning and management decisions relating to climate-sensitive sectors, through the provision of timely and accurate seasonal climate forecasts.

Looking forward

The observing programmes operating in the Pacific Islands region tackle all of the major components of the hydrological cycle, from oceans and climate to surface and ground water. By integrating the data, information and products from all three programmes, our understanding of a number of critical environmental processes and the ways in which they affect the lives of Pacific Island communities will be significantly enhanced. The combined data and information will, over time, help strengthen regional and national capacity for sound planning and decision making. In this way it will help to build more sustainable livelihoods across the Pacific Islands region.

The long-term vision for the Pacific is for countries to have the capacity to undertake the necessary observation programmes, to not only understand their climate, coasts, and water systems, but to use the information to guide sustainable development and mitigate against environmental hazards and threats. Until such time, programmes such as PI-GOOS, PI-GCOS, and Pacific HYCOS have a vital role to play in building observational capacity throughout the region. Their successful implementation will ensure that some of the most vulnerable nations on Earth are better equipped to serve their communities at the local level and also tackle the challenges and threats posed by global scale processes such as climate change. Support for the Pacific Island observing systems therefore needs to continue and in some cases be enhanced in order to build resilience among Pacific Island communities and ensure a secure and healthy environment that future generations can continue to benefit from.

Canada's National Land and Water Information Service

Ian Jarvis, Manager; Heather McNairn, Research Scientist; Allan Howard, Manager; Catherine Champagne, Scientist; Ryan Ogston, Scientist, Agriculture and Agri-Food Canada

A sustainable agricultural sector for Canada will be one that is innovative, competitive, proactive in managing risks and able to seize new opportunities while meeting the needs of increasingly health conscious and environmentally aware Canadians. A key component of promoting a sustainable sector is providing information to strengthen the ability of government and individuals to make sound decisions that will preserve the land, air, water and genetic resources for current and future generations.

Agriculture and Agri-Food Canada (AAFC) has established the National Land and Water Information Service (NLWIS) to provide on-line free and open access to agri-environmental data, information, tools and expertise to support land-use decision making. NLWIS is successfully bringing information from government and non-government organizations together, and developing partnerships with multiple agencies to permit sharing and access to data and products for the benefit of the broad Canadian user community.

NLWIS is also working to generate new information to fill critical gaps identified by the user community using the methods and innovations developed by AAFC research. NLWIS and AAFC's research community are working together in developing the next generation of Earth observation products to meet ongoing and emerging user needs.

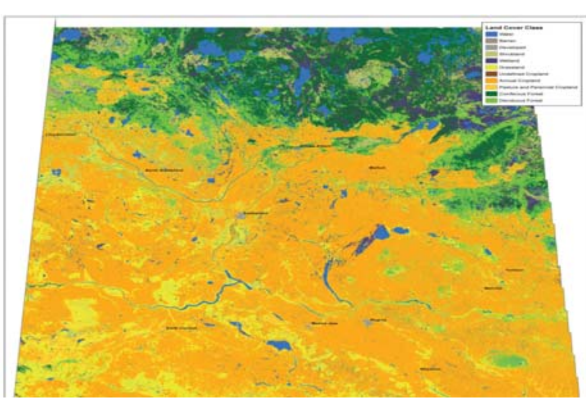
Earth observation initiatives are critical in providing the information needed on land and water resources. Land cover monitoring supports a range of agri-environmental information and application needs, including: decision-making and monitoring for land use and management; production insurance; development of agri-environmental performance indicators; climate change monitoring plus carbon and greenhouse gas accounting and verification; biodiversity monitoring; environmental farm planning; and incentive programs for the adoption of beneficial management practices.

NLWIS is developing medium-resolution land cover monitoring information for agricultural regions of Canada to identify areas of agriculture production in Canada, and set a baseline for tracking environmental change. The work currently includes a circa 2000 baseline inventory. Annual crop inventories are of value to a diverse user community. Annual information on crops will support programs to understand, assess, predict, mitigate and adapt to climate variability and its associated risks, contribute to sustainable agriculture and improve land management decisions. Earth observation technology provides an efficient approach to large area mapping of crop information. AAFC researchers have developed a methodology that integrates data from radar and optical satellite sensors to classify crops across Canada's agricultural landscape.

In addition to information on Canada's land-base, NLWIS is bringing together information to help monitor the state and impacts of a variable climate on the agricultural sector. Crop condition monitoring tracks the seasonal health of agricultural land and is useful in supporting water resources management, reducing vulnerability to risk, and supporting production risk programs. It is a particularly important contributor to several agri-environmental information and application needs, especially monitoring of drought and other risks to sustainability.

Data on Canadian crop conditions are required regularly and in near real time for crop condition assessment purposes. AAFC currently uses Advanced Very High Resolution Radiometer (AVHRR from NOAA)-derived

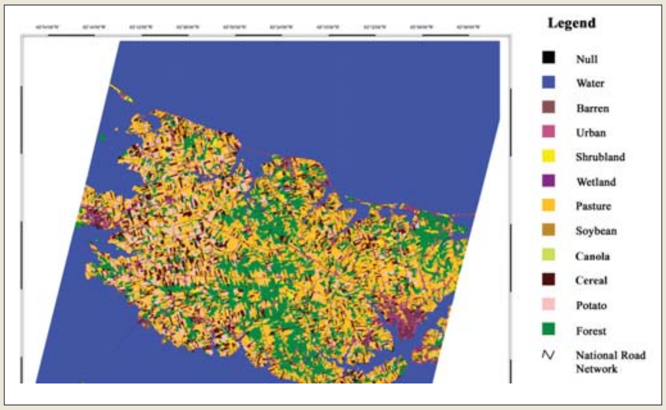
Province of Saskatchewan, Canada, circa 2000



Baseline Medium-resolution land cover maps will make it possible to monitor changes in the agricultural land base of Canada

Source: Agriculture and Agri-Food Canada, 2007

Crop inventory map, Province of Prince Edward Island, Canada, circa 2006



Annual crop inventories will provide information on changes in crop production, and can be used to track the impact of policies to promote sustainable agriculture

Source: Agriculture and Agri-Food Canada, 2007

1km-resolution Normalized Difference Vegetation Index (NDVI) data for crop assessment on the prairies (weekly composites) and across the country (ten-day composites). The next generation of NDVI products is being developed to use a system for processing 250m-resolution NDVI (MODIS from NASA) data for both weekly composites and multiple time-period composites for all of Canada.

Crop condition information is supplemented with key climate information. Knowledge of absolute and relative soil moisture is of critical importance to agriculture. Soil moisture is a sensitive indicator of crop moisture stress and the onset of drought, and plays a key role in crop productivity. It influences field activities (tillage, seeding, irrigation) and also is a key indicator of runoff potential, as well as a key input for weather forecast modelling. As such, soil moisture is a critical data requirement to support the agricultural policy outcomes of monitoring, forecasting and responding.

AAFC is currently using enhanced passive microwave data for the development of qualitative coarse-scale information on surface wetness and temperature. Researchers are also developing approaches to using Synthetic Aperture Radar (SAR) and multi-angle radar data that will improve the resolution and provide qualitative soil moisture monitoring data. In the future, soil moisture monitoring in Canada will be based on integrated monitoring networks that incorporate passive microwave systems with SAR and in-situ monitoring networks.

Near-real-time climate networks are also used to provide information on the state of Canada's agroclimate. The extent, location and severity of temperature and precipitation events relevant to agriculture are monitored and analyzed in near real time and distributed on AAFC's drought watch web site. AAFC is integrating Environment Canada's weather monitoring data and data from provincial networks to provide daily updates on conditions for the industry. Weather data is assembled into a common format, screened and verified where possible before maps showing several analytical products are prepared with geographic information system technology. The information is a key input for identifying drought and other weather-related disasters, as well as for developing mitigation programs.

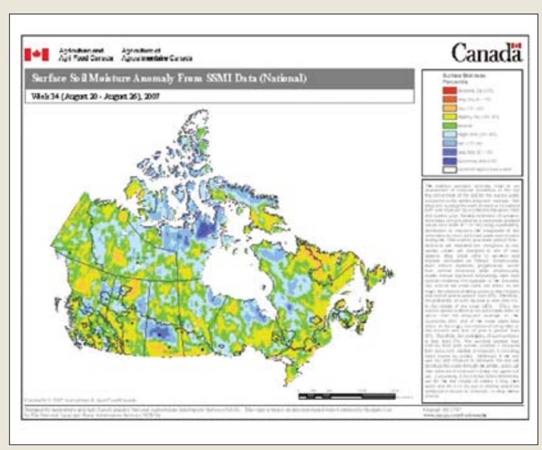
NLWIS is committed to supporting sustainable agriculture in Canada by being the authoritative source of geospatial data to support monitoring, forecasting and response programs. Within NLWIS, earth observation will play a critical role in helping to deliver on the monitoring to response agenda.

Weekly crop condition imagery (NDVI) from the MODIS satellite sensor

Crop condition maps are a valuable tool for monitoring the impacts of climate extremes on agricultural production

Source: Agriculture and Agri-Food Canada, 2007

Weekly surface wetness anomalies from enhanced passive microwave data



Soil moisture is an indicator of the onset of drought conditions, that could, in turn, adversly effect food production

Source: Agriculture and Agri-Food Canada and Commodity Hedgers Ltd., 2007

Canada's sustained Arctic monitoring programme

Doug Bancroft, Director, Canadian Ice Service, Environment Canada; Andrew Eddy, President, Athena Global; Guy Séguin, Director, Spacecraft Payloads, Canadian Space Agency

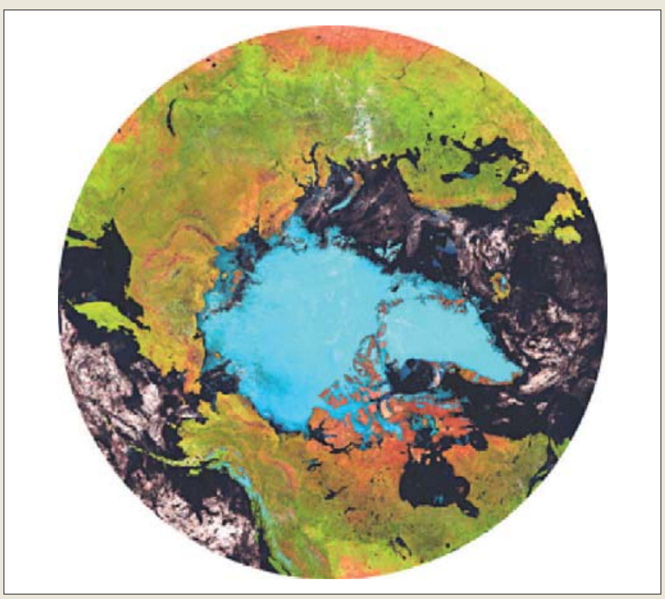
The recent recognition of accelerated long-term climate change has brought a sense of urgency to Arctic monitoring. Disappearing sea ice, melting permafrost and much warmer temperatures are causing dramatic changes to fauna and flora, as well as infrastructure local populations rely on.

Leveraging contributions other nations will make to the Group on Earth Observations (GEO) and the exceptional data collection that will take place under the International Polar Year (IPY), Canada is working to establish a sustained Arctic monitoring program that will identify key parameters to track these changes and monitor them over time.

The program will run in four phases: the inventory of existing Earth Observations (EO) and scope definition; a need and gap analysis; a demonstration; and the establishment of a comprehensive EO program. This program is undertaken in close cooperation with departments involved in Canada's north, particularly Environment Canada, Natural Resources Canada, Fisheries and Oceans Canada, Indian and Northern Affairs Canada, territorial governments and the IPY secretariat.

Ultimately, this program will offer governments and other northern stakeholders a vital source of information to support enhanced security, economic development and environmental stewardship, stronger territorial government, healthy and vibrant Arctic communities and the development of Arctic science.

MODIS-based circumpolar map



The MODIS-based Circumpolar Map was developed by the Canada Centre for Remote Sensing, Earth Sciences Sector, Natural Resources Canada as a contribution to Canada's Arctic monitoring program. It provides a fusion of MODIS land channels to produce a regional time series of multispectral surface albedo at 250m and 10-day intervals for climate change and terrestrial monitoring applications

Source: Trishchenko, A.P., Y. Luo, K. V. Khlopenkov, W.M.Park, SPIE, 2007. Courtesy of NRCan

Canada, an Arctic nation

Canada is one of the world's largest Arctic nations, exerting sovereignty over countless islands and one of the world's longest coastlines across the Arctic archipelago to the northernmost tip of Ellesmere Island. Canada's Inuit populations have roamed the Arctic for thousands of years.

In the 17th century, English explorers searching for the Northwest Passage sailed the icy northern waters and charted out channels, straits, bays and inlets, leaving clear traces of their passage on the land, in records and through Arctic legends and lore.

Today, the three territories of Canada's north account for roughly 40 per cent of Canada's landmass and freshwater reserves, with a population of 100,000 people, representing only 1/3 of 1 per cent of the Canadian population. In this context of sparsely populated wilderness and extreme temperatures, remote sensing is a critical tool to support economic and social development.

In recent years, international interest in the Arctic has grown dramatically. Global warming has led to rapid melting of Arctic ice. In summer 2007, the Northwest Passage was virtually ice free for the second year in a row, a first in modern history. This is a sign of things to come, and could herald a new age of Arctic exploration and development.

Canada's government has recognized this with the decision to increase investment in Arctic infrastructure. One of the most significant new investments announced is the decision to build a deepwater port for Canada's northern fleet in Nanisivik, to support policing the Northwest Passage and provide support to ships in trouble. Increased northern traffic will come from new development of the north, as well as cruise ships, the development of local fisheries, and transit cargo.

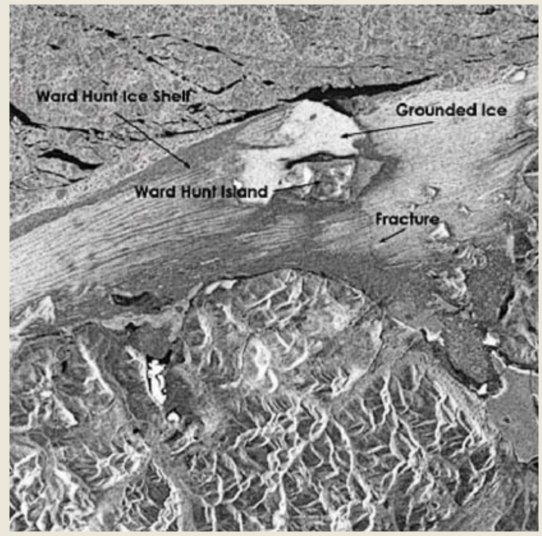
While eventually the Northwest Passage could offer a significantly shorter maritime route from Asia to eastern North America and Western Europe, it is unlikely to become a major shipping lane until environmental conditions are better understood and logistical issues are dealt with. Nevertheless, destination shipping seasons in the north are lengthening, bringing increasing traffic to the Port of Churchill and other locations. Important new port infrastructure is being built. Canada intends to ensure that maritime traffic in the north is safe and respects Canadian environmental legislation; satellite sensing is a key component of this strategy.

Building on existing observations

Canada already maintains a vast network of environmental monitoring stations across the Canadian north. In the future, more stations are expected to add to Canada's observations to support comprehensive weather and climate monitoring. The integration of this information with satellite-based observations is critical. Satellites already provide ad hoc coverage of the north to support specific operations.

During the International Polar Year, unprecedented volumes of satellite data will be collected to support scientific research over the Canadian Arctic. These data complement the 12-year background mission of Canada's RADARSAT-1 which has collected a unique archive of imagery over this area for future studies focused on changes over time. Until recently, the efforts deployed for the International Polar Year focused solely on observations during this time period to support science. Canada's Arctic monitoring program will ensure a legacy from the Polar Year observations by rooting them in on-going monitoring and providing a mechanism for information to be transmitted to decision makers.

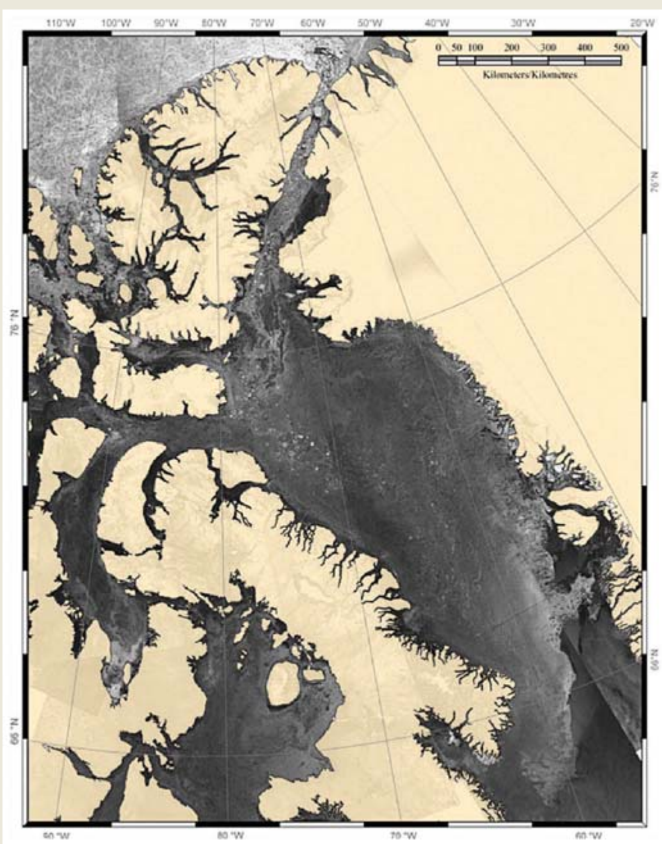
Ward-Hunt ice shelf imaged by Canada's RADARSAT-1



During a 12 year project RADARSAT collected a unique archive of imagery over Canada's Arctic area, for use in future studies focused on changes over time

Source: RADARSAT International

Eastern Arctic regional mosaic derived from RADARSAT data



Canada's Arctic areas are undergoing vast changes due to the acceleration in long-term climate change, including disappearing sea ice and melting permafrost

Source: Annual Arctic Ice Atlas (Winter 2007), Canadian Ice Service

Comprehensive EO to support northern development

The major federal government departments active in Canada's north are currently developing a federal Earth observation strategy that will include a major northern component. This observation plan will provide for sustained in-situ and remote observations of the Arctic, coordinated with international partners. It will also generate information products used to support decision making, whether in relation to resource development, infrastructure construction, pollution monitoring or other areas of decision support.

Canada's north is undergoing rapid change, and Canada's decision makers need new tools to track and understand this change. As wildlife such as Canada's polar bears struggle to adapt, mitigation strategies depend on comprehensive information and understanding. The unique but fragile environment of the north offers exceptional development opportunities but these must be pursued in a context of heightened stewardship and environmental awareness to ensure Canada's Arctic remains a beautiful and pristine legacy for future generations of Canadians.

TerraSAR-X — a new system in the system of systems

Dr Stefan Knabe, Infoterra GmbH; Dr Jörn Hoffmann and Achim Roth, German Aerospace Center

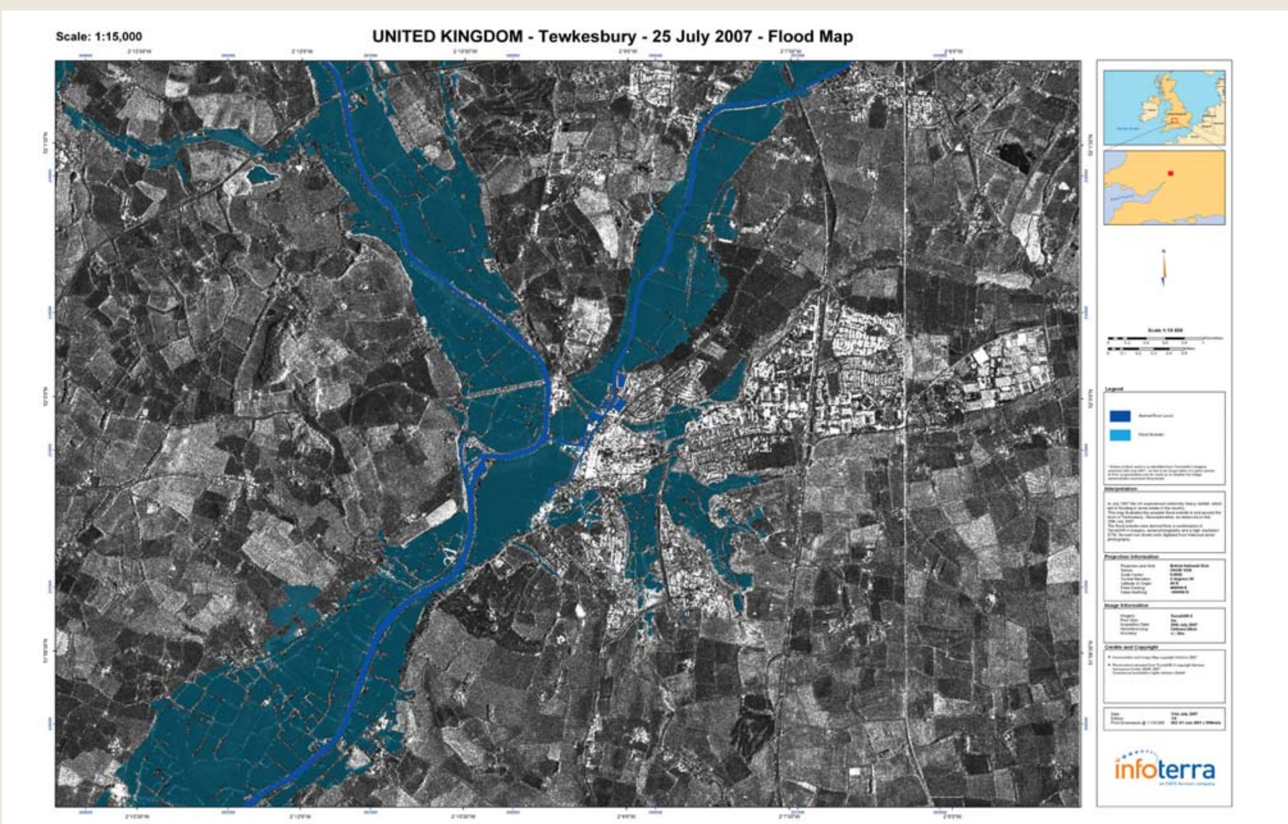
TerraSAR-X is a new German radar satellite that was launched on 15 June 2007. It carries a high frequency X-band SAR sensor operating in different modes of polarization, coverage and spatial resolution of down to 1 m. Using the microwave part of the electromagnetic spectrum, TerraSAR-X is able to monitor the Earth's surface independently of day or night time and weather conditions.

In addition to its ability to characterize the physical properties of the illuminated objects on the basis of the backscatter intensity (e.g. soil moisture, vegetation cover, etc.) TerraSAR-X can also be used for generating digital elevation models (DEM) and for measuring surface motion processes like subsidence or the flow velocity of river and ocean currents through interferometric analysis of the radar data (phase information).

TerraSAR-X partners

The mission has a scheduled lifetime of five years and is realized through a public-private partnership (PPP)

TerraSAR-X flood map



This map shows the extent of flooding in the area of Tewkesbury, UK on 25 July 2007, derived from TerraSAR-X data (spatial resolution: 3 m)

Source: Infoterra Ltd

between the German Ministry of Education and Science (BMBF), the German Aerospace Center (DLR) and EADS Astrium GmbH. Infoterra GmbH, an Astrium subsidiary, holds the exclusive rights for commercial exploitation of the data, whereas DLR is responsible for the coordination of the scientific data use. An equal share of mission resources, particularly data acquisition capacity, has been agreed for commercial and scientific use.

The relevance of TerraSAR-X to GEOSS

Many scientific applications, like monitoring the implications of global change, are dependant on the long-term availability of comparable datasets as the occurrence of these processes is only observable and verifiable over long time intervals. Therefore, long-term data availability is an important objective of the Global Earth Observation System of Systems (GEOSS).

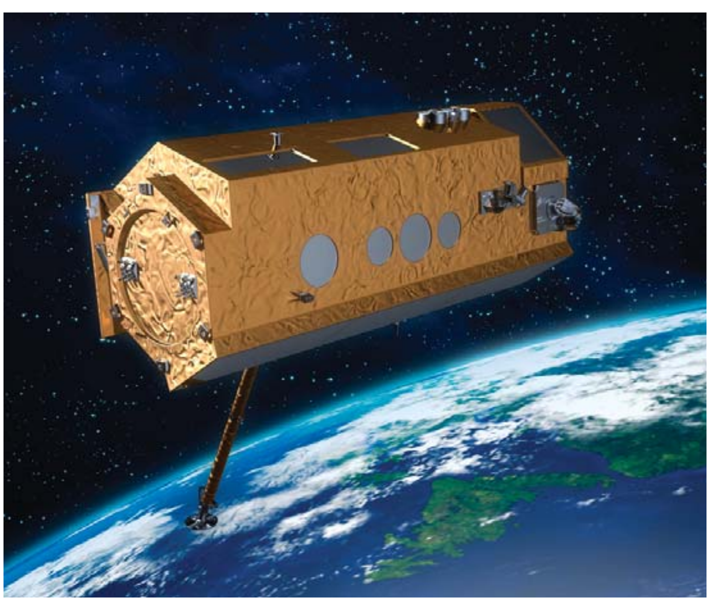
In the case of TerraSAR-X data, this premise is assured by Infoterra GmbH's commitment to reinvest profits from the commercial sale of TerraSAR-X data into the next generation satellite, TerraSAR-X-2. In addition, a second TerraSAR-X satellite called TanDEM-X will be launched in 2009 to enable the close-formation flight of two almost identical systems. This provides for a temporal extension of the availability of TerraSAR-X intensity data, although the primary mission objective is the creation of a global DEM at a very high spatial resolution.

TerraSAR-X image modes

Mode	Spatial Resolution (max)	Spatial Coverage (max)
Spotlight	1m	10 x 10km
Strip Map	3m	30 x 1500km
Scan SAR	16m	100 x 1500km

Source: Infoterra GmbH

Credit: Artists view of TerraSAR-X in space — © Astrium GmbH



TerraSAR-X uses the microwave part of the electromagnetic spectrum, and is able to monitor the Earth's surface independently of day, night or weather conditions

A second scientific demand also claimed by GEOSS is the consistency of data time series to allow an accurate observation of changes and processes including their variability. TerraSAR-X has been designed to support the monitoring of changes through precise orbit maintenance and stable radiometric performance.

In addition, supported by its very high spatial resolution of down to 1m, its very high temporal resolution of down to 2.5 days and its very short response time, TerraSAR-X and its successors are valuable and reliable tools, especially for disaster response activities (e.g. flood area mapping), which are of great importance to GEOSS and highlighted in the socio-economic benefit area 'disaster'. Negotiations between DLR and the international charter *Space and Major Disasters* regarding the use of TerraSAR-X for charter activities are also well advanced.

Besides the examples mentioned above, TerraSAR-X serves nearly all of the questions raised in the socio-economic benefit areas of GEOSS that address the properties of the Earth`s solid or liquid surface, due to its capability to characterize parameters like surface roughness (e.g. wave parameters), plant architecture (e.g. vegetation parameters) and differences in the dielectric properties of materials (e.g. soil moisture, etc).

With the TerraSAR-X mission Germany substantiates its commitment to GEO and its objectives: for scientific applications all TerraSAR-X data are made available to users worldwide at cost of reproduction if the scientific value of the proposed project is approved by DLR. Details can be found on the TerraSAR-X science portal: (http://www.dlr.de/tsx/main/science_en.htm). Furthermore, Germany is actively supporting the implementation of GMES, a key system within the system of systems, by making TerraSAR-X available to the maturing services.

Current status and next steps

The satellite commissioning phase will continue until late 2007, when the five-year nominal lifetime will start. With the planned launch of the TanDEM-X satellite in 2009, TerraSAR-X will contribute to realizing the implementation of high quality interferometric applications. After the end of the nominal lifetime of TerraSAR-X a new generation satellite called TerraSAR-X 2 is scheduled to be launched in 2012. As this constellation assures the long-term availability of comparable datasets, TerraSAR-X and its successors provide a reliable and valuable data source serving a multitude of scientific and operational applications promoted by the GEOSS.

KoFlux contribution to GEOSS: HydroKorea II and CarboEastAsia

Joon Kim, Department of Atmospheric Sciences & Global Environmental Laboratory, Yonsei University, Seoul; Sung Kim, Sustainable Water Resources Research Center/KICT, Korea

In-hyuk Choi always knew there was something special about being in nature. But it took several years after his trips to developing countries in Africa, the Middle East, and Asia to discover what was so special about it. His encounters with numerous people in desperate need had completely changed his *Weltanschauung* (world view). And Choi, who was trained as a hydrogeologist through the HydroKorea project with Yonsei University, has begun to serve as an 'Informed Steward' in Kenya by practicing what he learned from classes and laboratories.

Now, Choi leads a non-governmental organization ('Team & Team') as water and sanitation coordinator — cleaning, rehabilitating and repairing wells and pumps to provide clean water to more than 50 villages in Kenya. "What we really lack in Turkana and Garissa isn't water," he says. "It's water management. The people are poor, they have poor water quality, and their animals are dying at a worrying rate. The environment here is collapsing due to population pressure."

Prayer from Kenya

From the cowardice that dares not face new truth,
From the laziness that is contented with half-truth,
From the arrogance that thinks it knows all truth,
Good Lord, deliver me. Amen.

Fifteen years ago Anthes (1993), the president of the University Corporation for Atmospheric Research, projected the accountability of scientists in shaping the quality of human life on Earth in the 21st century and beyond. He used a metaphor known as the 'global trajectory,' pointing out a modern version of the 'Four horsemen of the Apocalypse.' These four death-dealers are: overpopulation, unsustainable economic development, poverty and environmental degradation. Driven by the first three horsemen, our environment has worsened over the last three decades. The concept of global trajectory forces us, as stewards of the Earth, to make certain assumptions and then to project the trajectory into the future. Having comprehended further the unknowns and the uncertainties in global change science and history, we are challenged to participate proactively in this escalating battleground as leaders and stewards — people who are willing and able to make tough yet informed choices that will protect our planet and its people.

The present disturbance in our Earth system calls for pressing attention from every discipline towards coping with one another. One of the main concerns is the potential role of terrestrial ecosystems under such unparalleled environmental changes in the history of human civilization. The scope of this question is very broad and deep due to close linkage and feedback mechanism in the fundamental processes with wide ranges of spatiotemporal scales. Clearly, this requires new scientific approaches and syntheses that cross both geographic and disciplinary boundaries, with particular emphasis on cycles of energy, water and carbon as an integral part of the human-environment system. In this context, terrestrial ecosystems in the Asian continent play a unique role due to dramatic alterations in land use and cover change through an alarming rate of economic developments. This is further complicated by the growing evidence that global climate changes, particularly over the Asian region covered by the seasonal brown clouds, could be significantly modified along with subsequent changes in hydrological cycles.[1]

Water and carbon are essential for life. They circulate on Earth, and the past and today's world exhibits clear evidence of the significant influence of their cycling on the global climate and the growth of human civilization. The cyclic nature of water at the local scale is clearly manifested in one of the longest precipitation records for Seoul, Korea. At first glance, the precipitation of Seoul has recurring dry and wet periods with a notably severe drought from 1884 to 1910. If the climate does cycle, should we not expect another brutal and prolonged drought in the very near future? In fact, the more important question is how much impact our human activities are having on this water cycle. The answer is clearer in the case of carbon, where the couplings between water and carbon cycles signify the implication. The Intergovernmental Panel on Climate Change (IPCC) Working Group 1 (WG1) Fourth Assessment Report warns that a range of forcing, originating from human activities, is expected to have planet-wide effects and perturb biogeochemical cycles of the Earth system. Furthermore, some systems, sectors and regions of less-developed countries would be particularly vulnerable to climate changes.

KoFlux is a domestic network of micrometeorological eddy covariance flux tower sites, which monitors the exchanges of water, energy and carbon between the atmosphere and key terrestrial ecosystems in and around the Korean Peninsula.[2] Along with ChinaFlux and JapanFlux, KoFlux is a cornerstone of AsiaFlux, the Asian arm of the global FLUXNET,[3] which provides strong partnership in observation, capacity building, management and governance, and sustainable development options of the Global Earth Observation System of Systems (GEOSS).

As originally conceived, the KoFlux programme was intended to last a span of ten years (from 2001 to 2011), with three major activity phases. The publication of this article marks the beginning of Phase 3. The construction of the infrastructure was the main theme of Phase 1 (2001-2004), during which KoFlux was launched by networking individual research sites with the limited available resources in Korea to support AsiaFlux. The KoFlux team developed a global network, proving that KoFlux data could be collected locally and shared anywhere through a framework such as GEOSS. As a byproduct of this work, the team published well over 100 technical papers and presentations in various journals and symposia.

Terrestrial ecosystems, particularly in Asia, are heterogeneous, and their spatial and temporal variability influences the lower atmospheric circulation and surface exchange of energy, water and carbon over a wide range of scales. Accurate assessments of multi-scale changes in our biosphere depend on the definition of practical 'scaling logic' that incorporates a synergy of field measurements, numerical modelling and remote sensing. Hence, built upon an augmented KoFlux infrastructure such as the 'Gwangneung Supersite,' Phase 2 ('HydroKorea' and 'CarboKorea', 2004 to 2007) focused on linking flux footprint, ecohydrological schemes and satellite images to bridge the gaps between different scales of exchange processes in heterogeneous and complex landscapes.[4]

Phase 3 of the KoFlux programme (HydroKorea II and CarboEastAsia) will improve the scaling logic methodologies developed during Phase 2 to accurately apply and monitor the water and carbon cycles from local to regional scales in monsoon Asia, thereby proactively providing options needed to minimize damage and encourage sustainable use of our biosphere. To continue to raise next generation leaders and stewards such as In-hyuk Choi, KoFlux successfully hosted the Second AsiaFlux Training Course on Micrometeorology in July 2007. More than 20 young scientists were invited for free training, from developing countries such as Bangladeshi, India, Indonesia, Nepal, the Philippines, Taiwan, Thailand and Vietnam along with those from China, Japan and Korea. Numerous voluntary lecturers from different continents (e.g. AsiaFlux, AmeriFlux) provided fundamental and comprehensive knowledge on issues from global change sciences to state-of-the-art flux monitoring theories and techniques. Also, contributions from the private sector, such as Campbell Scientific Inc., provided the trainees with superb hands-on experience to develop practical skills in instrumentation and data processing.

CarboEastAsia is another exemplary programme for capacity building among ChinaFlux, JapanFlux and KoFlux to cope with climate change protocols by synthesizing measurement, theory and modelling in quantifying and understanding of carbon fluxes and storages in East Asia. Based on an agreement between the National Natural Science Foundation of China (NSFC), Japan Society for the Promotion of Science (JSPS) and the Korea Science and Engineering Foundation (KOSEF), this 'A3 Foresight' programme supports joint research conducted by researchers in China, Japan and Korea. The three countries (A3) work as a consortium in advancing leading-edge research with the aim of establishing a top-level research hub in Asia to support the GEOSS framework.

In summary, finding simplicity in complexity is the challenge that KoFlux researchers are facing as informed stewards who are striving to reduce complex science issues of water and carbon cycling to fundamental questions and lay out detailed plans for the use of newly evolving theories and technologies to address these questions. We still know far too little on how ecohydrological and biogeochemical processes interact and their dynamics are manifested at different scales. We hope that the report presented here encourages more ground-breaking studies aimed at bridging the gaps in the cross-scale studies of couplings between climate change and global biogeochemical cycles. The stewardship of KoFlux along with ChinaFlux, JapanFlux and the recently launched IndoFlux, for example, is a sleeping giant just waiting to be awakened under the framework of GEOSS. Through the partnership with other GEOSS networks, it can make serious contributions to accomplish the vision of GEOSS in the Asia-Pacific region. We have the potential to help make the shift to a sustainable global trajectory that will ensure the survival and quality of life of humans and other species that share the planet with us.

Photo: Mr. In-hyuk Choi

In-hyuk Choi trained as a hydrogeologist through the HydroKorea project with Yonsei University, and now works as a water and sanitation coordinator cleaning, rehabilitating and repairing wells and pumps to provide clean water to more than 50 villages in Kenya

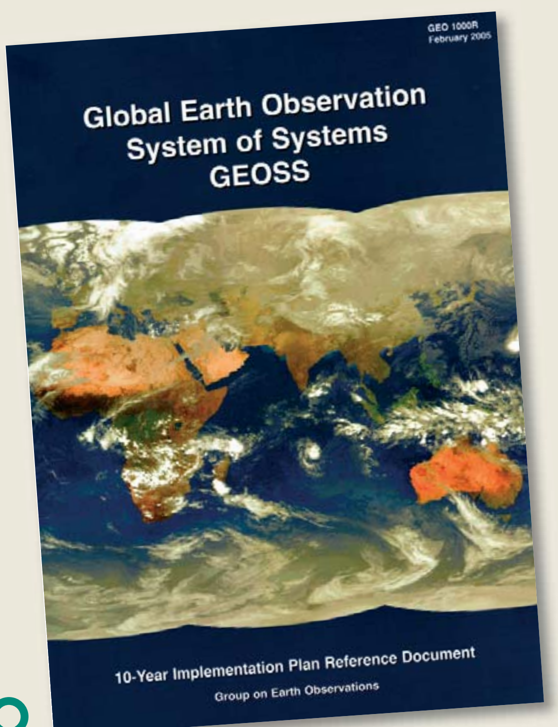
GEOSS architecture principles and the GEOSS Clearinghouse

Eliot Christian, United States Geological Survey

In 2003, ministers at the first Earth Observations Summit declared their intention to establish a system of comprehensive, coordinated and sustained Earth observation. This system became the Global Earth Observations System of Systems (GEOSS). In 2005, ministers created the intergovernmental Group on Earth Observations (GEO) to implement GEOSS. GEO then adopted the GEOSS 10-Year Implementation Plan and Reference Document (the 'GEOSS Plan').

GEO cannot pre-empt existing mandates of national systems and international programmes that already coordinate or manage Earth observation systems. Accordingly, the GEOSS Plan stated that GEOSS must be a 'system of systems' — GEOSS must not attempt to subordinate component Earth observing systems under central control. Rather, all component systems contributed to GEOSS must continue to operate within their own mandates.

The GEOSS plan 10 year reference document and logo



Although its component systems operate within their own mandates, GEOSS is to be much more than merely the sum of its component systems. Accordingly, it must enable its component systems to leverage each other's resources. The GEOSS Architecture is the primary mechanism for achieving such synergy among the contributed GEOSS components.

Synergy example: wildland fire warning

In areas with wildlands emergency managers, as well as electric power companies and park managers, need early warning of fire outbreaks. Accurate observations, forecasts, and maps are essential to mobilize protection efforts when there is a threat to people, wildlife, power facilities, and other property. But many different data systems provide observations; many different models generate forecasts, and many different mapping systems hold information that managers need to display. How can these emergency managers tap such diverse resources across a range of independent systems? Like GEOSS, they can use a system of systems approach.

Emergency managers periodically generate standardized maps of wildland fire potential, based on remote sensing of soil moisture and vegetation cover. These maps can incorporate standard maps of populated areas, terrain, power lines, and hundreds of other important features.

Actual wildland fires are detected quickly, through on-the-ground and remote sensing. When this occurs, fire warnings go out over pagers, voice telephone and fax machines to authorities, emergency managers and power companies. Authorities issue specific alerts to people in harm's way and to property owners. Tactical maps and evacuation routes are generated for response crews as they deploy. While fire-fighters battle the blaze, predictions of fire spread and smoke hazard, and the effectiveness of fire management efforts, are refined and communicated rapidly.

Events such as this fire are occurring right now in many places worldwide. Although many data and analysis tools are available, not all of them are interoperable enough to work well together. In some places, the technology norm is still paper maps with plastic overlays, and emergency managers still use pushpins and grease pencils. However, use of digital mapping is becoming more widespread. Mapping systems from different vendors are now highly interoperable, and telecommunications components are also becoming more interoperable.

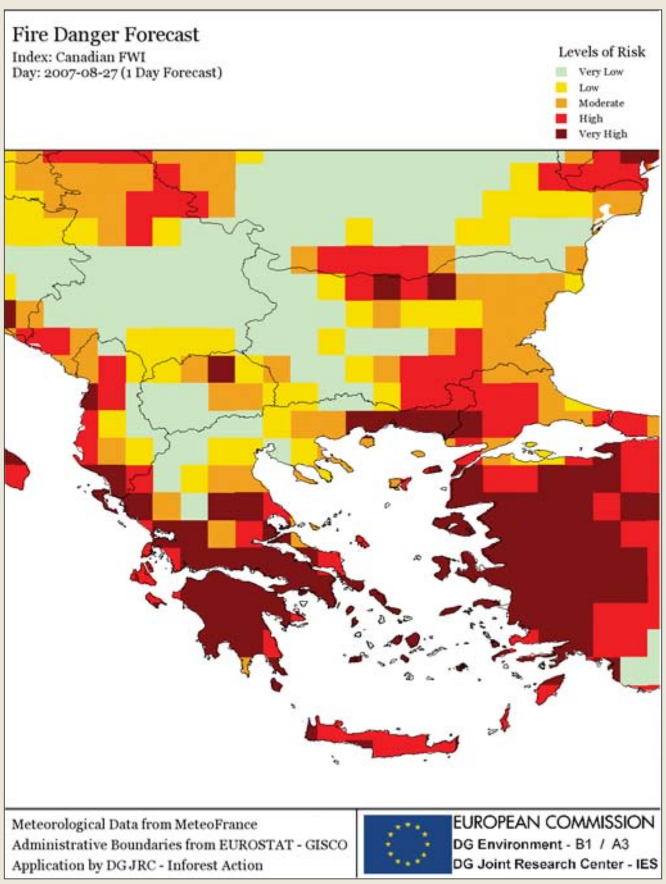
A major challenge for GEOSS is to tackle interoperability barriers specific to Earth observations: arranging for open and rapid data sharing; combing observations from different sources; turning data into information through models and other analysis tools; arranging for rapid acquisition of observations as events unfold, and so on. GEOSS Architecture principles, the GEOSS Clearinghouse and the adoption of international standards can all enhance interoperability.

Interoperability enabled by the GEOSS Architecture

Systems architects, like architects in other fields, are concerned with designing ways to fit components together to attain a larger objective. Just as a buildings architect may design a city with diverse components such as housing, factories and offices, the architects of GEOSS must accommodate diverse components.

GEOSS component systems encompass many scientific disciplines. The components range from primary data collection systems to systems for the creation or distribution of information products. The component systems span scales from national to global, and employ observing techniques from in situ to remote sensing. Most significant from an architect's perspective is that GEOSS component systems do not have common management.

European forest fire information system



A standardized map showing the critical area of a wildland fire.
Maps like these enable tactical planning for warning, evacuation and fire management

The wide diversity and essential independence of GEOSS component systems calls for a particular style of systems architecture: a style that emphasizes interoperability. Systems are interoperable when their differences are not a barrier to accomplishing a task that spans those systems. In the wildland fire scenario, real-time fire warnings must be interoperable with routine monitoring and background maps, and alerting systems must be interoperable across a range of communications media.

Interoperability among diverse systems is base on separate systems interoperating through standard interfaces and other interoperability arrangements. Support for standardized arrangements is the basis for interoperability among credit card systems, for example.

At the system of systems level in GEOSS, interoperability allows each system to operate within its own mandate, while also contributing synergistically to serve global goals. At the inter-system scale, interoperability allows systems to interoperate even though they are developed and operated independently. At the scale of a single system, interoperability means that a system is constructed from modular components. Such a modular system is more robust, more easily changed, and better able to use off-the-shelf, less expensive components.

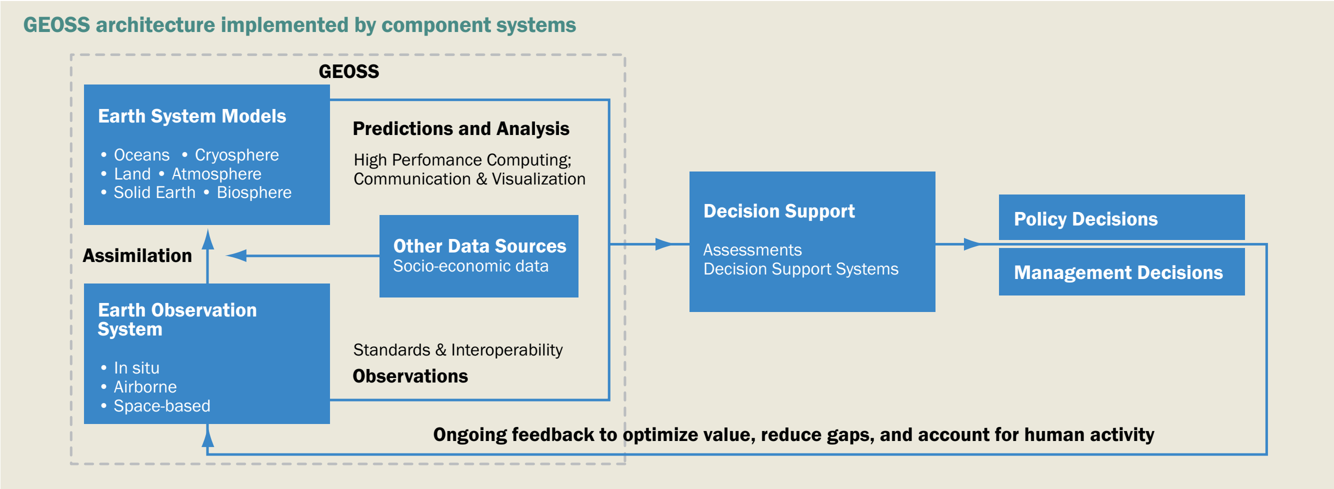
Given the expansive objectives of GEOSS, it is necessary that the GEOSS Architecture be embraced broadly. This means that the GEOSS Architecture must be mainstream and minimally prescriptive. Ideally, it should specify just those 'few things that must be the same so that everything else can be different'.[1] The focus of GEOSS is on how systems work together, and GEOSS will not constrain how any component system operates within itself.

Implementing a service oriented architecture

The GEOSS Plan asserts that component systems registered to GEOSS must share observations and products with GEOSS as a whole. To enable resource sharing, the GEOSS Architecture uses a style of systems interoperability known as service oriented architecture (SOA).

A 'service' is the basic unit of an SOA. The concept of a service is straightforward. By analogy to a restaurant, a service in operation is like a waiter handling a dinner order from a customer. Just as a customer is not expected to give step-by-step instructions to the kitchen, a service allows clients to precisely specify their requests, but it does not allow them to specify the exact procedure for satisfying those requests. This is very important feature for broad interoperability. Clients have no more control than necessary, and need not be concerned with the details of execution.

The GEOSS Architecture is most evident at the points of interoperability among the various systems



Source: Eliot Christian

contributed as GEOSS Components. "Interfaces" are the primary touch points between component systems--a way to plug one system into other systems. GEOSS interoperability emphasizes interfaces, defining precisely how system components can interface with each other. This minimizes impact on component systems other than where each system interfaces to the shared GEOSS architecture.

In the wildland fire scenario, there are various interfaces among the different systems in use. Many of these interfaces are implemented as services in the GEOSS Architecture sense. For instance, background maps of terrain, vegetation, roads, etc. are typically available through the standardized service for map display. These maps can be overlain with real-time fire warnings from a standard Internet news feed service. Finally, warnings for any hazard can be communicated across all available media using the standard format for alerts.

Standards and other interoperability arrangements

Overall, GEOSS is made up of contributed systems operating within their own mandates. GEOSS adds value to these component systems to the extent that they leverage each other's resources through standard interfaces and other interoperability arrangements. That synergy among diverse and independent systems is how GEOSS makes Earth observation data and information more accessible, comparable, and understandable.

The GEOSS Plan states: "The success of GEOSS will depend on data and information providers accepting and implementing a set of interoperability arrangements, including technical specifications for collecting, processing, storing and disseminating shared data, metadata and products." Any newly contributed GEOSS component must implement GEOSS interoperability arrangements as registered at the time when it is contributed.

Potentailly, thousands of existing standards could be relevant to one or another aspect of GEOSS, so how does GEOSS help the designers of contributed systems to choose between available standards and arrangements, in order to maximize interoperability with other GEOSS components? A few interoperability standards are referenced in the GEOSS Plan itself, but the GEOSS Plan sets only the most basic of requirements: "GEOSS interoperability will be based on non-proprietary standards, with preference to formal international standards." A consensus process is needed to consider additional standards and interoperability arrangements.

To support consensus seeking in matters of GEOSS interoperability, the GEO Architecture and Data Committee will call upon its Standards and Interoperability Forum, which was set up to address situations where GEOSS components cannot interoperate using one of the registered standards or other arrangements. Drawing on expert advice, the objective of the forum is to exploit existing standards to the maximum extent possible. The forum is not itself a standards body, but its participants will forward suggestions to standards organizations from time to time.

Standardizing services, syntax and semantics

As mentioned above, there are a few interoperability standards given in the GEOSS Plan itself. Because the GEOSS Architecture is an instance of an SOA, the GEOSS Plan addresses how service interfaces are defined. If a service interface is like a power connector, a service interface definition is like the specification for making plugs and outlets.

Software engineers have several ways to define a service interface at present. Because these languages are not equivalent, GEOSS has not specified a standard for service interface definitions. The GEOSS Plan states: "Systems interoperating in GEOSS should use any one of four open standard ways to describe service interfaces." In the wildland fire example, the standard for displaying maps is defined using one of these interface languages.

Today, building adaptors to achieve interoperability between systems can be frustrating. Even though most systems have network service interfaces, often such services are poorly documented. It is crucially important to have service definitions; it is less important that all service definitions are expressed the same way. Still, it is inconvenient that software designers must sometimes translate between service definitions. When the field of software design converges on a single standard, GEOSS service interoperability should be updated accordingly.

Search service

An example of a search service message, using the international standard adopted by GEOSS.

http://www.search.gov/gsdi/sru2kml.php?operation=searchRetrieve&version=1.1&maximumRecords=100&recordSchema=XML&query=(geo.bounds within/partial/nwse "43.8 –101.48 31.8 –77.8") and(geo.keywords any "biologic ecologic")

terms, etc

latitude, longitude boundaries

Source: Eliot Christian

Components of GEOSS are expected to interoperate primarily over network communication services by passing structured messages. The GEOSS Plan speaks about defining both the structure of messages (syntax) and the meaning of data elements within the message (semantics). With regard to syntax, the GEOSS Plan states: "Systems interoperating in GEOSS agree to avoid non-standard data syntaxes in favour of well-known and precisely defined syntaxes for data traversing system interfaces." On semantics, the GEOSS Plan states: "It is also important to register the semantics of shared data elements so that any system designer can determine in a precise way the exact meaning of data occurring at service interfaces between components."

In the wildland fire example, the standard for alert messages provides an example of using standards for syntax and semantics. Messages compliant with the alert standard are defined using both of the most common international standard data syntaxes. Also, the exact meanings of elements in those alert messages are defined using the international standard for data semantics.

Another key standard referenced in the GEOSS Plan concerns metadata. Metadata refers to descriptive information about the data itself, which is essential for many aspects of data processing. For instance, the GEOSS Plan calls out the standard for the syntax and semantics of geospatial metadata. (The term 'geospatial' includes anything referenced to a place on the Earth.) Just as a bibliographic catalogue entry specifies title, author, subject and publication date, this standard specifies important characteristics of geospatial data. Searchers use a few of these metadata elements to discover data that may be of interest. Other metadata elements are useful to evaluate what the data is about, and how it can be applied effectively.

The standard service interface for network search adopted by GEOSS is that used by libraries worldwide for searching online catalogues. Consequently, GEOSS searching spans all manner of resources, including geospatial metadata and alert messages, books, scientific articles, museum collections, archives, and virtually any other information.

The standard search service defines how to specify searches precisely. This includes latitude and longitude boundaries and scientific terms, as well as bibliographic citations. The standard can be used simply with Internet search engines, yet it has the expressive power for complex data searches such as chemical formulas and the pattern matching needed for images.

Bringing it all together with GEOSS Clearinghouse

GEOSS Clearinghouse acts as a cross-cutting catalogue among registered resources, including services and standards as well as data and information. GEOSS Clearinghouse provides registry services with a description of each of the formally contributed components of GEOSS; metadata about the various data and information holdings in each of the contributed components; technical specifications for using the services exposed by the contributed components, and descriptions of key interoperability standards in use across the contributed components of GEOSS.

The GEOSS Plan states: "GEO Members and Participating Organizations and their contributions will be catalogued in a publicly accessible, network-distributed clearinghouse maintained collectively under GEOSS. The catalogue will itself be subject to GEOSS interoperability specifications, including the standard search service and geospatial services."

Service interfaces to GEOSS Clearinghouse help users discover, evaluate and use data and information resource across all GEOSS components. For instance, the Global Spatial Data Infrastructure (GSDI) is a GEO Participating Organization and a partnership among 60 nations and organizations in its own right. Dedicated to sharing geospatial data, its GSDI Registry provides interoperable access to the holdings compiled through over 400 catalogue servers. The GSDI Registry is a contributed GEOSS Component and already complies with the standard search service interface and geospatial services given in the GEOSS Plan. This means that users of GEOSS Clearinghouse can already discover hundreds of thousands of geospatial data items across the interoperable catalogues registered by GSDI.

Of course, searchers for Earth observations data and services need to find more than just those resources and services specifically registered in GEOSS. Because GEOSS has adopted existing standards already in broad use, GEOSS Clearinghouse searchers can also discover, evaluate and use the broadest range of useful information — millions of items across many thousands of libraries worldwide, as well as Web pages and 'deep Web' databases.

GEOSS is meeting the challenge to realize a system of comprehensive, coordinated, and sustained Earth observation. Mindful of the wide diversity and independence of its component systems, the GEOSS Architecture embodies principles that enhance interoperability. With particular attention to international standards and common interoperability arrangements, the GEOSS Architecture and GEOSS Clearinghouse are enabling GEO Members and Participating Organizations to cooperate in realizing GEOSS. The resulting system of systems is simplifying access to all manner of relevant resources for all users worldwide.

GEONETCast: nerve system for the planet

Linda Moodie, US National Oceanic and Atmospheric Administration;
Michael Williams, EUMETSAT; Fan Jinlong, China Meteorological Administration

The well-being of the human species directly depends on the health and condition of the Earth. GEONETCast is a milestone in the dynamic and developing Global Earth Observation System of Systems (GEOSS), which endeavours to bring together the many disparate sources of environmental information, so that it can be directly applied in efforts to remedy today's pressing problems.

In recent years, scores of satellites and thousands of sensors on land, in the sea, and in the atmosphere have been deployed to gather information on every aspect of the environment. GEONETCast helps to improve the global availability of this information. The network transmits information on climate, crops, water quality, air pollution and more.

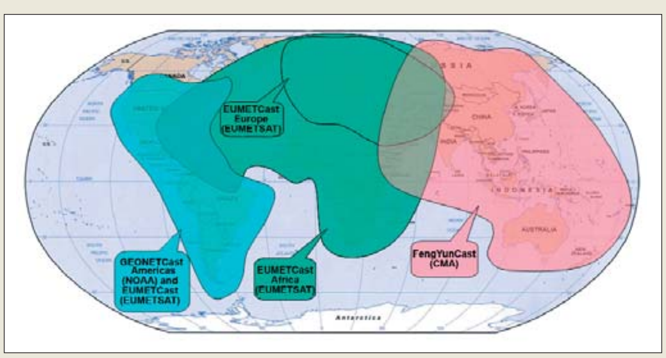
Conrad Lautenbacher, under secretary of commerce for Oceans and Atmosphere and US co-chair of the Group on Earth Observations (GEO) says: "The aim of GEONETCast is to put timely information into the hands of those who most need it, so they can make the right decisions about some of the most important problems facing our world today. It is a shared effort, and the entire world will benefit."

What is GEONETCast?

GEONETCast is a low cost, global, environmental information delivery system. Satellite and in situ data, products, and services from GEOSS are transmitted to users through communications satellites using a multicast, access-controlled, broadband capability.

The communications satellites allocated to each sector of the globe are provided by the GEONETCast partners, individually, or as a group.

Global GEONETCast Coverage



GEONETCast partners provide communication satellite coverage for dissemination of environmental information to sectors of the globe

Source: EUMETSAT and NOAA

The current coverage is based on contributions from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the United States (National Oceanic and Atmospheric Administration) and the China Meteorological Administration. Russia has also indicated an interest in providing coverage in Eur-Asia. In addition, the World Meteorological Organization is acting as a GEONETCast partner by contributing its experience in coordinating globally interoperable telecommunication systems, including satellite broadcast services, for weather-related information.

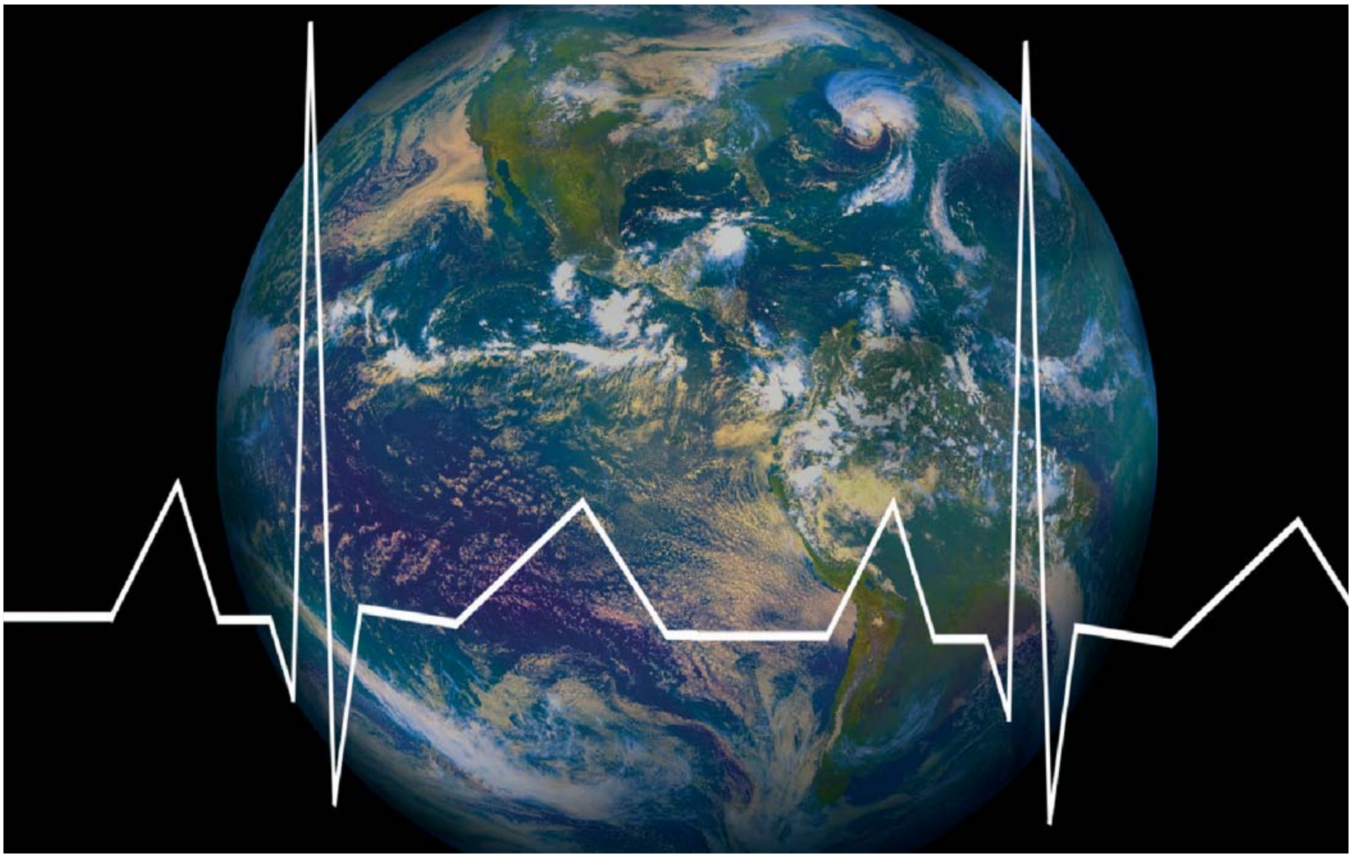
The day-to-day management of each global sector is the responsibility of each respective regional satellite broadcast provider. The regional components include one or more data collection, as well as management, and dissemination centres that receive, process, prioritize, and schedule the incoming data streams or products. In addition to the existing dissemination centres, GEONETCast also encompasses the exchange of data between the various centres.

Communication satellite providers broadcast using a standard protocol interface, such as is used for direct-to-home television transmission. Different data streams or products could be made available on separate channels. The user decides which data are to be received, managed, and saved locally. No Internet connection is required, and the receiving station is simply a standard personal computer, an off-the-shelf satellite television dish and a couple of computer cards. The total cost amounts to approximately euros1,500 or USD2,000. The result is expanded dissemination of urgently needed environmental data to users located anywhere on the planet, automatically 24 hours a day.

GEO's added punch

Data access and utilization are key issues to every participant in GEO. Without improved access, delivery, and sharing of Earth observation data and products, the intended applications for enhanced benefits to society will not materialize, particularly in developing countries.

At its second plenary in December 2005, GEO adopted the concept of GEONETCast and added it to its work plan. GEO recognized that GEONETCast could add value to existing operational and research efforts by expanding the delivery of data and information to users, particularly those in developing countries, at a reason-



GEONETCast transmits information to decision makers around the globe so that we may decide about our future

able cost to both providers and users. Furthermore, it was possible to improve access by broadcasting the information of complementary delivery systems, and thereby extending the reach of those systems.

GEONETCast has significant potential to enhance access to a wide range of information to users who may not previously have had access to such resources. GEONETCast is important from a diversity of data perspective, as it will deliver information on all nine societal benefit areas of GEO. It is equally important from a technical disparities perspective, since GEONETCast will be able to reach developing country users with limited or no access to high speed Internet. The GEO capacity building strategy identifies GEONETCast as a significant technology to enable sustainable infrastructure.

GEONETCast's impact

"It is all about public health, quality of life, knowing what the state of the environment is, knowing what the state of the land surface is, what the state of the seas is. Being able to 'take the pulse of the planet'" says Michael Williams, control centre head at EUMETSAT.

GEOSS systems track hurricanes from their earliest formation, display temperature trends in the oceans and scan entire continents for vegetation density. They predict where livestock will go hungry, which areas will be hit with erosion, and which regions will suffer an outbreak of disease. GEONETCast's import and impact is that it delivers this information to policy-makers in near real-time to help them make informed decisions.

Decision makers can focus on specifics by operating on localized scale: "One thinks of things like malaria and the pools of standing water and the moist conditions which are conducive to the breeding of mosquitoes," says Terry Newby, program manager at the Agricultural Research Council, Republic of South Africa.

GEONETCast also allows decision makers to operate on a larger scale. "We will now be able to get a global picture of data sets, which can really be useful in how we manage our biological diversity. It will begin, in my view, to probably resolve some of the big debates that we have at the global level," says Philemon Mjwara, director-general of the Department of Science and Technology, Republic of South Africa.

The pulse of the planet

Every body needs a nerve system to sense its condition and to communicate messages to its decision-making centre so it can make adjustments, take remedial measures and plan for survival. The Earth itself is no exception to this necessity. Fortunately, it now has GEOSS with its many component sensor and processing systems. The Earth now also has GEONETCast to transmit that information to decision makers around the globe.

GEONETCast is timely and in time to help us decide about our future:

- GEONETCast provides information essential to protecting lives and more effectively managing a world of resources
- GEONETCast helps to take the pulse of the planet
- GEONETCast allows for faster decision-making and policy responses.

The GEOPortal — gateway to GEOSS

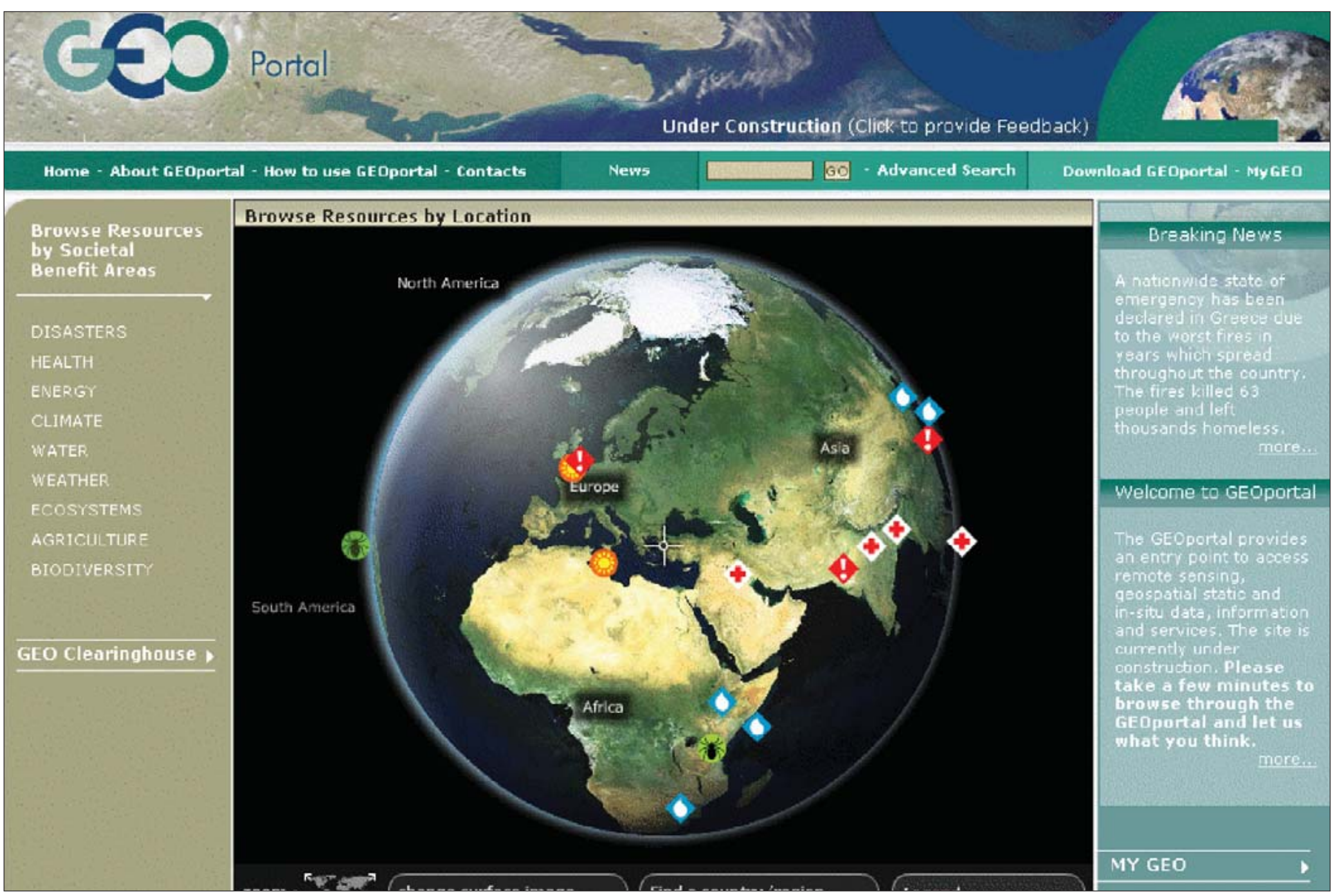
Hermann Ludwig Moeller and Jolyon Martin, European Space Agency

In the era of the Internet and over the past decade, many organizations have created their presence on the World Wide Web. Typically, this is achieved through the establishment of portals – information systems publicly accessible from the Internet and providing information related to the organization it is representing. In many cases portals are used to publicize the services of an organization and to establish an entry point to reach and make use of services. Such Portals are often of corporate nature, and they are managed and controlled centrally by the organization they represent. However, there are portals that may represent a group of organizations that have decided to appear as a Community. These portals are also referred to as 'community portals.' Typically, the way of presenting the community is agreed between that community's members. Such community portals are often operated by one member of the community on behalf of its members.

Portals in Earth observation

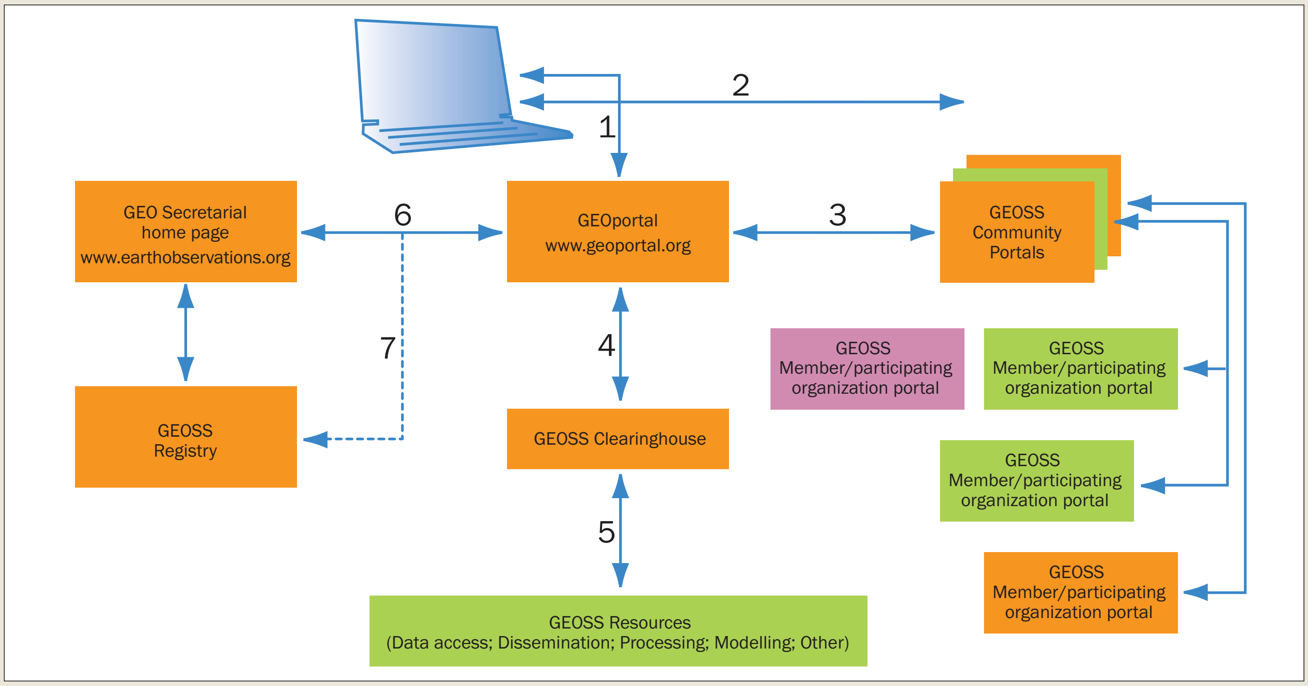
Following the evolution of the Internet, and within the Earth observation community, individual portals and community portals advertise and provide access to resources. Today, in many instances, such portals can be considered a commodity. In some cases, several members and organizations have established a community portal, for instance for their group of users or for the geographical region they are serving. An example of such a community portal is the eoPortal (www.eoportal.org) originally developed by the Joint Research Centre of the European Commission under the name Information for Earth Observation (INFEO); this has been further developed and is operated today by the European Space Agency (ESA).

Source: www.geoportal.org



A sample GEOPortal home page with global geographical access and access according to GEO Societal Benefit Area

GEOPortal and its interfaces to the GEOSS resources



The interface between the GEOPortal and the community and other portals of the GEOSS can utilize different mechanisms, e.g. Web services

Source: ESA Earth Observation Ground Segment Department

These portals existed prior the emergence of the Global Earth Observation System of Systems (GEOSS), and will continue to exist. However, they are typically established by each member and organization according to their own guidelines and rules. Or in the case of community portals, they are defined within the consensus reached within a community of users.

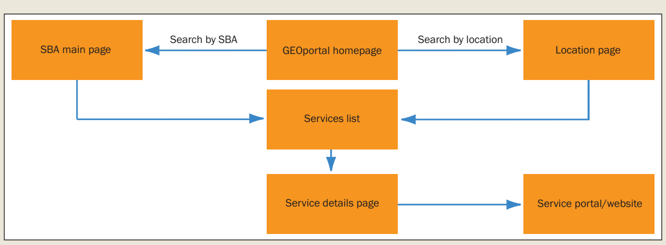
The GEOPortal and GEOSS

GEOSS is a system of systems contributed by GEO members and participating organizations. Each of its components is operated within its own mandate. By its very nature, GEOSS is heterogeneous. This applies equally to the portal components of the GEOSS. However, starting from the concept of community portals, the GEOPortal goes one step further. It extends the community concept to a global community and across all users of the GEOSS – no matter where the user is located or the nature of usage within the GEOSS areas of application, GEOPortal provides an entry point to the resources. It achieves this goal based on two key characteristics:

- A high-level structure of the information according to the nine GEOSS societal benefit areas (SBAs) – disaster, health, energy, climate, water, weather, ecosystem, agriculture, biodiversity
- A global coverage linking all resources contributed by the GEO members and participating organizations.

In addition, the GEOPortal provides a consistent look and feel agreed at GEO level. With this, the GEOPortal establishes itself as the gateway to global Earth observation data, information and Earth observation user services.

Navigation schema for discovery of service information



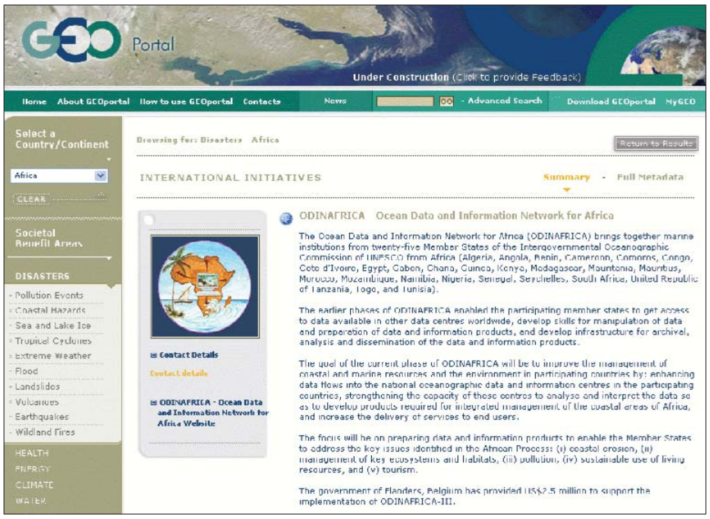
The GEOPortal supports the browsing through a comprehensive directory of earth observation information and resources and international initiatives relevant to GEO members and participating organizations

Source: ESA Earth Observation Ground Segment Department

The GEOPortal and the GEOSS architecture

The GEOPortal is part of the GEOSS architecture, with interfaces towards the different resources of GEOSS. It complements the already existing community portals and other portals operated by GEO members and participating organizations and as such, unlike most other GEOSS components, it does not belong to any single member or organization. The already existing access of individual users and user communities to the specific portals and related resources continues to exist, and may be used if the user is only interested in specific resources that are already known (see interface 2 in the diagram, GEOPortal and its interfaces to the GEOSS resources, on the previ-

Source: www.geoportal.org



Information on international initiatives that the GEOPortal can provide

ous page). For example, a regular user of the International Charter 'Space and Major Disasters' may continue to access the related portal directly, without going through the GEOPortal.[1] Another user may however opt to access the GEOPortal (interface 1) and select the SBA 'Disasters' to be pointed to all portals within GEOSS supporting disasters (interface 3). As a matter of fact, the GEOPortal allows a user to find and be linked to other portals registered within a given SBA.

The interface between the GEOPortal and the community and other portals of the GEOSS can make use of different mechanisms. It may use Web services, if available from the community and other portals to access metadata and data, or it may harvest metadata from the community portals, i.e. regularly collect data and import them locally within the GEOPortal. Or the GEOPortal may simply provide a link to the community and other portals. In addition, the GEOPortal may receive and display alert messages originating from Portals within GEOSS. If these alert messages contain a geographical reference they may be displayed on the GEOPortal. This allows immediate visibility and localization of events such as disasters.

It is understood that each of the community and other portals may be directly linked to a number of resource made available by the GEOSS member or participating organization. Such resources may comprise the direct access to data for download, dissemination services for data such as the service provided through GEONETCast, processing services and modeling services. With the help of the GEOPortal a user may discover the Community Portal most suited to their needs.

Another powerful way of accessing the individual resources and services of GEOSS is through a query interface between the GEOPortal and the GEOSS clearinghouse (interface 4). For example, the clearinghouse provides the GEOPortal with the capability to initiate a distributed catalogue search for specific data sets. The actual query into the GEOSS resources is hidden to the GEOPortal (interface 5), but the results will be displayed to the user of the GEOPortal, who may select a particular data set and require its display. This is a service provided by the GEOSS clearinghouse to the GEOPortal. Subsequent display of retrieved data sets may be supported by map display in a number of ways, including display projected on GoogleEarth.

In addition to the interfaces discussed above, the GEOPortal also provides a link to the home page of the GEO Secretariat (interface 6). This provides information about GEO and other organizational information. And the GEOSS registry may be linked to the GEOPortal to update its information on resources made available in GEOSS (interface 7).

All interfaces between the GEOPortal and any portal of the GEOSS shall be as open as possible, using encodings and schemas that confirm to OpenGIS specifications where possible.

The GEOPortal – user interface and navigation

As with all portals, the GEOPortal provides various ways to discover and access information. For example, considering GEONETCast, quick links from the GEOPortal front page using appealing graphics take the user directly to a summary page for the GEONETCast service. Browsing resources associated to the SBAs will also lead to an SBA main page, a page listing SBA relevant services and a link to a particular service like GEONETCast. Here the user is provided with to sufficient summary information to evaluate the resource before needing to leave the portal to access the referenced website.

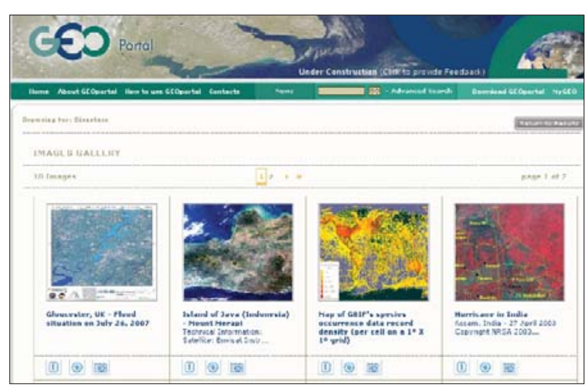
Whereas the definitive list of data sets and resources should be available via queries of the GEOSS clearinghouse, many data sets and services will merit to be showcased via the GEOPortal – illustrating the benefits of earth observation to decision makers and the general public. As an additional feature, the GEOPortal supports the display of alerts and remote feeds to provide up-to-date information on major events of relevance to GEO.

GEOPortal operations

The overall operations of the GEOPortal are under the authority of the GEO Secretariat, but the day-to-day operations are expected to be provided by an organization on behalf of the Secretariat. Typically, this can be achieved by operating the GEOPortal within the operations set-up of other existing portal services of an Earth observation user information service. The quality of service expected from the GEOPortal will be comparable to that of existing operational services of such an operator.

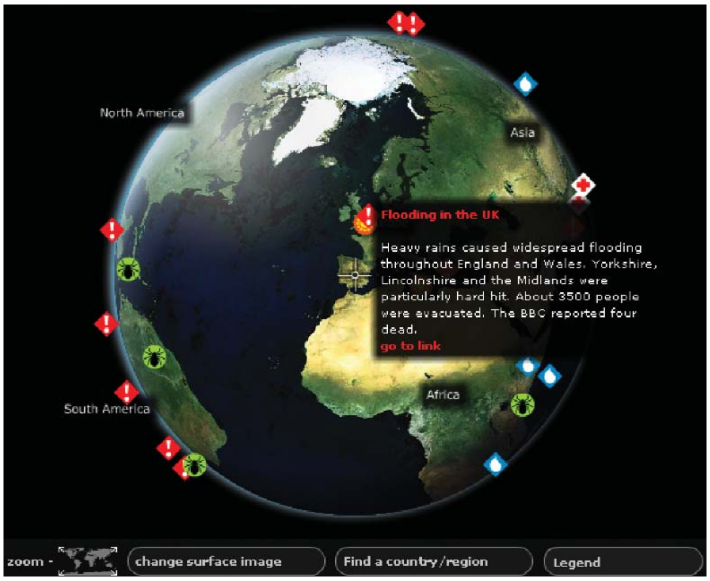
At present, GEOPortal operations are part of the Initial Operating Capability (IOC) of the GEOSS. However, already these initial operations are not limited to the operations of the technical infrastructure of the under-

Source: www.geoportal.org



A gallery of showcase images is made available in support of the GEO outreach

Source: www.geoportal.org



An example feed illustrating activation of the international charter 'Space and Major Disasters' following flooding in the UK

lying GEOPortal system, but include the maintenance of information contained locally within the GEOPortal and ensure the consistency of the links and interfaces to GEOSS. Local information may include up to date sample data sets representative of the different SBAs. Optionally, the GEOPortal may consider whether to provide value-adding services in that its operators proactively identify and highlight data and information, for example providing the latest data on the propagation of avian flu under the 'Health' SBA. Specific agreements with interested community portals may provide a framework for such features.

With the number of components of GEOSS growing, operations also need to ensure that any resources newly available to GEOSS can be discovered by the GEOPortal. And with a growing user base, one option would be to provide GEOPortal users with the option to pre-configure the GEOPortal tailored for their access needs, making it their MyGEOPortal (e.g. a portal automatically linking to a particular SBA or world region).

In perspective, the GEOPortal may also be used for creating community portals or individual portals if required by a GEO member or participating organization. The GEOPortal software is based on a number of open source modules which could be made available and be configured to create, for example, a portal for the 'Energy' SBA.

The GEOPortal may provide additional information in support to capacity building, either through selected information stored locally or through access to a capacity building portal containing a comprehensive set of related material such as training documentation.

The need for such features will be assessed taking into account first operational experience of the GEOPortal and user feedback. The level of use of various elements of the portal will be assessed on a regular basis to determine what kind of information is in greatest demand by a given user community. This will ensure that the evolution of the GEOPortal is targeted on areas of greatest need and use.

Status and next steps

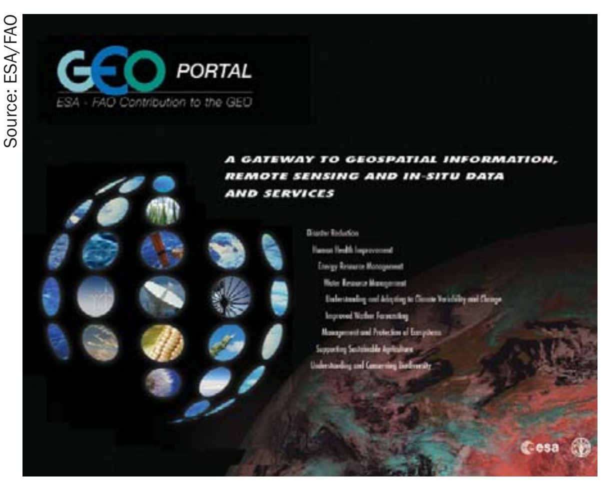
At the time of writing, a number of GEO members and participating organizations have established an implementation pilot and made available community portals accessible from the GEOPortal. These community portals are serving particular regions and/or are specific to a GEOSS SBA and related user scenarios. Initial contributions comprise: Argon/IM; the German Federal Agency for Cartography and Geodesy (BKG); European Community Joint Research Centre (EC/JRC); US Federal Geographic Data Committee Secretariat (FGDC); Global Biodiversity Information Facility (GBIF) in collaboration with GeoConnections, Global Earth Observation and Monitoring (GEOmon); George Mason University (GMU); Ecole des Mines de Paris; National Aeronautics and Space Administration (NASA); San Diego Supercomputer Center (SDSC), and the Regional Visualization and Monitoring System (SERVIR).

In addition, three contributions have been provided for establishing, hosting and operating a GEOPortal interconnecting the community portals and thus serving as an entry point into the GEOSS. Contributions comprise Compusult, Environmental Systems Research Institute (ESRI) and the European Space Agency (ESA) in cooperation with the Food and Agriculture Organization (FAO) of the United Nations.

The ESA/FAO contribution to the GEOPortal has been designed to be part of the Initial Operating Capability of GEOSS, including an initial funding for operations for the duration of the current GEO 2007-2009 workplan. Its quality of service is equal to that of ESA's Earth observation user services, and includes the maintenance of information content and software.

A clear concept for the GEOPortal and its place within the GEOSS architecture have been established. Accordingly, the GEOPortal system and its user interface have been implemented and a number of contributions to the GEOPortal, and community portals have been interconnected and are today part of an initial operating capability of GEOSS. Operations for an initial period until 2009 have been secured, and the GEOPortal is now open to serve the GEOSS and to further evolve, taking into account the requirements of its users.

Source: ESA/FAO



The GEOPortal is a gateway to geospatial information, remote sensing and in situ data and services

CBERS — the Chinese-Brazilian Earth Resources Satellite programme

José Carlos Neves Epiphânio, João Vianei Soares, Hilcéa Ferreira and Gilberto Câmara Neto, Instituto Nacional de Pesquisas Espaciais, Brazil

The world has been facing new challenges on its sustainability. Many fields of research including biology, meteorology, environmental and land use must provide their contribution so humankind can envisage a safer future to the planet. In order to take the right actions and work towards better practices on this changing planet, we need a deep understanding of nature, modeling its processes and dealing with each variable involved.

Satellites are fundamental tools to help understanding many of these variables and processes. Since the launch of the first civilian remote sensing satellite – Landsat-1-, back in 1972, many new satellites with different capacities have been launched, especially in the past 15 years. The benefits brought by satellites for studying and surveying the planet are enormous; and everyone agrees that it would be impossible to reach the understanding of the planet we have today without the data produced by them.

In general, each satellite belongs to only one country. However, in 1988, Brazil and China signed an agreement to build, launch and run jointly a remote sensing satellite. The CBERS Program - the acronym for China-Brazil Earth Resources Satellite - was developed under this agreement. The main objective for both countries was to develop the capacity to build and run a civilian satellite series that could provide remote sensing data to survey their huge territories autonomously. The agreement was a cost sharing arrangement for building and launching the satellites, and their operation performed by Brazilian and Chinese control centers, with a schedule to the handover of control to one another.


Photo: INPE Press

CBERS satellite being integrated and tested at INPE's assembly facility

Satellites

The first phase of the Brazilian-Chinese agreement comprised building two remote sensing satellites with the same characteristics. The first satellite — CBERS-1 — was launched from the Taiyuan launching base, in China, in October 1999. It worked for almost four years, until August 2003. CBERS-2 was integrated and tested in Brazil, and was successfully launched from the same launching base in October 2003. The satellite is still working (August 2007), beyond its expected lifetime. Both satellites were put into orbit aboard the Long March 4 rocket.

Two new agreements were signed to build CBERS-2B, and CBERS-3 and 4. CBERS-2B payload is similar to CBERS-1 and 2 carries a new high-resolution Camera. CBERS-2B was successfully launched in September, 20, 2007. CBERS-3 and 4 make up a new family, with new sensors and capabilities. They are scheduled for launching in 2009 and 2011, respectively.

The CBERS satellites have near-polar, sun-synchronous orbit at 778 km altitude, and cross the equator around 10:30 a.m., descending node. CBERS cycle is phased in 26 days, with around 14 orbits a day. The duty cycle is close to 20 minutes each orbit making for a global monitoring capacity. Up to now there are four ground receiving stations for CBERS: three in China and one in Brazil (32 years-old Cuiabá Ground Station). There are arrangements in progress to set up direct receiving capacities in other ground stations, especially to supply Caribbean and African countries needs. Besides the direct downlink, CBERS satellites are able to record data onboard from everywhere and downlink these images to the Chinese or Brazilian ground receiving stations. The onboard recording abilities will be improved for CBERS-2B and CBERS-3 and 4 to increase its global capacity.

Payloads

Besides imaging sensors the payload for CBERS carry a transponder that is a Data Collecting System, DCS, collecting data from ground-based platforms (such as automatic weather and river gauging stations, for example). The DCS is helpful to collect data in remote regions such as the rain forest, mountains and lakes.

The imaging payloads are optical cameras, working from the blue to the thermal infrared spectral regions. The cameras complement each other and provide a useful range of spatial, spectral and temporal resolutions. The payload for CBERS-1 and 2 are similar; for CBERS-2B there are two important changes in one of the cameras and in the recording technology. As for CBERS-3 and 4 all the cameras will change, and there will be new capabilities.

The main camera of CBERS-1, 2 and 2B is the CCD (High Resolution Imaging Camera), with a swath of 113 km, 20 m GIFOV (Ground Instantaneous Field of View), 8 bits quantization, and ±32o cross-track pointing ability. The nominal revisit time is 26 days; however, with the off-nadir pointing ability, the revisit interval can be less than five days. The spectral coverage of this camera is from blue to near-infrared in four bands, plus a panchromatic band.

The second camera is the WFI (Wide Field Imager) — a CCD device with a swath of 890 km, 260 m GIFOV, 8 bits quantization, and two spectral bands: red and near-infrared. With this large swath, its revisit is close to five days. This advantage makes it suitable for early warning and disaster assessment.

The third camera is the IRMSS (Infrared Multispectral Scanner). While the first two cameras are pushbroom-based technology, this is a whiskbroom imager. It has four channels: two in the shortwave infrared band and a panchromatic (visible and near-infrared) band with 80 m GFOV, and a thermal band with 160 m GIFOV. The swath is 120 km, and the revisit time is 26 days.

For CBERS-2B the IRMSS is replaced by a High Resolution Panchromatic Camera (HRC), with 2.7 m GIFOV and a 27 km swath. Since the satellite imaging track pattern is designed for CCD, a special mode was designed for CBERS-2B to house the HRC small swath while getting the best benefits from this HRC camera. Another important change for CBERS-2B is the improvement of its onboard recording capacity, based on solid-state technology, more reliable and with higher recording capability.

CBERS-3 and 4 will become the new generation of the CBERS family in the next five years. These satellites, while keeping the same orbital characteristics, were designed to house four imaging payloads. The CCD will be upheld as the main camera, and its characteristics will not change much from the previous satellites. A second camera is similar to the CCD in spectral coverage, but with 10 m GIFOV, and a panchromatic band performing in 5 m GIFOV. This camera has steering mirror ability, and a swath of 60 km swath. The IRMSS will be back, but with the spatial resolution improved to 40 m for the SWIR and panchromatic bands, and to 80 m for the thermal band. Finally, the payload will also incorporate an Advanced Large Field Imager (AWFI) with the same spectral bands as the CCD camera, but its GIFOV will be improved to 73 m (from 260 m on CBERS 1 and 2), for a swath of 866 km. This new generation of CBERS 3 and 4 will significantly improve the imaging capacities and the quality of images from the previous ones.

Operation and data policy

The operation of CBERS satellites is shared between Brazil and China according to a handover schedule. All special requests and agreements for direct reception in third countries are managed and negotiated by both sides. The data distribution policy adopted for CBERS Program has followed a pattern of enlarging the distribution while lessening the costs. In Brazil and China, the full resolution data are delivered free through the Internet. Third parties interested in receiving direct downlink CBERS data are encouraged to assume the same free data policy.

The application of this data policy in Brazil and in China resulted in an enormous increment of new users and new applications. In Brazil, for example, INPE (National Institute for Space Research) — the institution that collects, processes and distributes CBERS data — delivers regularly more than 300 scenes a week since the application of this data policy. Up to now, more than 350,000 CBERS-2 scenes have been delivered around the country. Seeking to improve the remote sensing in South America, and as part of this free distribution policy, Brazil has adopted the same policy for its neighboring countries. Because of this Brazilian policy, South America countries are regularly using CBERS-2 data for their remote sensing development and surveying policies.

In Brazil, governmental, private, NGO, educational organizations related to agriculture, environmental surveying, forest, law enforcement, are users of CBERS data. The free data policy has changed the way people work with remote sensing. New and better-trained professionals have been introduced to the remote sensing services market, as they are exposed to the satellite products in a routine basis in their schools and offices. Government organizations and NGOs can now use up-to-date CBERS data in their surveying and mapping projects and tasks. We believe part of the recent development of the remote sensing field in Brazil can be credited to the CBERS-2 data and to this data policy. In the last Brazilian Remote Sensing Symposium (April 2007, http://www.dsr.inpe.br/sbsr2007/), more than 100 papers were related to CBERS applications and developments.

The CBERS Program is a series of satellites that will be present in the remote sensing arena at least for the next 10 years. Discussions on CBERS-5 and 6 have started inside the Joint Program Committee with delegates from China and Brazil. Thus, this Program has an important role to play in the global watching initiatives from now on. It has proved to be indispensable in Brazil and in South America countries, and in China. And we expect CBERS to play an important role to the world representing a key initiative from Brazil and China for GEOSS, to the benefit of humankind.

China and Brazil are developing with South Africa, Spain and Italy a framework for direct downlink of CBERS-2B imagery. The satellite owners grant a free access to the satellite and the ground stations owned by the participant countries distribute the images to all countries inside their footprints at no cost, using the EO portal and GEONETCast when required.

GEOSS: a platform for sharing information and expertise for sustainable management of natural resources

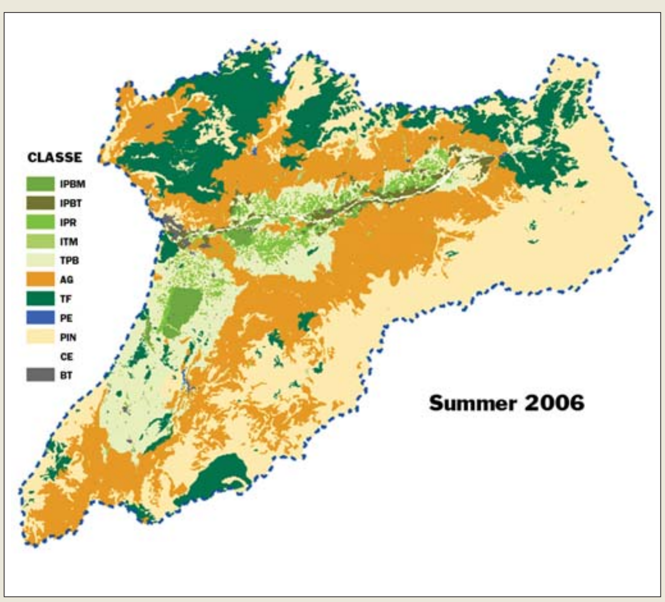
Driss Elhadani, Director, the Royal Centre for Remote Sensing

Population growth and subsequent socio-economic development create tremendous pressures on natural and environmental resources. On the other hand, decision makers are aware of a need to manage these resources in a sustainable and environmentally sensitive manner. Geoinformation, particularly Earth observation data, has demonstrated to be a powerful tool for addressing national sustainable development issues. Earth observation resources are used to produce comprehensive and operational information and therefore contribute to enhance decision-making processes.

Since it creation in 1989, the Royal Centre for Remote Sensing (CRTS) has prioritized three strategic actions. Firstly, to promote and develop the exploitation and the use of space technologies, notably remote sensing in development projects. Secondly, to ensure all users accessibility to Earth observation data and other geo-space information. Thirdly, to reinforce national capacity building and knowledge dissemination though an integrated training program, and to support to research and development activities.

Using these axes, a wide range of operational projects were developed to answer ministerial department needs in several fields. These applications include water resources management, forestry monitoring, city and urban growth, agriculture and drought and disaster management. This paper highlights some of the major and recent applications related to water resources and forest monitoring and management.

Water resources



Land use map for irrigated soils assessment/Agadir region, Morocco

Source: Royal Centre for Remote Sensing (2007)

Integrated system for water resources management

The use of remote sensing data in water related application has increased significantly over the last decade. This is mainly due to the fact that Earth observation images offer the unique opportunity to attain spatially distributed information over large, remote and inaccessible areas. The integrated management of water resources at national, as well as river basin scales, is a complex problem with regard to its multidisciplinary nature. It requires not only the relevant information, but also models and decision support systems fitting the needs of the water administrators.

The Souss-Massa region is one of the most important areas in Morocco for agriculture and tourist activities. The region contributes more than 50 per cent of Morocco's agricultural production and is also the second most economically productive region in the country. The development of agricultural activities is creating a huge demand on water resources, and the recurrent periods of drought require a proactive approach to manage the available resources.

CRTS, in cooperation with the water authority in the region (ABHSM), has developed a decision support system that provides value added information to the ABHSM for integrated water management. Cartography of land use changes, assessment of the development of soils under irrigation and mapping of geological lithology and structures were all used as input data sets for the hydrological models. New resources were also identified to supply remote villages with fresh water.

The developed system was largely based on the exploitation of Earth observation products such as SPOT, Landsat, RADARSAT and ERS, combined with modelling processes.

The analysis methodology was based on the identification of a series of indicators, including land use, moisture, fractures and lithography.

In addition the use of radar images was very helpful in understanding the interaction between water and soil. The combination of interpreted information collected from two images, resulted in a map of run off and infiltration zones. It also enabled a better understanding of the geomorphology and mechanisms of recharge. The result of this study was the identification of favourable sites for the establishment of boreholes with high yields.

Forestry

Morocco's forests play a major role in the environment and the economic well-being of the country. Defining these roles on a sustainable basis requires information, and there is strong evidence that the types and requirements for information are increasing. Earth observation images are technological tools that can assist practitioners and researchers in the mapping and monitoring of forest ecosystems at a variety of scales.

Most of the national forests are not adequately mapped. So maintaining accurate and up-to-date information is an ongoing challenge to understand the changes affecting forest areas, as well as determining factors of degradation. In order to monitor forest resources, to complete the national inventory and to up-date the existing maps at a low cost, the CRTS in cooperation with the Forest Department, conducts studies based on Earth observation images.

The availability of time series, covering three decades, was very helpful in establishing 'evolution maps', as well as in quantifying the spatial and temporal distribution of change in forest areas. A second study, which covered more than 75 per cent of the national territory, gave the Forest Department a complete picture of the National Forest Inventory. More than 200 maps were elaborated at different.

Forest fire assessment

Forest fires are a permanent problem in Morocco during the summer season. Annually, burned surface amounts to approximately 3,000 hectares. The project consists of the implementation of an operational system to monitor forests fires. This system comprises three components.

The first enables the daily identification of forest fire risk areas, through a global and dynamic cartography of sensitive and vulnerable zones. The approach is based on the combination of two indicators derived from NDVI and land surface temperature, namely: vegetation drought index and vegetation regression index. The second component is the following-up of fires by the detection and characterisation of hot spots. The developed algorithm is based on a threshold of thermal channels and reflectance channels from NOAA images. The third element of this system involves the evaluation of damage through the cartography of the burned areas. Both low (NOAA/AVHRR) and medium (SPOT) resolution images are used in this task.

Drought and desertification

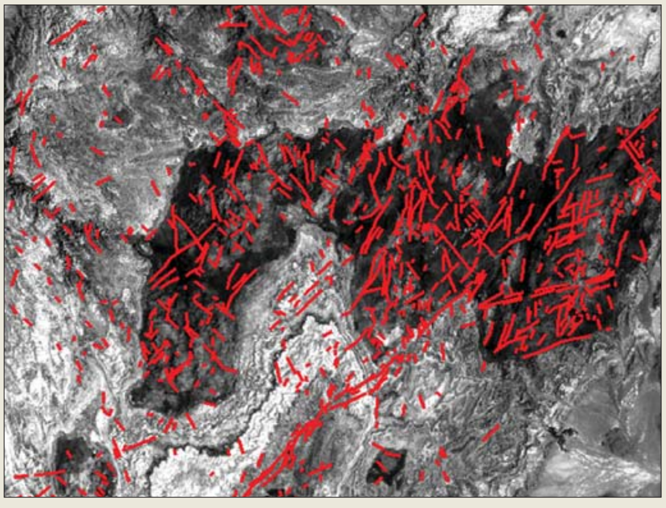
Drought occurs very frequently in the Mediterranean countries, with severe environmental, economic and social consequences. Policy makers need information and tools to improve drought preparedness and to mitigate impacts. Within the framework of cooperation between North-African countries (Morocco, Algeria and Tunisia), CRTS is conducting, in cooperation with departments of agriculture and forestry, a project called SMAS (System Maghrebin d'Alerte contre la Secheresse). Based on a combination of satellite data, meteorological measurements and in-situ observation, the proposed system aims to provide decision makers with sustainable information on the status of agriculture areas.

GEOSS to support sustainable resources management

The evaluation of the impact of the use of Earth observation data shows many direct and indirect benefits, including cost and time saving, which result from efficiency and effectiveness in planning and monitoring activities. In all these fields, the analysis of systems, such as hydrologic, forest and groundwater still requires information of a spatial and/or in-situ nature, as well as various methods, including modelling and geophysics. In this respect, GEOSS is considered by the user community as an opportunity to bring together several sources of information to offer a cooperative instrument to share knowledge end expertise.

In spite of these positive aspects, users still face significant hurdles, such as the availability of, and access to, space satellite data, as well as the gap between available data and end-user needs. GEOSS and its ten years implementation plan will bring, from our point of view as a developing country, a great step towards addressing such concerns. The most important of which is its impact on political awareness. Indeed, the participation of Morocco in the GEO summits at a ministerial level shows the political commitment of our country to contribute to this international challenge. Nevertheless, the full potential of GEOSS for economic and social development can be accomplished only with an enhanced level of international cooperation. One of the key elements for active participation in the GEOSS implementation by developing countries is their capacity to act as contributor and not only as beneficiary.

Ground water



Geological feature for potential ground water location/Ighrem village, Morocco

Source: Royal Centre for Remote Sensing (2007)

Capacity building networks for Earth observation and geo-ICT: a first step towards a virtual university

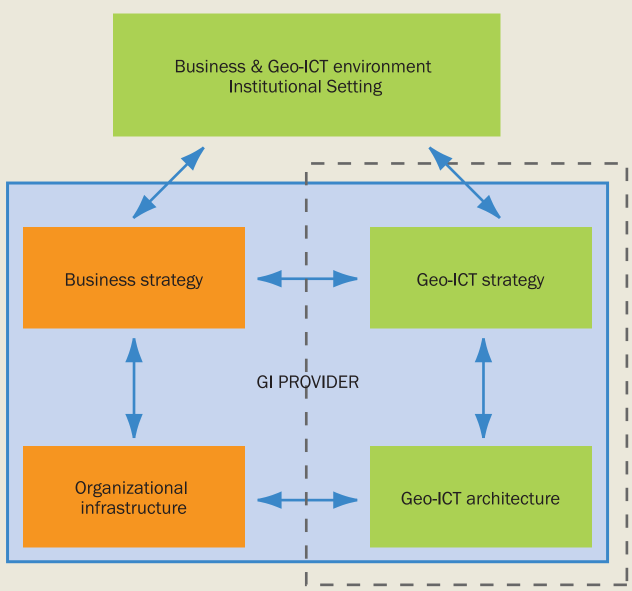
Martien Molenaar and Chris Mannaerts,
International Institute for Geo-Information Science and Earth Observation (ITC)

Earth observation and geo-information are essential for the monitoring of spatial processes that affect the sustainable development of our living environment. The management of these processes requires decision power at different administrative and political levels ranging from local to global scale.

A worldwide scientific and professional community develops and implements tools and methods to deal with these issues. They develop indicators at different resolution levels and their specifications based on profound knowledge of these processes and of the technology for earth observation and geo-information processing. Such a community should ideally be a worldwide one for several reasons. Three of the most important are:

- The awareness that these processes are of a supra-national and even a global scale implies that world wide efforts are required to deal with these scientific problems, and that all nations should contribute.
- The globalization of the economy implies the development of global delivery chains products and services.[1] Partners in these chains must have a common understanding of the specifications and conditions for product and service delivery. This should be developed through a global involvement in research, technology and service development.
- The fact that it is impossible for national economies to maintain sufficiently high investment levels over the full range of modern research sectors implies that national and regional priorities will be set for fields of interest. We will see an increasing regional or even (inter) continental spread of fields of expertise, first for research but consequently also for technology development and consequently for higher education.

Strategic alignment model, after (Henderson et al, 1992)



GI-providers and users must adjust their geo-ICT architectures continuously, which has technological, organizational and institutional consequences

Source: ITC

Problems faced by geo-information providers

Until twenty years ago production processes for geo-data, or maps, were quite stable and the development mapping technology and concepts allowed time horizons for investments to the order of 15 to 25 years. Presently the development of technology requires a time horizon for investments in hardware of three to five years and concepts for information products and services have to be adjusted every five to eight years. Consequently GI-providers and users must adjust their geo-ICT architectures continuously, which has technological, organizational and institutional consequences.[2]

The technology aspect concerns the development and application of concepts for spatial data modelling, for the information extraction from image data and for the processing, analysis, dissemination, presentation and use of geo-spatial data. The organizational and institutional aspects concern the development and implementation concepts for the structuring, organization, management and institutional arrangements of processes for geo-spatial data production and the provision, as well as the use of geo-information services.

Within the modern information society new business and geo-ICT environments are emerging which force GI-providers to develop new business strategies. These require scenario studies anticipating the opportunities of new technology and new geo-data infrastructures (GDIs). Hence, permanent capacity development of entire organizations is required so that 'lifelong learning' does not only apply to professionals, but also to their organizations.

Modern technology, the changing role of government and the globalization of the economy have a fundamental impact on the development of GDIs. Governments have a regulatory role with respect to information provision. They should facilitate the development of infrastructure through which geo-information is provided. But should they also be providers, or even producers? Clearly the development of GDIs is not only a responsibility of the public sector; GDIs will develop through public-private interactions. This implies that a strong private sector, and thus a private industry, is a prerequisite for sustainable GDIs.

Governments also have a direct interest in the use of geo-information, which is indispensable to the management of our living environment and resources. Governments have an important role here in the context of the international agendas and treaties for the sustainable development of our planet. Geo-information is a prerequisite for good governance at all aggregation levels, as well as at supra- or international levels. Because almost all human activities have a spatial footprint we could say that: 'good governance requires good geo-information'.

Three levels for capacity development

Purpose	Focus
Human Resources Development	Supply of technical and professional personnel
Organizational Strengthening	Strengthening the management capacity of organizations: embedding GITC (systems and processes) embedding strategic management principles
Institutional Strengthening	Strengthening the capacity to develop and negotiate appropriate mandates and modus operandi as well as appropriate legal and regulatory frameworks

Human resources development — aims at changing attitudes and behaviours, most frequently through training and education. It involves learning by doing, participation, ownership, and processes associated with increasing performance through changes in management, motivation, morale, and levels of accountability and responsibility.

Organizational strengthening — focuses on overall performance and functioning capabilities, such as developing mandates, tools, guidelines and information management systems for the ability of the organization to adapt to change. It aims to develop its constituent individuals and groups, as well as its relationship to the outside.

Institutional strengthening — concerned with the creation of 'enabling environments', ie the overall policy, economic, regulatory, and accountability frameworks within which institutions and individuals operate. Relationships and processes between institutions, both formal and informal, as well as their mandates, are important.

Source: ITC

Capacity development for the Earth observation and geo-ICT sector

All this implies that Capacity Development (CD) should have a high priority for organizations introducing new working methods and procedures, which will ultimately result in the structural adjustment of their geo-ICT architecture.

CD comprises human resources development, organizational strengthening and institutional strengthening as implied in the following two definitions. Capacity Development is to improve:

- The ability of people, organizations and society as a whole to manage their affairs successfully[3]
- The ability of individuals, institutions and societies to perform functions, solve problems, and set and achieve objectives in a sustainable manner[4]

The aim of CD is to strengthen organizations and institutions and through them civil society at large. For the international Earth observation and geo-ICT sector this means that not only technology oriented professionals are required but also staff that can formulate, design, manage and negotiate with other organizations and government in order to address organizational and institutional issues.[5] Therefore three levels for capacity development have been recognized.

CD programs should help the international Earth observation and geo-ICT sector to understand how technological, institutional and market developments lead to new geo-information products and services. They should be able to formulate geo ICT strategies to secure their institutional position and mandates in this field and to sustain their relevance. A profound knowledge of technological trends should therefore be complemented with a deep insight in the role that geo-information plays in the context of spatial policy and decision making. GI-providers and users formulating new strategies should anticipate the fast development of GDIs. At the institutional level organizations should be aware of the new roles of government, the new economic and market conditions and thus their changing business environment.

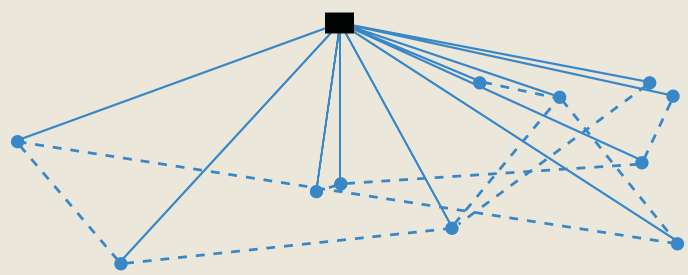
Partnerships, networks and globalization of service supply chains

International partnerships providing joint educational programmes are of great importance for CD. Building them requires a substantial investment by the partners in staff time, material provisions and institutional arrangements. Such investment is only worthwhile when partnerships are sustainable. Three types of sustainability are important[6]:

Academic sustainability — the partners should be able to continuously upgrade the contents of their joint programmes in correspondence with the related professional, scientific and market developments. This implies that joint education activities should complement joint research.

Institutional sustainability — partnerships have a proper institutional or legal setting, ie, the partners should have

Education networks for capacity development



Partners generally participate in several partnerships which could in principle be up-scaled into multilateral regional or even global networks

Source: ITC

an official mandate and legal position embedded in existing frameworks of higher education. Therefore it is important to involve academic institutions and university departments in these activities rather than only the training branches of professional organizations.

Financial sustainability — each partner should arrange funding for their own activities from their own regular resources. The student-related expenses are jointly pursued from a variety of fellowship and scholarship programmes.

Partners generally participate in several partnerships which could in principle be up-scaled into multilateral regional or even global networks. Within these networks decentralized supply chains for education services can develop.[7] Different partners in the network will have their own competences and fields of expertise; these can be combined into one educational program or course. Students will visit these partners for the different educational modules when following the programme.

A more relaxed form is possible too, where partnerships are based on agreements for the transfer of credit points. There is no joint programme, but students follow educational modules elsewhere as part of a programme at their home institute. These decentralized supply chains will make more and more use of distance learning approaches to reduce travelling costs to students.

The ITC example

The International Institute for Geo-Information Science and Earth Observation (ITC) has been involved in CD through educational partnerships for many decades. As part of the next stage ITC has developed partnerships with universities and institutes on four different continents. These partnerships deliver joint educational programmes and provide educational services in the countries or regions where many of the ITC course participants come from. The effectiveness, flexibility and productivity of the ITC educational system has thus been improved substantially.[8]

These partnerships have developed into an educational network called GI-NET, which will ultimately serve as a base for decentralized supply chains for educational services. e-learning tools are presently used for mutual support of the lecturers at the different nodes. But these tools are also used for offering short courses through distance learning and blended learning approaches, and we expect to offer complete degree courses in due time. The different nodes of the network will each take their share of the development and support of such courses. Through the global spread of the network 24/7 support will be possible. The nodes of the network can also give regional support to the course participants and alumni by arranging regional seminars and workshops

ITC acts as a driving node in this network and guarantees its academic sustainability through continuous impulses for academic and professional upgrading and innovations of the educational services.[9] Furthermore it also stimulates mutual exchange and support between the other nodes of the network.

The educational programmes at ITC's home base provide the experience. In this role, they serve as a vehicle for permanent educational innovation with respect to content, educational methods and tools, and quality assurance. Rapid developments in technology, as well as in the demand for information, imply the need for continuous upgrading of professionals through life-long learning. According to the InterAcademy Council, 2004[10]: "…all nations, particularly the developing ones, require an increased level of science and technology capacity to enhance their ability to adopt new technologies…. and adapt them to local needs".

Institutes for higher education must be up to date with these developments and a strong interaction between education and research is therefore needed. ITC is presently developing partnerships for research purposes with organizations in less developed countries, which often have no sufficient resources to develop their own research activities. This research network creates opportunities for the colleagues of those partner organizations to participate in the research programmes of ITC and of other strong research partners.

ITC is active in several other networks besides GI-NET, including the GIMA programme with three Dutch universities, an Erasmus Mundus programme with several European universities and the United Nations University (UNU) network. These networks are connected because they have ITC as a common node. Through this position ITC can transfer experience and knowledge between networks and also be the gateway for staff and students to move between networks.

Towards a virtual university for geo-information science and EO

Networks with decentralised educational service supply chains, with different types of educational partnerships and with different concepts for joint courses and joint degree programmes form an interesting starting position for the development of a virtual university for Geo-Information Science and Earth Observation.

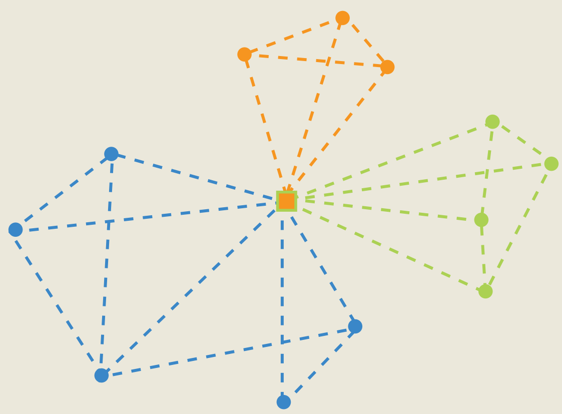
The present partnerships are bilateral. The first stage is always a memorandum of understanding stating that both parties have the intention to enter into a partnership. Based on this, they will generate an agreement which defines the set up of the joint educational programme, including the duties, contributions and responsibilities of both parties, as well as the financial arrangements.

The network structure required for the development of a virtual university is quite different from a standard joint education programme. This is a multilateral arrangement, where most likely not all partners will enter at the same time. Also, such a network would need to be dynamic so that partners come and go over time. In that case a multi lateral agreement might not be the proper institutional base. A more suitable idea is a charter drawn up by the founding partner, so that parties joining the network at a later stage can sign up to it later.

This charter should specify the domain in which such a virtual university will provide educational services, the type and content of the programmes and courses it will deliver, and how to evaluate their market relevance. It should specify the building blocks of these courses and units applied in its credit transfer system. Quality standards have to be specified and procedures for quality assurance and control (for example, internal — in the network — and external peer reviews) and choices should be made for accrediting organizations. The financial arrangements should be formulated, including course fees and financial compensation for marketing activities, course contributions and administrative support.

The road to a virtual university for Earth Observation and Geo-Information Science is certainly a long one. But there are good examples in other domains, and the present GEOSS process provides an ideal and unique opportunity for such an initiative.

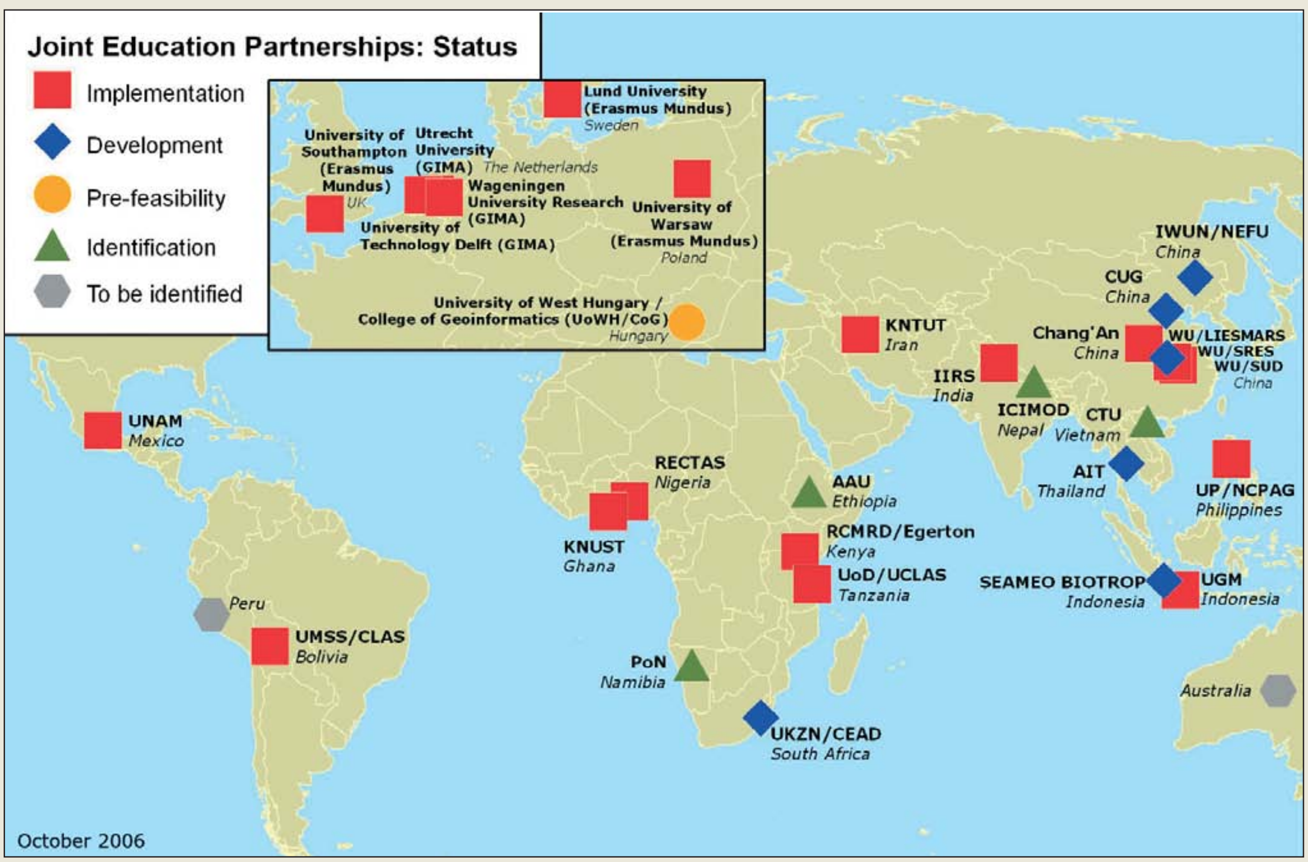
Linked networks



These networks are connected because they have ITC as a common node, and through this position ITC can transfer experience and knowledge between networks

Source: ITC

GI-NET, ITC's international network of partnerships for joint education



ITC has developed partnerships with universities and institutes on four different continents to deliver joint educational programmes and provide educational services

Source: ITC

European monitoring service: achievements, operational perspectives and new challenges

Marc Tondriaux, CEO and Gil Denis, Head of Business Development
GMES Applications and Services, Infoterra Group

Climate change and the impacts of human activities on the Earth and the environment are some of the most significant challenges of the 21st century. As a result, the key focus must be on developing mitigation plans to handle the potential impacts on environment and life; on water, food security and natural resources; on the frequency of natural disasters and humanitarian crisis, and on health and welfare. As these impacts could potentially shape our future for the next 50 years it is important to consider uncertainty management and the value of information for decision-making and long-term policies.

Global Monitoring for Environment and Security (GMES) is a large European initiative — a joint initiative of the European Space Agency (ESA) and the European Commission (EC) — aimed at monitoring our environment globally, for the welfare, health and security of all the people. GMES is vital to help understand and deal with what is happening as a result of climate change. It serves as a kind of global thermometer. Because GMES provides valuable information on the Earth, our environment and the evolution trends, it is a good measurement tool; reducing uncertainty and supporting better decision-making. Since 1998, continuous research and development activities have helped to set up the first operational European services. Astrium and Infoterra Group have been actively involved from the beginning, particularly in two of the three GMES core services — land monitoring and emergency response.

Involvement of Infoterra in GMES and GEOSS

Infoterra is working towards developing Earth observation services both within and beyond Europe; establishing capability in all aspects of value-added geo-information services; building a profitable, sustainable and expanding business in Earth observation services, and developing demand in future Earth observation systems.

Infoterra is a European group with three current entities established in France, Germany and in the United Kingdom. Infoterra also has an office in Hungary and is planning to open Infoterra Spain. In 2006, the group's turnover was EUR50 million, with a current staff of over 300.

Infoterra's GMES strategy is built on the following principles:

- Involvement of end-users and a tight link with the regional authorities
- Strategic importance of the continuity of the Earth observations space infrastructure
- Organisation of a European network of services providers
- Definition of suitable organizational and economic models for the provision of GMES services at the European level.

In order to achieve these objectives Infoterra is strengthening its leading position in two of the GMES fast-track services. With its partners involved in the ongoing European GMES projects, Infoterra is setting up and coordinating a network of European service providers committed to delivering operational GMES services.

The contribution of Earth observation satellites

Satellites play a critical role in monitoring climate change and evaluating the impact of humans on the environment at global, regional and local scales. Satellite data already provides information vital to understanding potential impacts, including floods and forest fires, biomass, sea surface rise, land use and land use changes.

Global satellite observing systems are ideally suited for collecting data in a cost effective way. Satellites are often the only way to highlight gradual change on a global scale. They also provide very high-resolution images on a local scale.

Satellites contribute hugely to:

- Providing routine and continuous monitoring to highlight gradual environmental change
- Models and computer simulations to help improve predictions and forecasts
- Emergency responses to natural disasters or humanitarian crisis
- Decision-making based on independent and autonomous information.

Information from Earth observation sources is global and continuously updated. In addition, these sources provide coverage for all timeframes: long term to real-time data in case of emergencies. A key success factor for GMES is the continuity of Earth observation missions and efficient coordination between European and national missions.

Foundations of GMES and current status

Important efforts have been made on the development of prototype services for GMES in Europe. The two main initiatives, FP6 and FP7, have been launched by the European Commission (integrated projects) and European Space Agency (ESA) GMES Services Element (GSE) programme, with an important investment in the space and services industry.

Research projects of the EC

FP6 has enabled three main lines of services (today known as the fast-track services - FTS): land monitoring core service, marine core service and emergency response core service. Preparatory activities also addressed the atmosphere chemistry and air quality, and security.

Other FP6 initiatives and INSPIRE have also fostered the development of GMES capacity in Europe.

The first space call of FP7 targets mainly the preoperational validation of the three FTS and two new pilot services. Five integrated projects have been submitted, with both continuity of the core consortia and integration of partners from the new member states.

GMES consortia include 40 to 60 European partners. These projects are a key contribution to research and service networking in Europe.

GMES Collaborative Projects in the frame of the RDT programme of the European Commission

	FP6 (ongoing projects)	FP7 (new proposals)
Land	Geoland (Infoterra GmbH)	Geoland 2 (Infoterra GmbH)
Ocean	Mersea (Ifremer)	Myocean (Mercator Océan)
Emergency response	PREVIEW (Infoterra France)	SAFER (Infoterra France)
Atmosphere	GEMS (ECMWF)	MACC (ECMWF)
Security	GMOSS LIMES (DLR) (Telespazio)	GMOSAIC (Telespazio)
Sustainability	BOSS4GMES (Infoterra Ltd)	

BOSS4GMES, the sustainability of GMES services

Coordinated by Infoterra Ltd, Building Operational and Sustainable Services for GMES (BOSS4GMES) is a large integrated project that includes the teams of the three FTS and the new pilot services. The joint aim is to define the sustainability criteria and study transverse issues.

The main objectives are:
- To support the implementation of the three main fast-track services (FTS); land, emergency response and maritime core services
- To prepare the operational foundation for the long-term sustainability of the GMES services.

In the short term, BOSS4GMES supports the implementation of the three GMES fast track services:
- Land Cover Core Service (geoland/GSE Land)
- Ocean Environment Core Service (MERSEA/MarCoast)
- Emergency Response Core Service (PREVIEW/RESPOND)

BOSS4GMES will ensure continuity of activity on the fast-track services between the end of the sixth FP funding and the first contracts under the seventh FP.

The project consortium includes 37 participants from 11 European countries. The total budget is EUR20 million, with the EC funds around EUR12 million.

GMES service element (ESA)

ESA has contributed the GMES service element (GSE). After an initial consolidation stage, ten service portfolios are now organized. These services constitute important contributions for the fast-track services or GMES pilot services.

Infoterra Group leads three GSE projects:
- GSE Land is led by Infoterra GmbH. It develops and validates end-to-end services for the land monitoring core service
- RISK-EOS (led by Infoterra France) and RESPOND (led by Infoterra Ltd) contribute to the development of the emergency response core service, addressing respectively risks and natural disasters for RISK-EOS and support to humanitarian relief operations for RESPOND.

Benefits of GMES services developed by Infoterra Group emergency response and humanitarian relief

Infoterra plays a leading role in the development of the European capacity for emergency response. Since 2000, Infoterra has designed and managed the main cooperative projects and initiatives for the GMES services specialized for risk management and emergency response, humanitarian relief and crisis mitigation, at national level (e.g. PACTES funded in France by CNES and the ministry of research) or European level, funded by the EC or ESA.

RISK-EOS (funded by ESA) and PREVIEW (co-funded by the EC), coordinated by Infoterra France with a network of partners (service and data providers), target natural risks such as forest fires, floods or landslides. RESPOND, funded by ESA and managed by Infoterra Ltd, addresses the humanitarian relief services. These projects, including industrial and institutional service providers, research institutes and end users, focus on users' involvement and validation of an operational capacity.

A new project, Services and Applications For Emergency Response (SAFER), has recently been proposed by Infoterra Group to the EC for the 2008-2010 period. SAFER aims to implement preoperational versions of the Emergency Response Core Service (ERCS).

The main goal is to upgrade the core service and to validate its performance with two priorities.

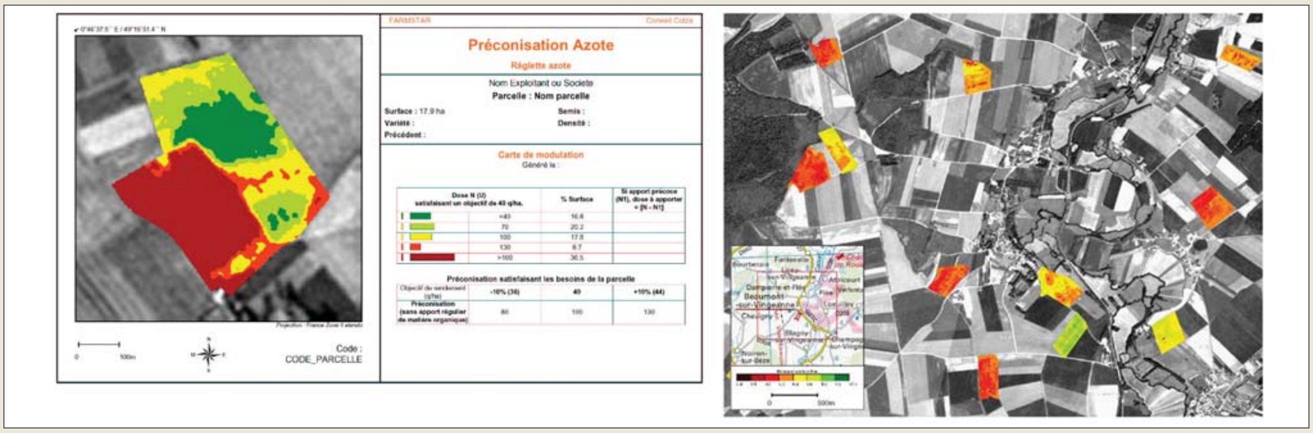
The first priority is the short-term improvement of crisis response with rapid mapping capacity after disastrous events, including the relevant preparatory services. For validation purposes, from 2008 the project will deliver services at full scale for real events or during specific exercises. The main performance criterion is the response time.

The second priority is the extension to core service components before and after the crisis. It targets the longer-term service evolution through the provision of thematic products, which are to be added to the portfolio of services. The main performance criterion is the added value of products with risk-specific information.

Land management and agriculture

Infoterra GmbH, coordinating the projects Geoland and GSE Land, has recently proposed the Geoland2 project

Examples of agri-environmental services developed by Infoterra



In the longer term, GMES will also certainly monitor agriculture practices. Even though agriculture's share is decreasing, it still constitutes the largest part of European budget (46 per cent in 2006). Agriculture was responsible for 14 per cent of global greenhouse gas emissions in 2000 (source: WRI — 2006), with fertilizers the largest single source (38 per cent). The reform of common agriculture policy and cross-compliance implies an increasing importance for the monitoring of good agro-environmental conditions (GAEC).

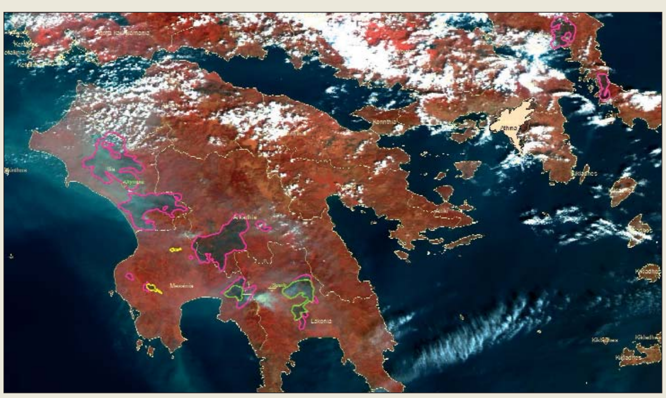
Infoterra Group and its partners have validated specific services at a regional level to support the water framework directive. This includes crops inventory, irrigation monitoring and assessment of diffuse pollution.

These validation activities have demonstrated that relevant information products can be readily implemented in various regions and on a European scale. The services provide multi-use information products and can also be integrated into GIS systems, models and users' decision support systems.
The picture above shows a typical FARMSTAR product, developed by Infoterra. From this, commercial services can be easily derived for similar applications within local or regional management, better/optimised used of fertilizers and reduced water pollution

Source: Infoterra

to the EC. The three components, local, continental and global, of the Land Monitoring Core Service (LMCS) are to be addressed. The goal of Geoland2 is to prepare, validate and demonstrate preoperational service chains and products that will underpin the LMCS, as well as proposing and demonstrating a concrete functional organisation for it.

Emergency response



Forest fires during the summer 2007 — validation of the operational capacity
Following the forest fires that raged across Europe during July and August 2007, Infoterra operated its emergency response services, in the frame of GMES, and produced an assessment of the affected areas using imagery acquired by SPOT and ENVISAT satellites.

A comprehensive assessment was produced on the 30th August 2007 of the fires in the past week in the Peloponesian area. The main benefit here is the revisit capacity of ENVISAT on large areas, very useful to monitor large size events with a long duration

Source: MERIS image ©ESA — Processing ©Infoterra

The three core mapping service tasks are:
Land cover and land use — At a local scale, it produces very high resolution (VHR) urban atlas inventory and change on European cities. At a continental scale, it produces high resolution (HR) land cover inventory and change (21 classes with 1-5 ha mapping unit).

Biogeophysical parameters — In near real-time and off-line, they describe the continental vegetation state, the radiation budget at the surface and the water cycle.

Seasonal and annual change monitoring — Operates at continental scale over Europe and sub-Saharan Africa, delivering an area frame sampling over permanent samples (describing European and African environmental/ ecological conditions for annual statistics of land cover and land cover change), a complete continental coverage of seasonal and annual vegetation parameters to produce land cover, land cover change and agricultural land use.

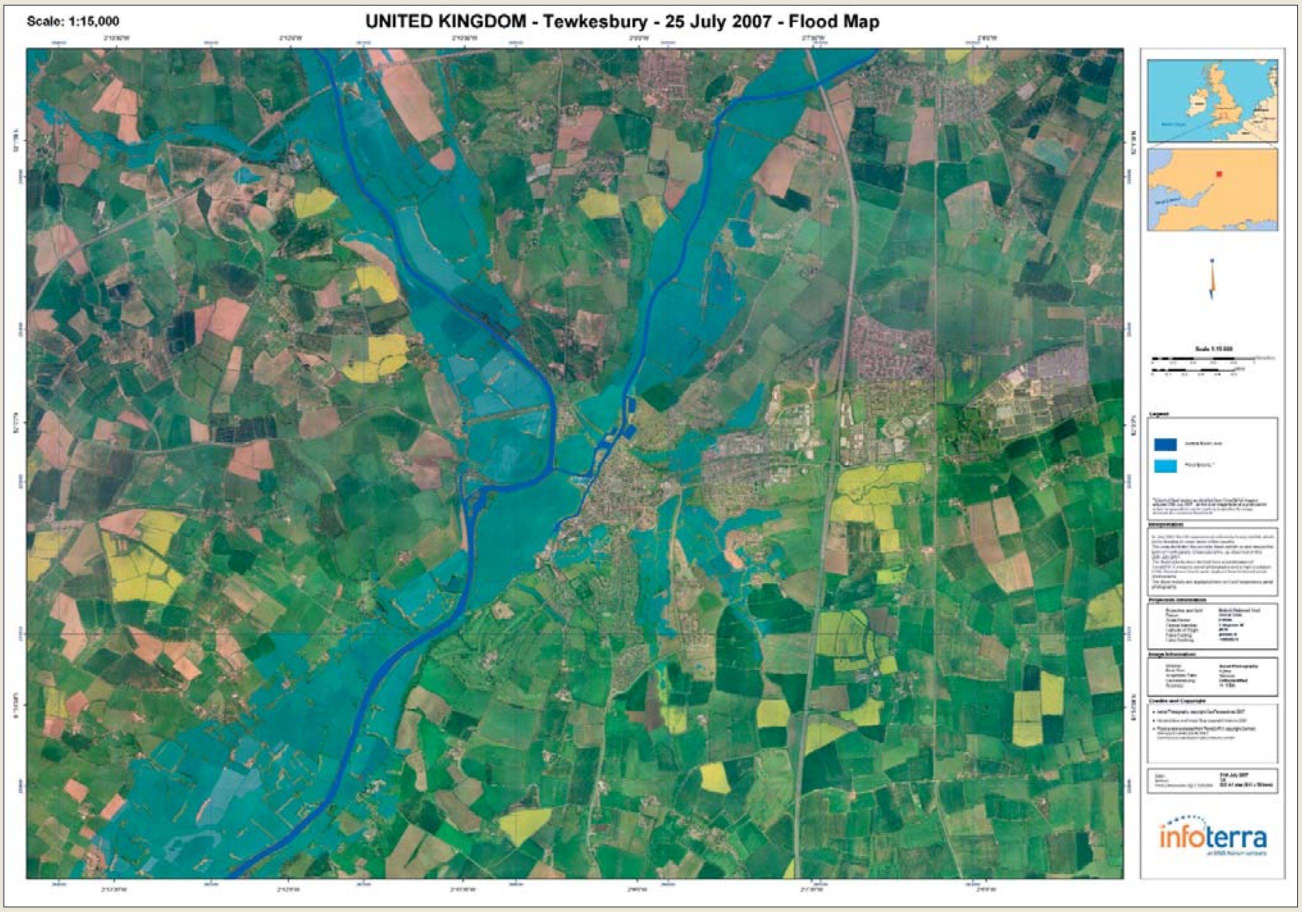
Seven core information services addressing important sectoral policies and showing examples of GMES end-to-end services are being set up with the following aims:

Spatial planning — Describe, explain and forecast urban land use change in Europe.

Water — Integrate Earth observation-derived land cover/land use data in water quality models that can contribute to water management in Europe in a flexible, sustainable and cost-efficient way.

Agri-environment — Indicators assessing the impact of agriculture on the environment and the effectiveness of agri-environmental measures in Europe.

Flood mapping using new high resolution SAR images



Launched in June, the TerraSAR-X satellite has already delivered extremely impressive test images displaying a remarkably high level of detail and quality.

The satellite is a joint venture under a public-private-partnership between DLR and Astrium. Astrium developed, built and launched the satellite; the exclusive commercial exploitation rights are held by Infoterra.

In July 2007, as a demonstration of the system capacity, TerraSAR-X was used to map the extent of the floods affecting the United Kingdom. Infoterra by combining radar imagery from TerraSAR-X with aerial imagery, produced a flood footprint to show the impact and extent of a flood at that point-in-time.

Infoterra has produced a set of information layers combining real-time EO imagery and GIS data, very useful for the decision-making during and after the crisis. Infoterra's experts also ran various simulations using these information products.

In addition to the Charter satellite fleet, TerraSAR-X satellite has been tasked to provide high resolution radar imagery of other flooded areas, although the satellite is still in the commissioning phase

Source: ©Infoterra ©GeoPerspectives

Forest — Improved forest class and biodiversity information at a Pan European level.

Land carbon — Understand and assess the impact of weather and climate variability on terrestrial biospheric carbon fluxes in the context of international conventions.

Natural resource monitoring in Africa — Environmental monitoring capacity in African countries.

Global crop monitoring — Provides objective, real-time crop assessment and yield forecasts to support EC policies in agriculture (Common Agriculture Policy) and food security.

Next steps, new challenges and perspectives

The 2008-2010 period will be a key stage for the progress of GMES and the success of its operational implementation. There are several key challenges including, involving end-users and successfully collaborating with the regional authorities; defining the balance between mutualisation of resources at European level and subsidiary at regional/member state level; building on current preoperational services developed by the

European service industry; ensuring sustainable public funding for the operation of core services; guaranteeing continuity of Earth observation sources and increased coordination between satellite missions, covering sensor types, resolution and revisit; promoting education, user training and public awareness, and coordinating synergies and integration with other international initiatives.

The Infoterra Group, along with all of its partners in Europe, continue to contribute to the successful implementation of GMES, by providing geo-information services, based on Earth observation data, to support the day-to-day management of our changing world.

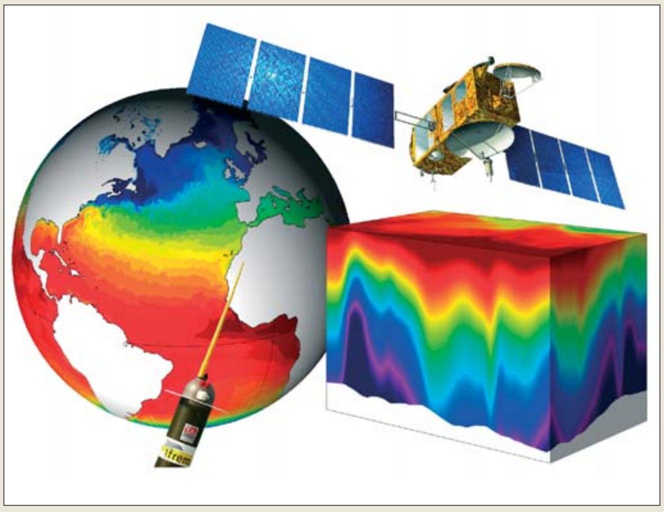
European Marine Core Service: global and regional ocean monitoring and forecasting, a service to society

Yves Desaubies, MERSEA project and European Marine Core Service Consortium

The pervasive influence of our planet's ocean, seas, and coastal areas on climate and their impact on a range of essential activities is widely recognized, and forcefully argued elsewhere in this volume. Mankind, living on less than 20 per cent of the Earth's surface, is heavily dependant on the ocean and its seas for living and mineral resources, notably fisheries, sea farming and offshore industry. Most of the transport of goods, in particular oil, is by way of the seas; on the ocean floor are laid countless pipe and gas lines; fiberoptic cables convey information and data from continent to continent. A large part of the Earth's population lives in coastal areas, vulnerable to storm surges, sea-level rise, erosion and pollution.

It is understandable that responsible management and wise use of our planet's resources requires global observations of the highest quality. But beyond observations and data, a wide range of stakeholders — policy makers, scientists, service providers, the general public — expect information and specific products designed for their needs. They also expect a service that not only provides easy access to the information and data, but also assistance and expertise.

Global Ocean Observing System



The EMCS combine observations from space and in situ (from the Global Ocean Observing System) to monitor and forecast the state of the global ocean and the European regional seas. Here, a global sea surface temperature analysis

Source: Mercator Ocean

The European Marine Core Service (EMCS) is being set up to provide an integrated service in support of safe and efficient offshore activities, environmental management, security and sustainable use of marine resources. The service relies on an integrated European operational system of global monitoring and forecasting of the ocean and a coordinated network of regional systems tailored to European waters. EMCS delivers a set of basic, generic information products based on physical and biogeochemical state variables.

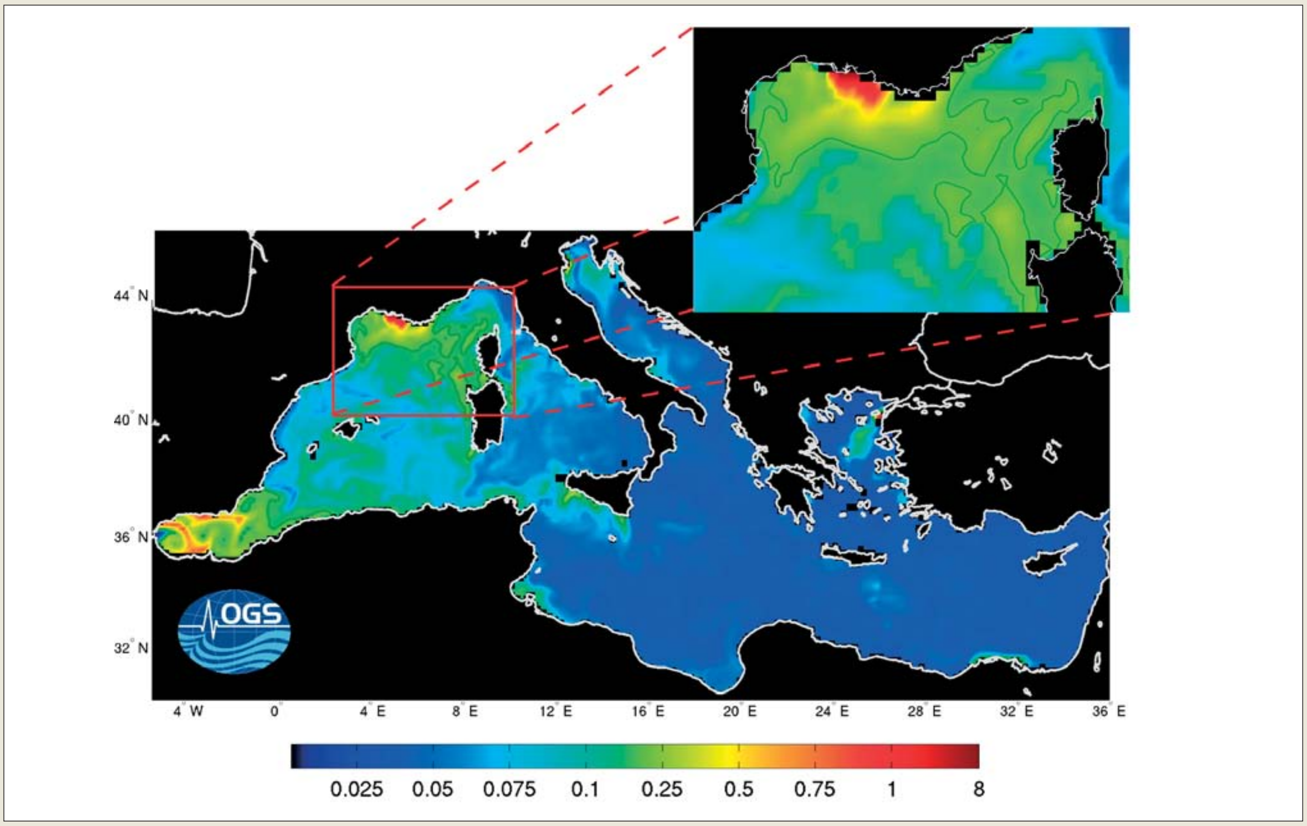
Although the services are developed primarily to fulfil the reporting, monitoring and forecasting requirements of European agencies and stakeholders, they do have a global scope. The provision of services is based on access to ocean products and information, such as long time-series data to define the mean, fluctuations and past trends in the state of the marine environment; to record its evolution and the success or otherwise of policy responses and, with predictions of future change, to establish baselines for effective environmental management.

The system is critically dependant on the availability of Earth Observation data from satellites, from global in situ networks, such as the Argo[1] array, surface drifting buoys and other moored and ship borne data, and from coastal observing systems. EMCS validates, combines and merges all available data to produce regular and systematic reference information on the state of the global ocean and of the regional European seas.

From data to information: the challenge

The Global Ocean Observing System (GOOS) delivers diverse data sets, from satellite sensors and from in situ networks, over the global open ocean and over coastal areas, mostly in industrialized countries. The coverage is very sparse, leaving vast areas unsampled, and it is irregular in time and space: repeat tracks from orbiting satellites can range from 10 to 30 days, inter-track spacing from 300 to 100 km, with different swath width; observations along ship lines are repeated once a month. Or, a

GOOS-derived image of the Mediterranean



Surface chlorophyll is predicted every week over the European regional seas

Source: Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS

few years later, moorings are placed in a few selected locations. The Argo network provides deep measurements every ten days on average.

One of the challenges and objectives of the EMCS is to combine those data sets into coherent syntheses, to obtain systematic, uniform and regular information on the state of the ocean. The basic method to achieve the synthesis is well known, and widely used, for instance, in weather forecasting. All available data are merged and assimilated into high-resolution ocean models in order to monitor the ocean physics, biogeochemistry and ecosystems and to provide forecasts on prediction timescales ranging from days to months. One of the main features of the system is its ability to provide consistent estimates of the state of the ocean and regional seas as it is now, as it was over the recent past (up to several years), and in the near future (forecasts to a few weeks).

Satellite sensors provide invaluable data on such key parameters as sea surface temperature, sea-ice concentration, extent and drift velocity, wind and waves, sea level height, surface currents and optical properties (which are related to biological processes). The sensors are either active (high accuracy altimeter for sea level, synthetic aperture radar or scatterometer for sea ice, wind and waves), or passive (radio-meters operating in different spectral bands for sea ice, ocean colour, or sea-surface temperature). Since the data come from different satellites, each with its own characteristics, careful inter-calibration work is needed to construct uniform validated and merged data sets for any given parameter.

But satellites see only the surface of the ocean; processes taking place in its great depths cannot be detected from space. Deep, global in situ observations are necessary. This is a formidable challenge. One of the key components of the Global Ocean Observing System (GOOS) is the Argo network, which has been progressively deployed during the last decade, to the point where it is now reaching its nominal target of 3,000 floats in operation.

The information provided by the EMCS consists in regular, operational, best estimates of ocean fields: temperature, currents, waves, ice, heat content, surface fluxes (evaporation), nutrients, chlorophyll, primary production, etc. The products include observational and model data, real-time mapping and forecasting. Ocean bulletins, indicators, synthesis and statistics are prepared. Baseline data are obtained from long-term retrospective analysis.

EMCS architecture: a system of systems

The system of systems relies on a network of monitoring and forecasting centres, thematic data assembly centres, and the associated information management infrastructure. The present pre-operational system comprises global and regional monitoring and forecast centres (Arctic, North-Atlantic and European shelves, Baltic, and

Mediterranean[2]), handling assimilative 3D modelling capacities, and data assembly centres for satellite altimetry, ocean colour, sea ice, sea surface temperature, and forcing fields, and for in situ data. Atmospheric analyses and forecasts are provided by the European Centre for Medium Range Weather Forecasting (ECMWF) and National Weather Services.

The centres, located throughout Europe, are interconnected to form an integrated system of systems thanks to information management components (global workflow monitoring and supervision systems). They are organized to ensure three groups of activities or 'divisions':

- A research and development group which can be partly internal and external to the centre
- A production "unit" in charge of routine production and quality control
- A service division in charge of service operations, including bulk delivery and provision of expertise and assistance.

The components are networked into a single framework and information management system to deliver integrated services. All components of the EMCS are being developed in line with the transverse areas concepts of GEO, in particular the architecture, interoperability and data management standards. They adhere to internationally agreed protocols, formats and other recommendations of the Intergovernmental Oceanographic Commission and other relevant bodies.

Serving user needs in the societal benefit areas

The basic tenet underpinning the EMCS is that it delivers generic information, serving the needs of intermediate users in support of their missions and activities. Users include public agencies (national and international, e.g. the European Environmental Agency, the European Maritime Safety Agency), research laboratories, and private companies.

The EMCS is highly relevant to several of the societal benefit areas identified by GEO, as illustrated by several examples:

Reducing loss of life and property from natural and human-induced disasters — forecasting of ocean currents and sea ice in support of ship routing and offshore operations, coastal management, storm surge forecasts, oil spill detection and drift forecasts; support to search and rescue operations at sea.

Photo: Canadian Coast Guards

Ice monitoring and forecasting in support of ship routing and climate change studies

Understanding environmental factors affecting human health and well-being — coastal water quality monitoring, pollution detection and monitoring, harmful algal blooms, responsible fishing strategies.

Improving management of energy resources — lending support to offshore operations and maritime transport.

Understanding, assessing, predicting, mitigating, and adapting to climate variability and change — the role of the ocean in all climate issues is paramount and obvious (heat, sea ice, carbon cycle). EMCS monitors sea level, storm surges and extreme events, works to develop ocean climate indicators, and monitors ocean circulation and heat patterns changes.

Improving water resource management through better understanding of the water cycle — understanding the role of the ocean in the global water cycle, e.g. evaporation-precipitation.

Improving weather information, forecasting and warning — extended weather forecasts need timely, high-quality ocean information; in particular, hurricane prediction requires information on upper-ocean heat content.

Improving the management and protection of terrestrial, coastal and marine ecosystems — the MCS delivers boundary conditions needed for coastal monitoring systems. The development of ecosystem models in the coastal domains is an active area of research; their implementation and validation into the EMCS is ongoing.

Understanding, monitoring and conserving biodiversity — the products of the EMCS on the physical and primary ecosystem variables contribute to understanding the oceanic environmental factors.

Supporting sustainable agriculture (including fishery) and combating desertification — the coupling of the physical state of the ocean to the biogeochemical state and the influence on ecosystem development is of great importance for a sustainable ecosystem based fishery management.

Present status and perspectives

The EMCS has been developed with significant support from national agencies,[3] from the European Commission and the European Space Agency. EMCS participates in the Global Data Assimilation Experiment (GODAE). Most of the centres are in operation, and deliver regularly high-quality data and products. Further developments are underway to consolidate and transition to fully operational status, and to be included in the European Global Monitoring for Environment and Security (GEMS) system. Research results (in particular in ecosystem modelling) are regularly incorporated into the operational systems.

A special focus is given to the development of the services and to the engagement of users; links with coastal systems are strengthened.

The EMCS provides significant added value to Earth observations, for the benefit of society in Europe and worldwide. It is inherently dependent on the availability of data from Earth observation satellites and from in situ ocean observation networks. Continuity of those is crucial for the future.

Linking GEOSS and European environmental monitoring

Markus Erhard and Tim Haigh, European Environment Agency;
Bo Normander, National Environmental Research Institute

The demand from all parts of society for environmental information is increasing. Public rights regarding access to environmental information and public participation are granted by the Aarhus Convention.[1] Equally, pressure groups, experts, and interested citizens are demanding accurate information with clear and relevant messages. Commercial users are interested in running business applications based on environmental data. Policy makers demand that the information is reliable, easy to understand and relevant, while also being as up-to-date as possible.[2]

Key challenges that must be addressed to respond to these needs include data quality, harmonization, sufficient geographical coverage, timeliness, data accessibility and integration of data from multiple sources.

A second set of challenges relates to making the data available together with tools that allow users to undertake the task they need to (e.g. experts to do their own analyses), and to communicate them in ways which the public can readily understand and use as a basis for their own actions. New technologies often summarized under the term 'Web 2.0' are fostering availability and access to information across sectors and societies.

A look at two examples of new approaches to address some of these challenges, linked to GEOSS Societal Benefit Areas 'human health' and 'water', will provide a view of the movement toward a Shared Environmental Information System (SEIS); a concept aligned with GEOSS principles.

European environmental data flows and assessment

Data and information from monitoring and other activities in member countries is channelled to support assessments on the state and trends in the environment across Europe. Many of these data flows are handled by the European Environment Agency (EEA)[3] and its network of member and participating countries. The network is known as the European Environment Information and Observation Network (EIONET).[4] It involves 38 countries and more than 300 institutes.

Many data flows are established by legislative reporting requirements and provide data and information where there are environmental policies in place, including globally legally binding commitments. Others are more voluntary initiatives, in particular for areas where data flows are not regulated by European policies.

The data flows cover a wide range of environmental themes such as air and water quality, biodiversity and land use. The EEA makes use of them to help the EU and member countries to make informed decisions about improving the environment, integrating environmental aspects into economic policies and moving toward sustainability.

Reporting and technical progress

Providing up-to-date information is one of the main challenges for reporting on the state of the environment.[5] The production cycle of international reports on the state of the environment usually takes several years. Thus the demand for timely data is not easily met in the normal production cycle of comprehensive, hard-copy reports. International reporting requires inputs from many countries and authorities and undergoes time consuming data and text validation procedures. The average time lag of the underlying data in a number of international State of Environment (SOE) reports by EEA and OECD has been shown to be as much as three-to-four years.[6]

Many efforts have been put into improving the timeliness of environmental information, including the use of indicators, harmonization of data and improvements to data flows [7]. Integration of data from different sources faces numerous technical and organizational challenges. However, integration of datasets leads to significant benefits in terms of increasing understanding of trends and the ability to communicate complex environmental issues.

Data accessibility is a key constraint that determines the quality of information for decision making. GEOSS fosters awareness of good practice in data accessibility, and this in itself can ease the data access burden, thus facilitating examples such as the projects described below.

The fast progress of the Internet and other communication technologies provide new opportunities to deliver timely and relevant environmental information to the general public. It takes less time to add information to a website than it does to publish a hard-copy report, and a website can be updated continuously. The advent of flexible, widely accessible Internet standards has facilitated a great potential for data exchange.[8] For this reason, more and more web-based online information systems are being developed. Two examples — one for integrated assessments on water-related issues, and one for near-real-time air quality monitoring, are described below.

Water Information System for Europe

In 2007, EEA established the Water Information System for Europe (WISE: http://water.europa.eu). This is an operational web-based service where users can view interactive maps and related information on water quality collected by member states as well as European and international bodies. The website is an example on how combining different thematic maps and data sources can create added value to environmental data. WISE addresses data integration by combining spatial data from different legal reporting instruments as well as from different sectors.

In its current version, WISE makes use of water quality monitoring data, river networks, catchments, digital elevation models, administrative boundaries, land cover and land use, as well as statistics. By sharing water-related data in this way, WISE delivers improved information on the state of Europe's water systems, and the trends and pressures they face.

The website focuses on:

- Water quality in rivers and lakes (nitrates, ammonium, phosphates, ecological quality)
- European water bodies at risk or highly modified
- Regional information (My river basin)
- Urban waste water treatment
- European bathing water status.

WISE will be further developed according to the WISE implementation plan. The approach will be to make use of innovative technologies and to take a more decentralized approach in accordance with the evolving principles of the SEIS of Europe.

WISE

WISE information showing water bodies at risk in Northern Spain and Southern France

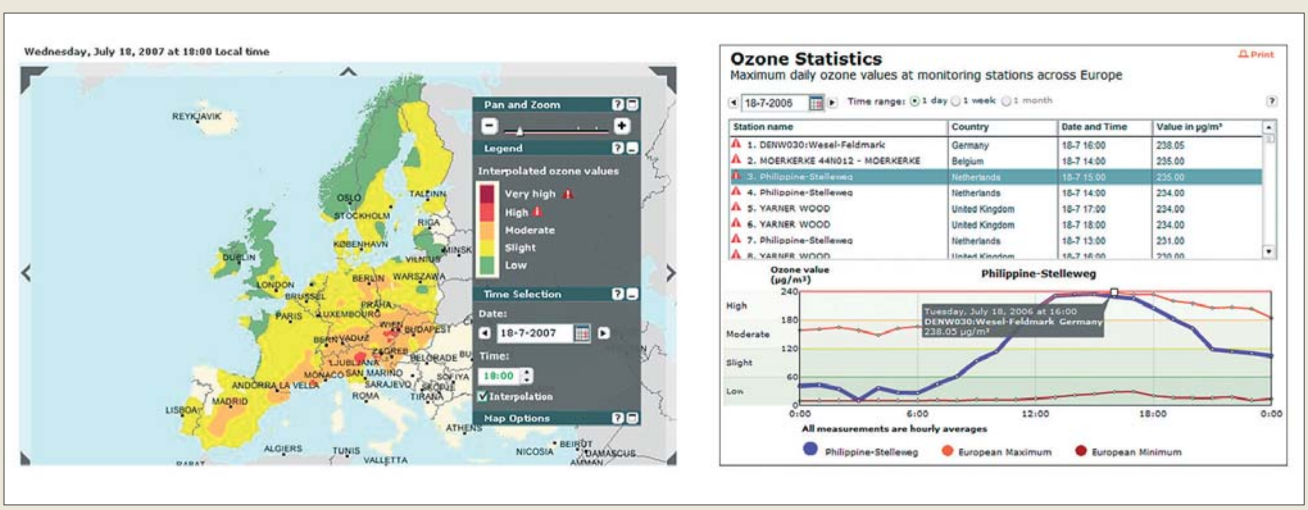
Source: WISE; http://water.europa.eu, EEA, 2007

Ozone Web — near-real-time air quality information

Ground-level ozone conditions across Europe are mapped in near-real time based on hourly data from more than 700 air quality measurement stations (http://eea.europa.eu/maps/ozone). Ground-level ozone presents one of the most prominent air pollution problems in Europe. Up to 30 per cent of Europe's urban population is exposed to ozone concentrations above the threshold levels set by the EU. Ozone pollution is responsible for as many as 20,000 deaths in Europe every year. It can irritate airways, causing breathing difficulties and damaging lungs after only a few hours of exposure.

Timeliness of data availability is thus key to increasing awareness of ozone pollution. The Ozone Web site is kept up to date with near-real-time ozone data from over 43 data providers[9]. It provides an overview of the situation on a European level, as well informing users about more local air quality information sources such as national and regional air quality websites.

Ozone Web



Ground level ozone concentration over Europe on 18 July 2007 at 6:00 p.m. local time, and ozone concentration over the whole day as measured at a station in The Netherlands

Source: Ozone Web http://www.eea.europa.eu/maps/ozone, EEA, 2007

As a joint European project, Ozone Web reflects the international character of air pollution. Air pollutants are emitted in one place but may have an impact in another many hundreds of kilometres away. The website demonstrates how an international institution can create partnerships with member countries to provide near-real-time information on the environment to serve and empower citizens.

Functionality of the web tool includes:

- European status (the situation in Europe) including live status data, recent historic status, stations and their location in Europe
- Advanced mapping tool
- Interpolated maps
- Comparison and trends
- Supporting texts.

In the coming years, the project plans to expand data coverage to other pollutants such as particulate matter (PM).

These online services are seen as the first steps toward a seamless Internet-based pan-European information system. The system is expected to be interoperable with standards set by the European Directive on Infrastructure for Spatial Information in Europe (INSPIRE),[10] as well as ISO and OGC.

Outlook — toward a shared environmental information system

The European capacity to access and manage the wide range of information and services required for environmental management is still very fragmented, suffering from great heterogeneity in terms of organization, system architecture, technical implementation, data structure and data access policy. The challenge is to interconnect the many information sources and to build an integrated and dynamic information area for environmental management.

In dialogue with member states, the European Community has recently agreed upon the concept of a SEIS for Europe. The scope of SEIS is to establish an integrated and sustained environmental information system to improve the sharing of data within Europe and beyond. Such an information system should lead to improvement, both in the quality of environmental data and information, and in its management, use and dissemination. The benefits of such a shared information system are compelling and have already been recognized by regional and international organizations beyond the EU, such as UNEP/MAP's proposal to establish a shared environmental information system for the Mediterranean region.

SEIS will be built incrementally upon the information and systems that already exist in the EU member states and at the European level. The concept of SEIS is based on similar principles as those which are applied in the EU Directive for spatial information in Europe (INSPIRE):

- Information should be managed as closely as possible to its source
- Information is provided once and shared with others for many purposes
- Information should be accessible to enable clients to make comparisons at the appropriate geographical scale (e.g. countries, cities, catchment areas)
- Information should be made available to the public after due consideration of the appropriate level of aggregation, given possible confidentiality constraints, and at national level in the national language(s).

SEIS will be based on a distributed or decentralized network of public information providers for sharing environmental data and information. This concept reflects, on the one hand, Europe's commitment to open society and governance and, on the other hand, the possibilities offered by today's information and communication technology.

Links to GEOSS — toward a global monitoring system

The mission of EEA is closely aligned with the GEOSS vision "to realize a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information."[11]

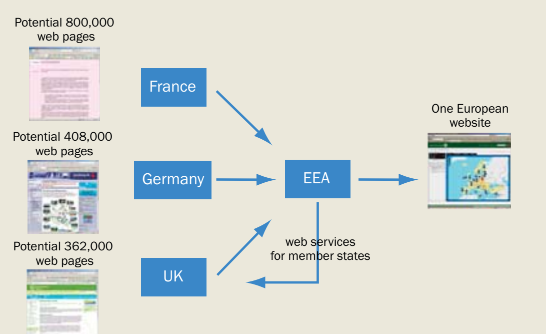
In this context, EEA sees strong connections between specific EEA projects, the European initiative on a shared environmental information system and the GEOSS process. The two web applications discussed above are examples of early achievements in support of the GEOSS SBAs:

- The EEA near-real-time ozone website contributes to "understanding environmental factors affecting human health and well-being"
- EEA water information systems for Europe contribute to "improving water resource management through better understanding of the water cycle."

In the coming years Europe's monitoring capacities and infrastructure will be further strengthened by the Global Monitoring for Environment and Security (GMES) programme. This programme aims to integrate satellite and ground-based monitoring data into operational services to provide geo-spatial information for policy and decision makers.[12] GMES is anticipated to be the main EU contribution to GEOSS. Four services are currently in scope, covering 'atmosphere', 'emergency response', 'land monitoring' and 'marine' services, and are expected to be available from 2008 onward.

The ongoing activities of EEA, its network EIONET and other EU institutions on improving European environmental data flows and GMES will support GEOSS goals to achieve significant progress in the nine SBAs of the ten-year implementation plan.

SEIS – Shared Environmental Information System for Europe



The concept of SEIS is a distributed network of information providers that enables the sharing of environmental data and information. Members (here e.g. France, Germany, and UK) deliver information and profit from tools and services of pan-European web services

Source: EEA, 2007

SERVIR: putting Earth observation science and technology into practice

Carrie Stokes, US Agency for International Development

Unlike their neighbours in North and South America, the countries of Central America do not have their own satellites or space agencies. They have traditionally had to make important decisions affecting their populations and diverse natural resources in absence of the significant information that Earth observation can provide. Recently, however, the countries of the region have been able to leverage the satellite resources of other countries, such as the United States, to implement a unique system which makes available Earth observation data, monitoring tools and the capability to visualize Earth information in three dimensions. Known as SERVIR (the Spanish acronym for Regional Visualization and Monitoring System), the system is based in and serves all seven Central American countries and southern Mexico. It is the first regional system of its kind in the world and is a testament to leveraging North-South and South-South collaboration for putting Earth observations toward the benefit of society.

How it works

Each participating country contributes to the implementation of SERVIR by submitting its own geospatial data to a central hub in Panama, located at the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC). The SERVIR team integrates this data and links it to various types of satellite imagery collected regularly over the region. Once integrated, the data is disseminated to decision-makers, researchers, educators, students and the public via a web portal (www.servir.net) in both Spanish and English. The portal allows for online map-viewing and makes available for cost-free download intuitive tools that help the user understand the data. Additionally, the centre in Panama that houses the SERVIR computers provides training to environment ministries and meteorological services of the region to build their capacity to use SERVIR tools in their everyday work. With information and tools concerning biodiversity, climate change, disaster management, ecosystems, health, water and weather, SERVIR provides previously inaccessible information that can be applied to directly benefit society. Importantly, it also encourages the standardization of disparate data sets from multiple sources and the sharing of data across international boundaries.

Photo: Science@NASA

The SERVIR team at CATHALAC

What it does

With so many different kinds of data accessible via a single web portal, SERVIR can be used to address many different problems faced by society and its leaders. In the two years since SERVIR has been operating, it has been used in numerous ways, and the demand for what it can do is growing. The most common application of the system is to analyse the weather, arguably the single most important factor influencing economic development in Central America.

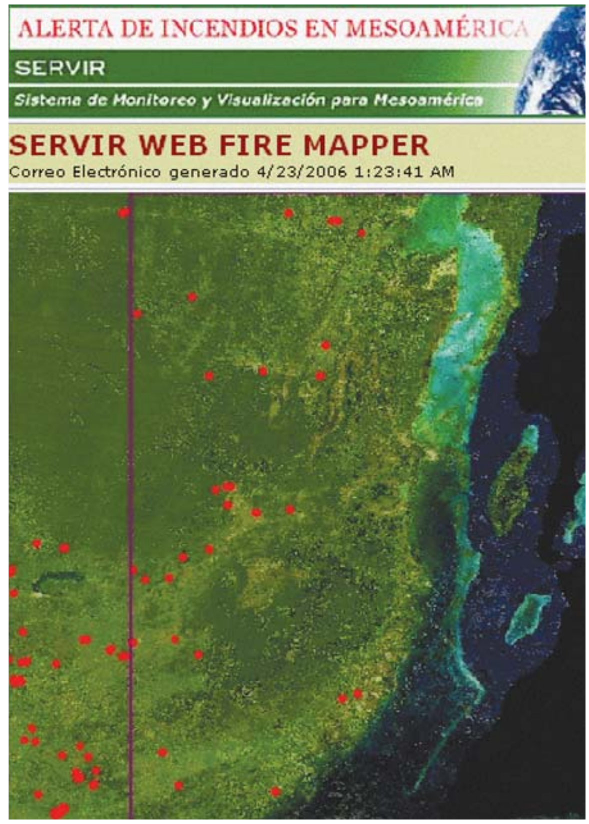
Weather forecasting — The SERVIR system provides cost-free products for both monitoring and forecasting weather conditions on an hourly basis. The system's servers ingest data provided by the region's meteorological services to produce 48-hour forecasts of a host of variables, including temperature and precipitation. In a region possessing very few weather radar stations, the system also makes available cutting-edge research products, such as a satellite-based 'virtual radar' system which can forecast thunderstorm development an hour in advance, with important implications for flash flood forecasting. In Panama and El Salvador, weather forecasters on the major television stations make use of SERVIR forecasts in their daily televised weather reports.

Disaster response — The SERVIR system has become an important tool for policy makers in times of emergency. In November 2006, a stationary front in the Caribbean caused severe flooding and landslides in Panama. Roughly 1,300 people were left homeless, while 13 were reported dead or missing. Faced with further damage to the country as the storm continued to develop, the President and Vice President of Panama, along with the Ministers of Housing and Health, visited the SERVIR facility in Panama to get assistance with formulating a course of action to address the crisis. The analysis by the SERVIR team regarding potential scenarios of the storm provided the Panamanian Government, for the first time in the nation's history, with important information to issue advisories to the communities at risk. To ensure that the vulnerable populations received evacuation notification, the civil protection authority worked with private phone companies to send warnings via cell phone text messaging. As a result of the advisories, the inhabitants of Panama's northwestern provinces were prepared for the flooding and landslides, which occurred as forecast. Among others, the SERVIR team has also provided decision support in the case of Hurricanes Stan and Dean, in the flooding of the Sixaola River between Costa Rica and Panama, and the 2007 Mountain Pine Ridge fires in Belize.

Fire monitoring — SERVIR is used by managers of protected areas throughout Central America. By monitoring hotspots throughout the region, the system's Web Fire Mapper, implemented in partnership with the University of Maryland, detects burning fires and can alert users via e-mail about the location of the fires. In Nicaragua, the forestry department sends out ground crews to assess the situation upon receipt of fire alerts from the system. Fire alerts can be made available to anyone who requests them through the SERVIR web portal.

Red tides — Harmful algal blooms in the ocean indicate toxic conditions for fishing. Commonly referred to as red tides, algal blooms can be detected with remote sensing technology. The SERVIR system makes available satellite data that can be used to monitor the ocean tides. In El Salvador, for instance, the Ministry of Health uses SERVIR to check potentially unsafe areas, thereby avoiding health problems for fish consumers and maintaining an economically healthy market for domestic consumption and export.

Air pollution — In May 2007, the countries of Guatemala, Costa Rica and Nicaragua alerted their citizens of a toxic cloud hovering overhead that was perceived to have blown across the Atlantic Ocean from Africa. Concerned about breathing the outdoor air, people remained indoors and authorities considered keeping children out of school and even closing businesses. Amid multiple reports in the media of the toxic African cloud, the SERVIR team was asked to conduct analyses of the cloud to better understand the potential threat to the population. Using satellite and model data from the SERVIR system and recreating the region's weather patterns, the team was able to show that the cloud did not originate in Africa, but within Central America. The 'toxic cloud' was actually smoke from areas burning in Central America, and had circulated back over the land due to an unusual calming of the trade winds. Once the media obtained the SERVIR analysis, news reports allayed public concern about the cloud, and people returned to normal life.



SERVIR provides resource managers across Mesoamerica with access to information on daily fire hotspot locations, shown here as red dots

Who is involved

The innovative SERVIR system is the result of collaboration between many partners. The US Government, through direct technical and financial support from the National Aeronautical and Space Administration (NASA) and the US Agency for International Development (USAID), and indirect support from the National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS), works with CATHALAC, the Central American Commission on Environment and Development (CCAD), and participating countries to implement the system. Key partners include the World Bank, the United Nations Environmental Programme (UNEP), the Nature Conservancy (TNC), the Institute for the Application of Geospatial Technology (IAGT), the University of Alabama in Huntsville (UAH), the University of Maryland (UMD), and others.

Future plans

The SERVIR system is expanding functionality to provide decision support for climate prediction, coral reef monitoring, biodiversity conservation, agricultural crop forecasting, and air quality monitoring. Upon request, the system can be replicated and tailored to the needs of other geographic regions. Current expansion efforts are focused on Africa.[1]

The socio-economic and environmental benefits of a revolution in weather, climate and Earth system analysis and prediction

Melvyn Shapiro, Jagadish Shukla, Brian Hoskins, John Church, Kevin Trenberth, Michel Beland, Guy Brasseur, Mike Wallace, Gordon McBean, Jim Caughey, David Rogers, Gilbert Brunet, Leonard Barrie, Ann Hendersen-Sellers, David Burridge, Tetsuo Nakazawa, Martin Miller, Phillippe Bougeault, Rick Anthes, Zoltan Toth and Tim Palmer

Scientists from the World Weather Research Programme (WWRP), World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP) and the natural-hazards and socio-economic communities[1] have identified an urgent necessity for establishing a weather, climate and Earth-system prediction project. This will increase the capacity of disaster-risk reduction managers and environmental policy makers to make sound decisions, in order to minimize and adapt to the societal, economic and environmental vulnerabilities arising from high-impact weather and climate.

Impacts of extreme weather and climate events

Clockwise from top left: Brush fire in Macedonia during the south-eastern European summer heat wave of 2007; the town of Upton-upon-Severn in Worcestershire, England, surrounded by water during the devastating flooding of July 2007; an Ethiopian goat herder leads his livestock through the dust in the desert where severe drought in East Africa has forced overgrazing, which destabilizes the soil; refugees from Hurricane Katrina wait for evacuation

Rationale

The socio-economic, environmental and health impacts of recent extreme weather and climate events, such as the destructive flooding rains over India, China, England, and the United States and the simultaneous south-eastern Europe severe heat wave and drought during the summer of 2007; the devastation of New Orleans by Hurricane Katrina in 2005; the deadly European heat wave of August 2003, and the persistent multi-decadal African drought that ravaged the semi-arid regions of the Sahel, demonstrate the vulnerability of modern humanity, economies, and the environment to high-impact weather and climate. Effective mitigation of, and adaptation to, such events requires accurate prediction of the likelihood of changing weather and climate at global, regional and local scales, combined with enhancing the capacity of disaster-risk reduction managers and environmental policy makers to utilize this information to make sound decisions that minimize the societal vulnerability, economic and environmental losses and that maximize economic opportunities arising from high-impact weather, climate variability and climate change.

We stand at the threshold of providing and responding to major advances in observations, analysis and prediction of high-impact weather and climate events, and the complex interaction between the physical-biological-chemical Earth system[2] and global societies. This opportunity arises from the notable progress in our ability to monitor and predict short-term weather hazards and climate variability and change, and the utilization of this information by disaster-risk-reduction managers and environmental policy makers. For example, short-term regional forecasts (hours to three-day periods), prepared on spatial scales of a few kilometres, are currently capable of predicting the occurrence of flooding rainstorms, air-quality emergencies, coastal storm surges, severe wind events, hurricane track and land fall, with reasonable skill. Global weather prediction has advanced to the point that national weather centres routinely provide useful forecasts with a five-day forecast accuracy comparable to the two-day forecasts of 25 years ago, including ensemble prediction systems that provide probability estimates of their expected level of skill for a week or more (see Bougeault and Toth, this Volume). Climate projections of global temperature and precipitation distribution over timescales from seasons to centuries provide the scientific underpinning for international treaties to limit activities that contribute to the emission of carbon dioxide and other greenhouse gases. The consequent assessment models have become increasingly important tools in evaluating the socio-economic and environmental benefits and outcomes of different decisions. These accomplishments represent some of the most significant scientific, technological and societal achievements of the 20th century.

Building on the advances in observing systems and predictive skill over the past three decades, there is potential for further major scientific breakthroughs that will enable governments to achieve a more effective mitigation of and adaptation to extreme weather and climate, and to realize higher levels of societal, economic and environmental benefits. The high priority of expanding our weather, climate and Earth system observation, analysis and prediction capability is justified by both evidence of the increasing incidence of weather and climate extremes as reported by the International Panel for Climate Change,[3] and by the ever-increasing vulnerability of society, economies and the environment to high-impact weather, and climate variability and change. More than 75 per cent of the natural disasters around the world are triggered directly or indirectly by weather and climate events.

The artificial distinction between weather, climate and Earth system prediction, and the link with its socio-economic and natural-hazards mitigation applications is transitioning into a seamless suite of models applicable over all relevant decision-making spatial and temporal scales. Within this paradigm shift, socio-economic and environmental demands are an integral component in the design and implementation of a new generation of science-based global to regional early warning systems that will enable major advances in mitigation and adaptation to daily through multi-decadal hazards of high-impact weather, and climate variability and change. In the same way that the atmosphere encompasses the Earth, the expertise to exploit further advances in observations, monitoring and prediction of the physical-biological-chemical Earth system and its interaction with the global socio-economic system, resides across many nations, international organizations and diverse scientific disciplines. Advancing the skill of weather, climate and Earth system prediction to enable sound decisions to minimize and adapt to the societal, economic and environmental vulnerabilities arising from high-impact weather and climate is a global enterprise for the 21st century.

Recent progress

Global societies of today reap substantial benefits from weather and climate observations, analyses and predictions. These benefits include early warning systems to assess risk and reduce vulnerability arising from weather, climate, and air-quality hazards; weather, climate, and complex Earth system prediction systems tailored for the specific needs of societal, economic, and environmentally sensitive sectors (e.g. energy, water resource management, health, air and water quality, transportation; agriculture, fisheries, leisure industries, ecosystems, biodiversity and national security), and quantitative measures of the probability of occurrence and potential severity of a given socio-economic or environmental outcome. It is recognized that mitigation and adaptation strategies require predictions of the probability and uncertainty of occurrence of extreme events on both weather and climate timescales. The occurrence of extreme weather and climate events may be infrequent, but the consequences can be catastrophic to those societies and ecosystems that are affected.

Recent progress in the atmospheric, oceanographic, Earth system and socio-economic sciences; observations, computer technology and global communication systems, affords the opportunity to accelerate further advances in the accuracy of weather, climate prediction information and its use. These advances include greatly expanded observations of the atmosphere, oceans, land and ice surface, including their biogeochemical properties, more accurate weather, climate and Earth system prediction models, aided by improvements in numerical methods, representations of physical processes, probabilistic (ensemble) prediction systems and the continuous increase in the capacity of high-performance computers; advanced knowledge of the theoretical and practical limits of atmospheric and oceanic predictability, including the influence of climate variability and change on high-impact weather events, and the societal, economic and environmental utilization of weather, climate and Earth system information to assess, mitigate and adapt to natural and human-induced environmental disasters.

Core elements

The core elements of an international weather, climate and Earth system prediction project will build upon the above achievements and will include the following.

High-resolution observations and models — High-resolution observations and models of the atmosphere, ocean, land and biogeochemical processes will monitor and predict the seamless interaction among weather, climate, the Earth system and global socio-economics; resolve the detailed properties of the atmosphere, land surface, atmospheric composition, biogeochemistry, and energetic oceanic eddies and boundary currents with computational resolution consistent with the spatial scale of the applications; address daily, seasonal, interannual and multi-decadal prediction for short-term societal functions and long-term policy decisions, and provide scientifically-based assessments of the impacts of predicted changes and actions to mitigate them, including assessments of the potential consequences of emerging geo-engineering intervention hypotheses designed to modulate climate variability and change and associated high-impact weather.

High-resolution assimilation and analysis — High-resolution global and regional data-assimilation and analysis systems are needed to enhance the utility of the full spatial/temporal resolution of observations from space, land/ice surfaces and oceans. This requires advanced high-resolution data-assimilation systems which employ weather, climate and Earth system prediction models as an integral component in the analysis of the observations and so provide a sensor-integrated synergy for the monitoring and forecast verification of weather, climate, and biochemical properties of the Earth system. User-friendly high-speed and high-bandwidth integrated data distribution systems are needed to allow access to most information in near real time for use by environmental prediction centres and major research centres.

Underpinning research — This will improve the performance and application of models, providing a basis for predictions of known confidence through improved knowledge of weather, climate and Earth system processes, and their fluctuations and change. For example, one of the great research challenges is advancing the capability of weather and climate models to initiate and maintain organized tropical precipitating convective systems. Progress on this problem is a critical element in advancing forecast skill on timescales of days in the tropics and globally at one week and beyond. This research will also include the analysis of observations collected routinely and in special multidisciplinary field campaigns; development of advanced data-assimilation methods; process experiments and full-system simulations, predictions and hindcasts driven by observed climate-system forcings, and studies to assess and advance the socio-economic use and value of the products derived from advanced observation, analysis and prediction systems for weather, climate and Earth systems.

Advanced high-performance computers — to enable the implementation of next-generation weather, climate, and Earth system monitoring, assessment, data assimilation and prediction systems; ensemble-prediction systems that include many possible projections for the future, thereby allowing probabilities of events to be deduced, performed with high resolution for weather, climate variability and Earth system prediction, and long-term (multi-decadal) integrations for climate models with a high degree of Earth system complexity for climate variability prediction and climate change projections. It is envisioned that these three elements will require access to dedicated supercomputing facilities with sustained speeds of at least 10,000 times that of the most advanced computers of today, each supported by a critical mass of scientific and technical effort. Each facility could be supported by a cluster of countries with a common interest in high-resolution prediction of weather, climate variations and change. Advanced data processing and visualization methods are required to fully realize the research and operational benefits of high-resolution analyses and predictions that will be generated by high-performance computing.

International coordination — An internationally-coordinated weather, climate, Earth system and socio-economic data and forecast information system and archive will provide universal access to observational, experimental and operational global databases, commensurate with the highest resolution achievable given near-term observational and computational constraints. It will also facilitate advanced analysis and visualization representations of observed and predicted weather, climate, Earth system events and their impacts.

Information — The production of information for policy makers and stakeholders is crucial in assisting critical decision-making processes regarding adaptation to and mitigation of weather and climate events, and sustainable development by exploiting advances in the following: forecasts of short-term weather hazards; observations and analyses of changes that have occurred; predictions of climate variability and change at the regional and local scale and of their inherent uncertainties, including predictions of the climatology of extreme events (e.g. tropical cyclones, winter storms, regional floods, droughts and dangerous air quality); consequence assessment tools, which can utilize environmental, economic and social information to predict societal and environmental outcomes.

Required investments

Delivering the benefits from this ambitious endeavour will require building upon the Group on Earth Observations (GEO) as an international organizational framework that will coordinate the proposed Weather, Climate and Earth-system Project across the weather, climate, Earth system, natural hazards and socio-economic disciplines, including the infrastructure required to support the project elements described above. The effort will also require the following:

- Stemming the current decline in surface and upper-air global observing networks and the development and implementation of a new generation of in-situ and space-based observing systems to meet the ever-increasing observational demands of prediction early warning systems today and in future generations.
- High-performance computing facilities with sustained speeds of more than 10,000 times the most advanced computers of today (achievable within 10-20 years), including advanced data processing, information distribution and visualization systems. Each facility needs to be staffed with a critical mass of scientists and technicians, and linked to a global network of research, forecast and early warning centres.
- Education, science and technology transfer projects to enhance awareness and utilization of weather, climate, environmental and socio-economic information.
- Infrastructure to transition project achievements into operational products and services.

The way ahead

The proposed weather, climate and Earth system prediction project will be comparable in scale to the Apollo Moon Project, Genome Project, International Space Station and Hubble Telescope, with socio-economic and an environmental benefits-to-cost ratio that is much higher. It will provide the capacity to: realize the full benefits of GEOSS, and to accelerate major advances in weather and climate prediction and their socio-economic and environmental applications. It will require unprecedented international collaboration and good will, but the global scope of the problem makes this inescapable, as no single nation possesses the scientific capacity and infrastructure to meet the challenges set forth here. As nations, we have collaborated in the advancement of weather forecasting, climate prediction and global observing systems. As the Group on Earth Observations, we must now extend this collaboration to embrace the Earth system and the socioeconomic and environmental applications of our science. It is a task that must be undertaken.

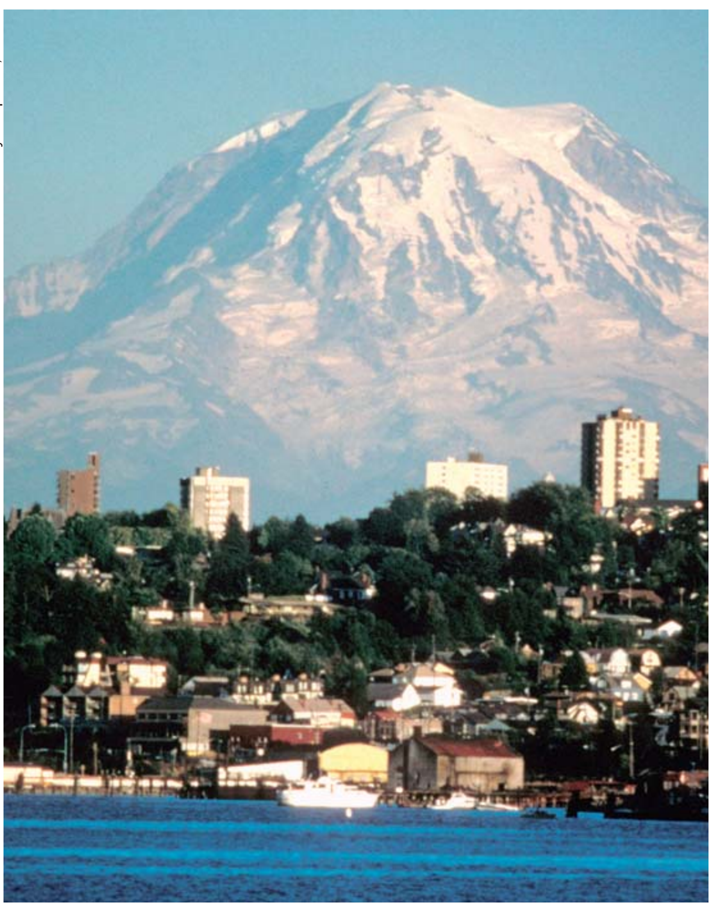
All-hazards, all-media public warning standard

Eliot Christian, United States Geological Survey

When data shows a volcano threatening a major eruption, scientists and emergency managers rush to evaluate the danger. Airborne and satellite observations supplement on-the-ground sensor data, helping local authorities decide where and when to issue official public warnings.

Nothing challenges our humanity, and modern technology, as much as a major disaster. With today's sophisticated Earth Observations, detailed maps, communications and information technology, you would expect that countless lives are saved by early warnings. Yet, for many events in places around the world, societies continue to suffer horribly from disasters. Lives that might have been saved are still being lost, often for lack of solid, timely warnings.

Photo: Lyn Topinka, USGS



All-hazards, all-media warnings are vital in saving lives

Improved early warning of disasters is one of the targeted societal benefits of the new Global Earth Observations System of Systems (GEOSS). In addition to enhancing observations and models, authorities should have the information they need to quickly warn everyone in harm's way, using all available communications media.

Recently, experts agreed on the content standard for all-hazards and all-media public warning. The Common Alerting Protocol (CAP) standard addresses the long-standing need to coordinate all of the mechanisms used for warnings and alerts. Maintained by the Organization for the Advancement of Structured Information Standards (OASIS), the CAP standard is also known as International Telecommunication Union (ITU) Recommendation X.1303.[1]

Obviously, it is a major challenge to assure that standards-based, all-hazards, all-media public warning becomes available to societies worldwide. The ITU is urging nations to implement the CAP standard. Guidelines for developing nations are being published by the ITU Development sector. In addition, official alerting authorities everywhere can now take advantage of the commercial vendor offer of no-charge, high-performance and high-reliability hosting of CAP alerts, including authentication.

Official CAP alerts for earthquake and volcano events around the world are already available. CAP alerts for severe weather and other kinds of events are available on an experimental basis for some regions.[2] In 2007, the United States is implementing a new law that updates its national Emergency Alert System. This will require CAP-based public warning by wireless communications and other service providers.

Benefits of the Common Alerting Protocol

With adequate warning, people can act to reduce damage and loss of life from natural and man-made hazard events. The key is to get timely and appropriate warnings to everyone who needs them, and only to those who need them. Yet, appropriate and complete alerting is a complex challenge given the wide variety of warning systems. Many are specific to a certain type of disaster, such as an earthquake or typhoon, or to a certain warning media, such as a siren or television announcement.

Photo: Cyrus Read, AVO/USGS

Volcanoes are monitored to warn of an eruption

CAP serves as a kind of universal adaptor for alert messages. The CAP standard message format has the features essential for both existing and emerging alert systems and sensor technologies. This means CAP can replace many single-purpose interfaces between alert sources and dissemination media. From the perspective of warnings technology, CAP is also a breakthrough standard that opens the door to technical innovation. For example, location-aware receiving devices use the standardized geospatial information in a CAP message to select messages based on the device's current location.

A key benefit of CAP for sending alert messages is that the sender can activate multiple warning systems with a single input. Using a single input reduces the cost and complexity of notifying many warning systems.

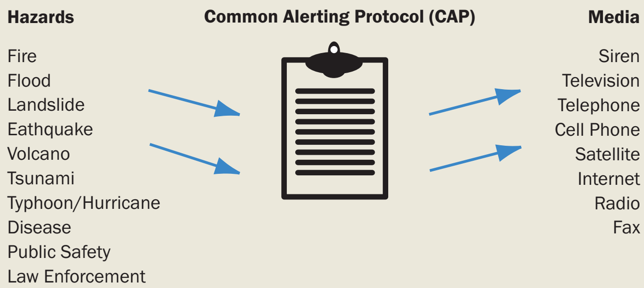
CAP also provides consistency in the information delivered over multiple systems. It is very important that people get exact corroboration of warnings coming through multiple channels. Research has found that people do not typically act on the first warning signal, but begin looking for confirmation. Only when convinced that the warning is not a false alarm, will people act.

CAP is compatible with all kinds of public alerting information systems, including broadcast radio and television as well as data networks. Rather than being defined for a particular communications technology, CAP defines a digital message format applicable to all types of alerts. CAP is therefore compatible with new technologies such as Web services, as well as existing formats. CAP is also very useful where alerting systems serve multilingual and special-needs populations.

A further benefit of CAP for emergency managers is that standardized warnings from many sources can be compiled for situational awareness and pattern detection. Managers are then able to monitor at any time the whole picture across all types of local, regional, and national warnings.

CAP diagram

CAP can replace single-purpose interfaces between alert sources and dissemination media



Source: Eliot Christian

CAP alert messages can also be used at the actual sensor systems, as a format for direct reporting of relevant events to collection and analysis centres.

CAP format for warning messages

Effective warning systems should reach everyone who is at risk, wherever they are and whenever the event occurs, yet not alarm people unnecessarily. Systems must be easy to use, reliable and secure. Messages must be accurate, specific and action-oriented. Messages must also be understandable, with attention to the prior knowledge and experience of the receivers. It is also critical that times, places and instructions are easily understood.

In addition to text instructions and a description of the event, CAP messages convey the event's 'Urgency', 'Severity' and 'Certainty'. Urgency describes how much time is available to prepare, Severity describes the intensity of the impact, and Certainty states how confident is the observation or prediction.

An event is typically assigned to a category (e.g. geophysical, meteorological, safety, security, rescue, fire, health, environmental, transportation or infrastructure). A CAP message can also include digital images and audio. Including audio in a CAP message allows for broadcasting a warning directly on radio, without requiring an announcer to read the message.

Each CAP message has a unique identification number, and may reference related CAP messages. CAP messages include the status and time sent, allowing one message to serve as an update or cancellation of a previous message. CAP messages are compatible with digital encryption and signature techniques that ensure the reliability and security of the message.

A CAP message can have multiple segments. This allows parts of the message to be tailored for different audiences and languages. Each segment also has a geographic description, so that multiple segments might have information for different areas. For example, perhaps an industrial fire threatens a major explosion. The alerting official prepares one message with separate instructions for three areas: evacuation within a mile of the fire; shelter-in-place for those in the dispersion plume, and warning for aircraft to stay above 2,500 feet near the fire. The sender typically designates geographic areas by drawing on a map while creating the CAP message.

CAP coding

An example of a CAP message, warning of a severe thunderstorm. By using standardized coding, the warning can reach those at risk, across all communications media.


```
<?xml version = “1.0” encoding = “UTF”-8”?>
<alert xmlns = “urn:oasis:names :tc: emergency :cap:1.1”>
  <identifier>KS TO1055887203</identifier>
  <sender>KS TO@NWS.NOAA.GOV</sender>
  <sent>2003-06-17T14:57:00-07:00</sent>
  <status>Actual</status>
  <msgType>Alert</msgType>
  <scope>Public</scope>
   <info>
   <category>Met</category>
   <event>Severe Thunderstorm</event>
   <responseType>Shelter</responseType>
   <urgency>Immediate</urgency>
   <severity>Severe</severity>
   <certainty>Observed</certainty>
   <senderName>National Weather Service Sacramento
   CA</senderName>
   <headline>Severe Thunderstorm Warning</headline>
   <description>Radar indicated a severe thunderstorm
   over Alpine County... moving southwest at 5 mph.
   Hail...intense rain and strong damaging winds are likely
   with this storm.</description>
   <instruction>take cover in a substantial shelter until the
   storm passes.</instruction>
   <area>
    <areaDesc>extreme north central Tuolumne County in
    California, extreme northeastern Calaveras County in
    California, southwestern Alpine County in
    California</areaDesc>
   <polygon>38.47,-120.14 38.34,-119.95 38.52,-119.74
   38.62,-119.89 38.47,-120.14</polygon>
  </area>
  </info>
</alert>
```


Source: Eliot Christian

Call to action for GEO

Although responsibility for warnings is a matter for local authorities, the Group on Earth Observations (GEO) is a unique forum for coordinating natural hazards information worldwide. All-hazards, all-media public warning applies to eight of the GEO societal benefit areas:

- Disasters — natural and man-made hazard alerts
- Agriculture — disease, pests, drought alerts
- Biodiversity — invasive species alerts
- Ecosystems — oil spill, algal bloom alerts
- Energy — infrastructure, geomagnetic storm alerts
- Health — disease outbreaks, public health alerts
- Water — floods, droughts, water quality alerts
- Weather — severe weather alerts.

In 2004, many lives were lost due to ineffective public warning even after detection of the tsunami. Today, GEO is helping to raise consciousness about standards-based all-hazards, all-media public warning. Soon, more actions will follow, by ministers whose agencies create alerts, and by ministers whose agencies regulate information and communications technology.

The North American Drought Monitor and a Global Drought Early Warning System

Jay Lawrimore, Richard Heim and Tim Owen, NOAA National Climatic Data Center, USA; Mark Svoboda, National Drought Mitigation Center, USA; Valentina Davydova, Servicio Meteorólógico Nacional, Mexico; Dwayne Chobanik, Agriculture and Agri-Food Canada, National Agroclimate Information Service; Brad Rippey, US Department of Agriculture; and Doug LeComte, NOAA Climate Prediction Center, USA

Water availability is emerging as a critical concern for the 21st century. While drought is a recurring phenomena that has plagued civilizations throughout history, today it is one of the world's most costly and far-reaching natural hazards. In many countries, such as Australia, China, and the United States, drought occurs over a portion of the country each year. Even in countries such as Brazil where tropical climates dominate, drought is a recurring and costly event.

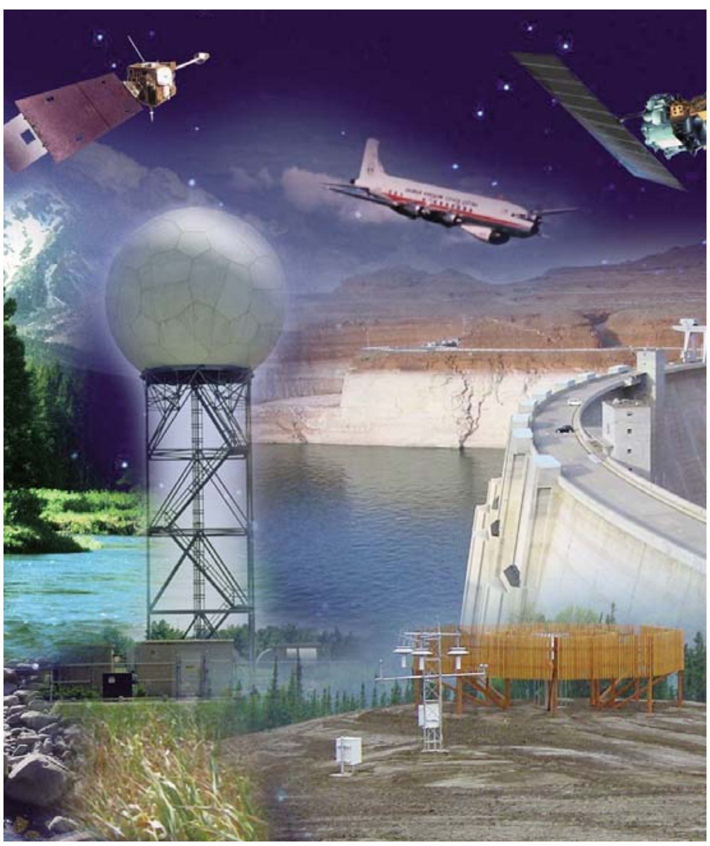


Photo: Brad Udall

Observations from in situ observing systems, satellite, and radar are essential for drought monitoring; included among key measures of drought are temperature, precipitation, streamflow, snow pack, reservoir levels, and groundwater

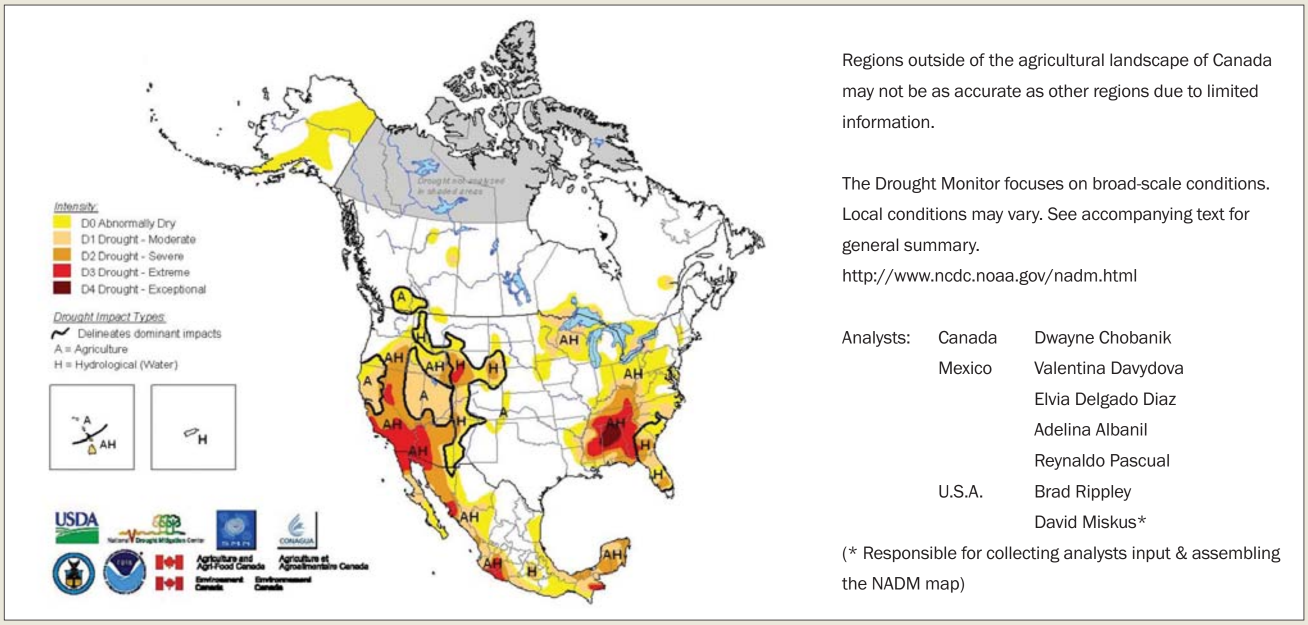
There are warnings of potential increases in the frequency and intensity of droughts as a consequence of climate change. This expected change in drought climatology, coincident with population increases and other factors such as health crises, conflict, and unsustainable use of natural resources (especially water) combine to magnify drought's impacts. While the world's poorest people most frequently and severely feel the effects of drought, it has a universal impact on natural habitats, ecosystems, and the economies and societies within both developed and developing nations.

In the US drought affects more people than any other natural hazard and it is one of the most costly, with direct losses that average between USD6 to 8 billion each year.[1] In Mexico, 78 per cent of the federal funds spent by the program of Attention to Natural Disasters and Climatological Contingencies between 1995 and 2005 was directed to combat the effects of drought. Furthermore, a new response and planning strategy for the period of 2007 to 2012 is being developed as part of the National Hydric Program (Programa Nacional Hidrico).

On the continent of Australia, drought has affected the most heavily populated areas since 2001, with severe precipitation deficits in 2002 and 2006 helping to rank the past six years alongside 1895 to 1903 and 1938 to 1946 as eastern Australia's most severe long-term droughts since European settlement.[2] The long-term increase in temperature has worsened the severity of drought in Australia,[3] as it has on other continents, and within the past 30 years there is evidence of an increase in the incidence of drought worldwide.[4]

On the continent of Africa, the combination of arid climates and variable rainfall patterns leaves many nations extremely vulnerable to drought and climate change is expected to magnify these problems.[5] Between 1980 and 2000, drought killed more than two million people in Ethiopia, Sudan and Mozambique alone. Almost one million of them died in the Ethiopiaan famine of 1984. Beyond the human cost, drought in

North American Drought Monitor



Example of the North American Drought Monitor map for 1 June 2007. The NADM product is produced on a monthly basis and has been available since 2003 at www.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/index.html

Source: NOAA; SMN; AAFC

Africa causes economic losses of tens of millions of dollars and can reverse years of national development gains.[6]

Defining and monitoring drought

Drought, sometimes referred to as the 'creeping disaster', has a unique character that defies a universal definition. The spatial extent of drought is often greater than other natural hazards and its impacts are often hard to quantify. While all droughts originate from a deficiency in precipitation, a drought's onset may be rapid but most often it develops slowly, making it difficult to determine a beginning and end. Drought may last from months to years, and its severity and spatial extent may vary with time, moving back and forth in amoeba-like fashion through various stages. The way drought responds to anomalies of temperature, precipitation, wind speed, and solar radiation differs depending on time of year, character of the local environment, and type of climate.

Because of drought's unique nature, varying impacts, and indistinct temporal and spatial boundaries, no single set of observations or single objective measure is sufficient for defining its severity or onset. Only through a convergence of evidence is it possible to define the boundaries of drought and produce a depiction of drought severity that can be used by a diverse group of decision makers.

Great quantities of environmental observations from a myriad of land and space-based observing systems are essential to defining the severity and spatial extent of drought. These include, but are not limited to, in situ measurements of temperature and precipitation, soil moisture, humidity, wind speed, and cloud cover. These surface observations are augmented by satellite measurements, which help fill gaps in coverage, while also providing measures of other indicators of drought, such as vegetation health. Computer models that estimate terrestrial and atmospheric conditions such as soil moisture and evaporation also provide key indicators of drought conditions. Other critical sources of information include such measures as reservoir level, streamflow, snowpack, and groundwater conditions.

When data from numerous and diverse observing systems, many of which are unique to individual countries, are openly shared among nations, it becomes possible to fill gaps in knowledge and clearly define the state of drought within and across international borders. In addition, it is essential that there be avenues for communication and collaboration between drought and technical experts within and among nations.

Experts familiar with the unique physical aspects of drought within their country and in similar environments of other countries, through collaboration with others in the scientific community, can develop an accurate and cohesive picture of drought within and across national borders. Furthermore, international partnering and collaborative research efforts lead to more rapid advances in drought monitoring science than would otherwise be possible.

The North American Drought Monitor

The US, Canada, and Mexico,[7] recognizing the need of decision makers for better drought monitoring information, formed a trilateral partnership to enhance drought monitoring on the North American continent.[8] These three countries established the North American Drought Monitor (NADM) programme to provide information on drought conditions across the continent on an ongoing basis, and in so doing, helped achieve the

GEO vision of a future wherein decisions and actions for the benefit of humankind are informed via coordinated, comprehensive and sustained Earth observations and information.

The centrepiece of the NADM is a group of drought experts and database specialists from across the continent working together in an ongoing operational capacity, to carefully compile and analyse disparate climate observations at multiple scales. This service, which is produced in English, French and Spanish translations, serves the needs of user communities within sectors as diverse as agriculture and forestry, water resource management, energy markets, and health.

Because no single definition of drought is appropriate in all situations, drought experts developing the NADM product depend on several key indicators and indices when performing each analysis. Daily temperature and precipitation data for stations across the US, Canada, and Mexico are provided by each country on an operational basis. Monthly temperature and precipitation values are computed from these daily data and used to generate several drought indices, including the Standardized Precipitation Index, percent of normal precipitation, and the Palmer Drought Severity Index. These in situ indices are combined with satellite-based indices and modelled soil moisture data to provide a comprehensive and consistent assessment of moisture conditions across the North American continent, including drought transitions across the international borders. These objective indicators are further combined with input from experts at the local and regional level from across the continent to provide NADM drought experts with information on impacts and conditions which are not available from observations alone.

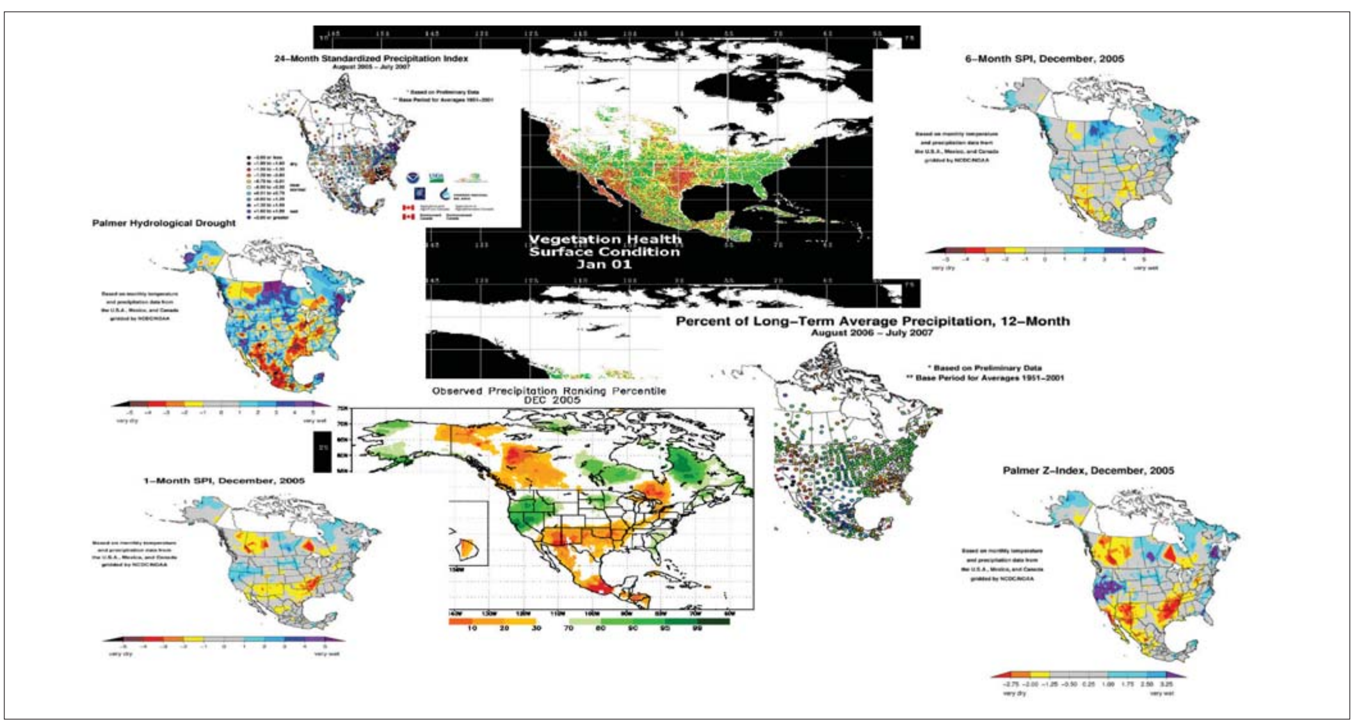
GEOSS principles and functional components formed the basis for development of the NADM program. Close coordination among government leaders and scientists in each country provided the means for identifying critical gaps in existing programmes and in establishing methods for addressing deficiencies. Processes were established to facilitate the open exchange of data and information across borders, which proved a key element of building the capacity to monitor drought conditions on an ongoing basis across the continent. While this effort was successful in improving the delivery of drought information to end users, it also established a precedent for how nations, when working together within a GEOSS framework, can turn disparate observing systems and limited individual resources into an integrated program to enhance decision making.

The National Integrated Drought Information System

Within the US, government leaders have recognized the need to improve the nation's capacity to manage drought-related risks, to provide appropriate information tools to those affected by drought, and to improve the nation's readiness to mitigate the consequences of drought. To meet these needs, a National Integrated Drought Information System (NIDIS) is being established.[9]

Through NIDIS, a drought early warning system will be created with the capabilities to provide accurate, timely and integrated information on drought conditions, at the relevant spatial scale, to facilitate proactive decisions aimed at minimizing the economic, social and ecosystem losses associated with drought. The US intergovernmental leadership and partnerships will be key to the implementation of an integrated national drought monitoring and forecasting system, and NIDIS will support research that focuses on impact mitigation and improved predictive capabilities.

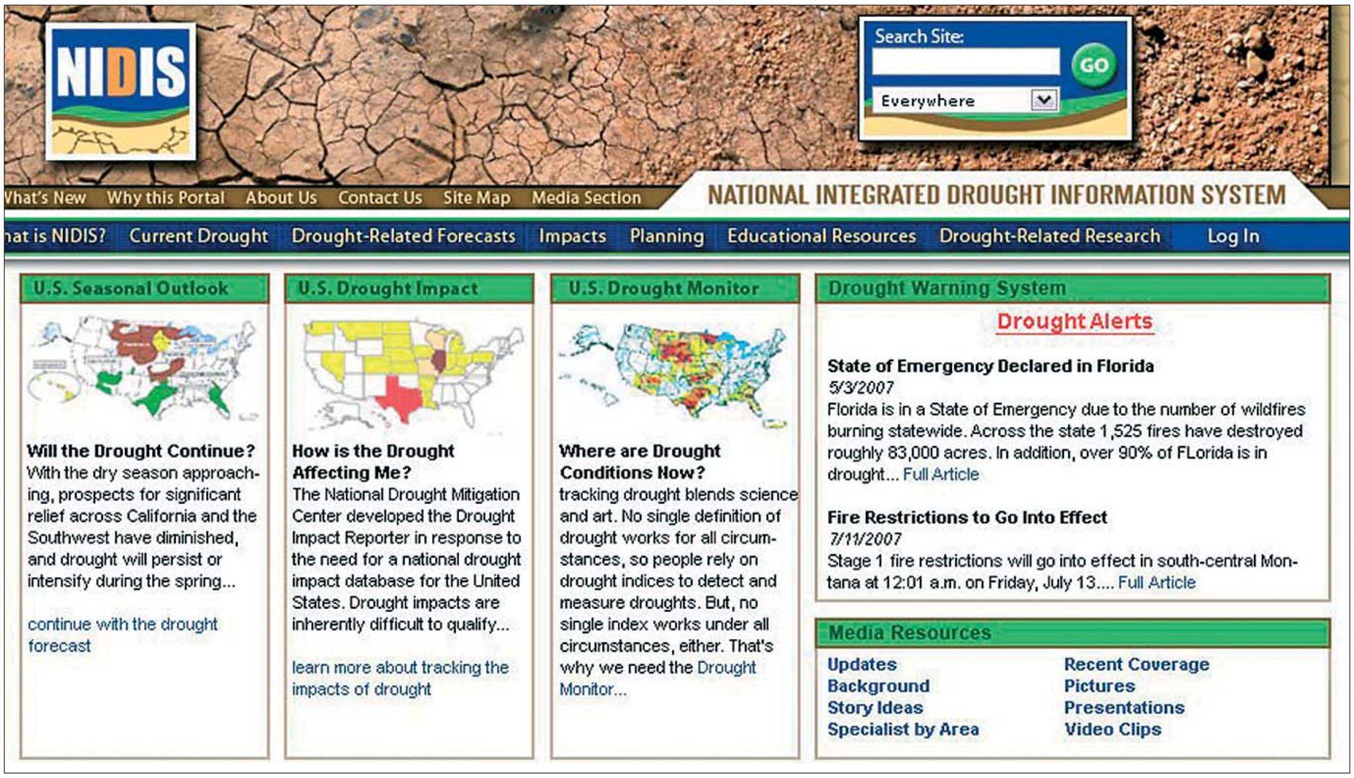
NIDIS will tie operational and research facets of the drought issue into an interactive delivery system for



Source: NOAA; SMN; AAFC

Drought experts rely on numerous objective indicators to determine drought severity levels across the continent

Source: NOAA; NDMC



The US Drought Portal, a key part of the US National Integrated Drought Information System, provides reliable information on drought conditions at county, regional, and national scales, as well as serving as the primary point of entry for drought-related queries to a variety of user groups

drought information, and will provide a framework for interacting with and educating those affected by drought using a web portal environment. While this first-of-a-kind drought information system will provide the US with advanced capabilities for dealing with future droughts, more importantly, it will provide the basis for similar activities on a continental, hemispheric or global scale.

Toward a global drought early warning system

With water availability emerging as a critical concern in the 21st century, international cooperation in water management and drought monitoring and mitigation takes on growing urgency. The NADM and the US National Integrated Drought Information System provide a guidebook for the development of a global drought early warning system. A coordinated early warning system can synergistically develop products, data, and information that span all dimensions from local to national and international. It can provide decision makers with information which is essential for assessing potential impacts and developing planning and response mechanisms to protect societies.

Many nations have important components of a drought early warning system, but no one nation has all of the tools, products, and data to deliver the best system. Through international collaboration the development of knowledge, tools and products needed for an effective early warning system can be greatly accelerated. For example the US and Canada are working together to integrate weather and soil moisture monitoring. While collaboration is in its early stages, improved data and modelling of drought indices and other weather extremes has already been realized.

A global drought early warning system can weave together data from current and future observing systems to provide: information for drought response, planning, mitigation and recovery; an interactive set of analysis tools; and critical drought information to countries with inadequate monitoring resources. In the future the system can provide for data and information sharing, communication, and capacity building to take on the growing worldwide threat of drought. A network of drought experts across the world will work to issue real-time international drought severity assessments as frequently as possible, with increased frequency during a crisis.

A global drought early warning system can also provide benefits including enhanced information for response to disasters such as forest and wildland fires, and where possible, management of the effects of water deficits on water quality and terrestrial and ocean ecology. It will also support improvements in information for water management decisions for human and industrial consumption, agricultural use and energy production.

Through the many observing networks of GEO nations, the world's capacity to monitor drought is greater now than at any time in the past. Building upon this foundation of global observations, capacities to monitor, forecast, plan, and respond to drought can be greatly enhanced with the establishment of new partnerships and the development of new avenues for sharing data and other resources. By acting now the international community will be helping to guarantee nations are prepared to meet the growing threat of drought in the 21st century.

GEOSS and the prediction of short-term changes in the oceanic environment

Ian T. Hunter, Principal Researcher, South African Weather Service

On 14 October 2007 an Apex profiling float belonging to the United Kingdom surfaced 200 nautical miles to the northwest of Cape Town. It had just completed a ten-day operational cycle, spending most of its time drifting at 2,000 metres then rising slowly to the surface, whilst measuring water pressure, temperature and salinity. The data is made available semi-real-time via the satellite-based Argos data collection system. This particular buoy was deployed in September 2005 by the *SA Agulhas* on her way to Gough Island, and has since completed 76 such cycles.

Apex buoys are just one of several different types of profiling floats which make up the Argo network. In October 2007 there were over 2,900 active floats, forming a dense network across the global oceans. This observation system is but one of many that fall under the umbrella of GEO's Global Earth Observation System of Systems (GEOSS). Another such system is the World Weather Watch (WWW) of the WMO. Within WWW the South African Weather Service (SAWS) has a dense network of land-based observation sites and also acts as an important communications hub in the Global Telecommunications System.

With regards to marine observations SAWS has maintained a network of drifting weather buoys in the South Atlantic for three decades. The service has three island-based automatic weather stations and runs a comprehensive measurement programme on the *SA Agulhas* that covers surface and upper air. This vessel also

Photo: courtesy Smit Marine South Africa

The polar relief vessel *SA Agulhas* owned by the South African Department of Environmental Affairs

The Envisat satellite of the European Space Agency. This giant satellite (10x4x4 metres) boasts a multitude of EO sensors including an Advanced Synthetic Aperture Radar (ASAR)

provides an important platform for the deployment of buoys for the Global Drifter Program as well as the Argo project. SAWS operates manned weather stations on Gough and Marion Islands, where meteorologists record surface data and do atmospheric soundings twice per day.

Observing the ocean from space

The value of satellite-based remote sensing of the earth cannot be overemphasized, particularly over the ocean where in situ data may be very sparse. Low earth orbiting satellites measuring upwelling radiation in the visible, IR and far IR portions of the electromagnetic spectrum provide information on a variety of ocean features, at an ever-improving resolution. Particularly important however are those sensors, active and passive, which make use of the microwave portion of the spectrum to essentially bypass the blocking effects of cloud cover and precipitation, and to also continue observations in the dark.

Typical examples of satellite-derived ocean surface parameters are ocean colour (chlorophyll), sea surface temperature, wind vectors, wave height and sea level. The synthetic aperture radar is a particularly versatile satellite-borne sensor which provides very high resolution imagery of sea ice and other ocean features, as well as wave spectra. A good example of the value of satellite data is the measurement of sea ice in the Arctic region, which has revealed a marked downward trend in the residual summer coverage. This could only have been possible with regular satellite passes (over a period of three decades) and the use of a passive microwave sensors.

However, there is still a need for in situ data, which is used to develop and improve the algorithms that turn the raw data from the satellite sensor into useable information.

Modelling the ocean — short-term ocean prediction

Much of the focus on ocean observing systems has been on the modelling of the oceanic environment in order to provide long-term predictions of change, even to the extent of climate trends. However the ever-increasing network of marine observing platforms, fixed and free-drifting, is just as valuable as input to the numerical models which predict what might be referred to as 'ocean weather', which is to say, changes in the ocean environment over periods of a few hours to several days. Obviously this data has to reach the modelling centres as soon as possible after the observation time. Fortunately most oceanographers recognized the benefit of getting data in real-time mode some time ago. With a fixed platform such a wave-measuring buoy or a tide gauge one can at least rectify any fault before too much valuable data has been lost. Even in the case of drifting platforms new generation satellite data communication is two-way, making it possible to activate backup sensors or program transmission changes.

A lot of additional responsibilities tend to be given to National Meteorological Services (NMS) which are not directly related to meteorology. Indeed, some have no relation to meteorology at all. This is simply because NMS are often the only national service which operates day and night, 365 days a year. An example of the former is the prediction of ocean waves. Although surface winds play a very important role in their generation, they are essentially still in the realm of the oceanographer. The

Photo: Ken Mann

Storm surge damage on the east coast of South Africa, March 2007

modelling and prediction of tsunamis has no connection with meteorology at all. Yet the WMO's GTS is utilized to disseminate tsunami warnings, with several NMS having an even more direct involvement in tsunami warning systems. Thus it is quite possible that some NMS may be called upon to run the ocean models when they become fully operational.

The assimilation of data, in situ and satellite-derived, into prediction models is not a simple matter. The introduction of new types of input data may render a model unstable, or even *adversely* affect predictions. Nevertheless the science has progressed such that most of the available real-time data is successfully assimilated into the short-term prediction models: satellite-derived sea temperatures and scatterometer winds into the atmospheric models; altimeter wave heights, salinity and temperature profiles and sea level data into the ocean prediction models. It is also important to remember that the two types of model need to be fully coupled.

Benefits of short-term ocean forecasting

One of the major benefits of the development of ocean prediction models is the new capacity for the analysis and forecasting of ocean circulation, throughout the water column. Some examples follow.

Wave and current interaction, the development of abnormally high waves and the danger to shipping are issues particularly pertinent to the east coast of South Africa (beyond Port Elizabeth, most vessels move inside of the Current, aiming to round Cape Agulhas). There is a long history of vessels suffering major hull damage or even foundering in this region. Wave prediction models have developed to such an extent that their predictions are usually within 0.5-1 metres of the measured wave height and their timing accurate to a matter of hours (the air pressure data from the drifting buoys far off to the southwest play a significant role). SAWS was one of the first NMS to provide warnings of possible abnormal wave conditions. However, with predictions of the position and curvature of the Agulhas Current, much more accurate warnings will be possible and with fewer false alarms. Ten per cent of the vessels rounding the Cape are large tankers — a major oil spill on the coast could have a devastating effect on coastal economies formal and informal.

On a shorter time scale, over smaller distances and in relatively shallow water it is possible to predict oil spill trajectories when the oil is close to the coast. The benefits of these forecasts range from planning the prepositioning of booms to evacuating sensitive marine animal populations. Cape Town has been particularly unfortunate in this regard. In June 2000 a large ore carrier, the *Treasure*, sank at the entrance to Table Bay. Even though this was not a tanker, its 1344 tons of heavy fuel oil affected over 20,000 African Penguins, which are a threatened species. A similar incident occurred in June 1994 when the *Apollo Sea* sank in the same area. This was also a large ore carrier, but the fuel oil was sufficient to pollute a large portion of the pristine Peninsula coastline, and oil over 10,000 penguins. A synthetic aperture radar flying on Radarsat 1 showed clearly the extent of the oil, even through cloud cover.

Photo: Sydney Marais, South African Weather Service

The FPSO (floating production storage offloading) platform *Dalia*. Cables parted in rough seas off the South African coast as the newly built 300 metre vessel was being towed to Angola

More recently a storm surge on the South African east coast resulted in damage totalling hundreds of millions of rands. Furthermore, ongoing financial loss is being experienced by the large tourist industry because the exposed coastline continues to lose sediment. Although fixed structures obviously cannot be moved, much of the property loss could have been prevented if there had been sufficient warning to enable residents to relocate movable objects. An ocean model run in hindcast mode can calculate the long-term likelihood of such an event, providing coastal authorities with advice on reasonable limits to coastal development.

Despite the drive to move away from fossil fuels, the fact is that the oil and gas industry continues to explore for new offshore reserves in increasingly deeper water. Ocean prediction models will be called upon to ensure that these new developments do not threaten the sustainability of other activities in the region. One of the major requirements is a need for ocean current information throughout the water column. Off the southern coast of Namibia is one of the richest offshore *diamond* fields in the world. Numerical ocean modelling supported by data from the GEOSS network and also any additional locally-collected information, would help to predict more accurately the effects of new developments on the environment, as well as to optimize operations in the high wave energy environment.

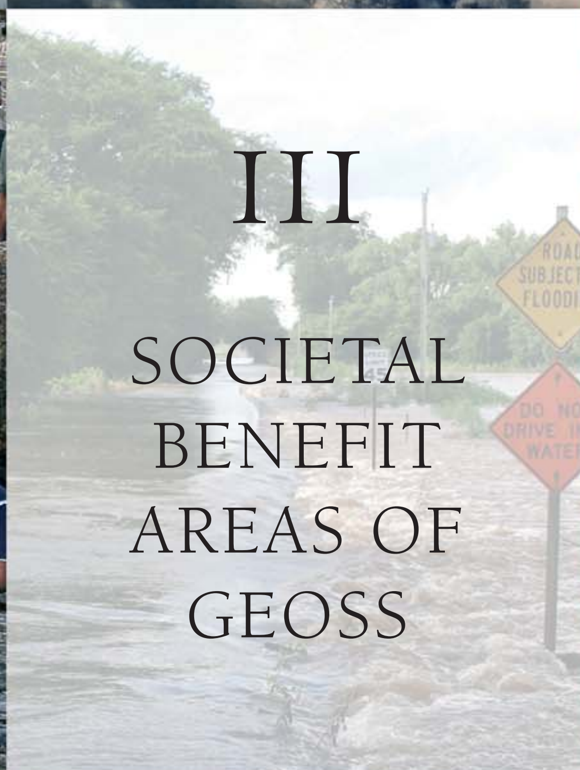
Coastal populations are rising rapidly and Cape Town is no exception, with the municipal population rising by over 15 per cent in the past decade. This puts increasing pressure on the coastal environment, particularly when it comes to getting rid of sewage and waste products from industry. Outfall pipes need to be designed to withstand the heaviest wave and current conditions. In the latter case particularly, actual data is usually very sparse and consists of short records. The only way to generate sufficient data for design purposes is to model the circulation and then run the model in hindcast mode. In May 1984 a very intense low-pressure system southwest of Cape Town resulted in significant wave heights of over ten metres, which caused one of the City's main outfall pipes to rupture.

The role of the smaller maritime NMS in GEOSS and ocean prediction systems

National Meteorological Services with limited resources cannot be expected to run their own ocean models and indeed there should be no need for them to do so. The resolution of global models is ever-improving as computing power increases and it is generally accepted that ocean prediction, like GEOSS, is a global partnership. Smaller NMS are not in a position to contribute to extremely expensive satellite programs. Where they can still play a significant role however, is the collection of quality marine data in their own waters, and by ensuring that they maintain close contact with their international community. Even ocean data which is not available real-time can still perform a vital role by providing verification data for the models, especially in data-sparse waters.







III

SOCIETAL BENEFIT AREAS OF GEOSS




Introduction

The societal benefits of GEOSS

The Global Earth Observing System of Systems (GEOSS) will only succeed if it is user driven. It is therefore most appropriate and promising that its implementation is already being driven by a large variety of users, from developed and developing countries, and from governmental departments and ministries, scientific institutes, industry, and national and international organizations. This chapter of *The Full Picture* offers a broad overview of the many different users and uses that will benefit from GEOSS.

The Implementation Plan for GEOSS posits nine distinct groups of users and uses, which it calls 'societal benefit areas'. The nine areas are disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity. While it is indeed useful to consider the benefits that GEOSS promises to these nine domains, each with its distinct features and needs, the Implementation Plan also recognizes that each benefit area cannot be viewed in isolation. Instead, they are mutually interdependent. They require many 'cross-cutting' or 'synergistic' observation systems, data sets and solutions. The nine societal benefit areas constitute a useful device for helping us to understand more easily an extremely complex and multi-dimensional Earth Observation System of Systems. For the convenience of the reader, the 42 user-oriented outputs and projects that are presented in this chapter are therefore organized according to the societal benefit area that they most closely match.

Disasters

Reducing the loss of life and property from natural and human-induced disasters requires access to a wide range of environmental information. When disaster looms, rapid access to weather forecasts, land and ocean parameters and conditions, the location of transport links and hospitals, and socio-economic conditions can save uncounted lives.

But Earth observations have value long before the need for an emergency response arises. They can also help planners to reduce vulnerability and strengthen preparedness and early warning. And after disaster strikes, environmental information can be used to ensure that any housing or public infrastructure that has been destroyed is reconstructed in a way that reduces future risks.

Ultimately, the key to long-term risk reduction is a better understanding of the relationship between natural disasters and sustainable development, an understanding that can be achieved in part through Earth observations. For example, scenarios of climate change suggest that new types of hazard will emerge in the decades ahead, and that existing hazards may be magnified. Climate forecasts must therefore be an integral part of sustainable development planning and be applied to strategies for adaptation and risk management.

Essential players in establishing GEOSS as a tool for managing disasters and natural hazards include: the UN's International Strategy for Disaster Reduction, which is defining and implementing the multi-hazard approach, whereby early warning systems and response teams can address more than one type of hazard; the Committee on Earth Observation Satellites, which supports the use of satellites for risk management; the Charter on 'Space and major disasters'; the Intergovernmental Oceanographic Commission, which promotes tsunami early warning systems; the United Nations Office for Outer Space Affairs, which is implementing the UN Platform for Space-based Information for Disaster Management and Emergency Response; and the World Meteorological Organization, which is initiating a disaster risk reduction programme.

Health

Understanding the environmental factors that affect human health and well-being requires large quantities of timely data and information on: airborne, marine, and water pollution; stratospheric ozone depletion; persistent organic pollutants; nutrition; noise levels; weather-related disease vectors; and many other variables. GEOSS will improve the flow of environmental data and health statistics to the health community, thus promoting a stronger focus on prevention and contributing to continued and potentially dramatic improvements in human health worldwide.

For example, GEOSS promises to make it possible for vaccination teams from the World Health Organization and other health agencies to integrate their epidemiological maps with Earth observation maps of climate, weather, water supplies, soil conditions, and ecosystems, as well as with maps on topography, bathymetry, population, and transport infrastructure. Thus empowered, health experts will be able to anticipate outbreaks of infectious diseases and to prioritize the supply of vaccines to the areas at highest risk.

Disaster risk reduction and mitigation provisions and a multi-hazard/multi-risk approach are key to development planning

Other health-related uses for integrated Earth observations will include: forecasting potential famines; evaluating the quality and quantity of water and soil needed or available for human use; anticipating water-borne diseases, harmful algal blooms and seafood contamination; addressing the risks of wildland fires, severe weather events and pollution. The key is presenting such comprehensive data sets to health service providers, researchers, policy makers and the general public in user friendly formats that make rapid action possible.

Energy

Improving the management of energy resources, a trillion-dollar economic sector that includes coal, oil and gas as well as solar, wind and hydropower resources, is of critical importance to all countries. Key issues include reliable access to energy, the efficient management of energy resources, stabilizing or reducing greenhouse gas emissions, and reporting energy emissions levels to the UN Climate Change Convention and other bodies.

GEOSS will help governments and companies to manage the environmental impacts of energy, match energy supply and demand, reduce weather-related and other risks to energy infrastructure, provide more accurate inventories of greenhouse gases and pollutants, and evaluate the potential of renewable energy sources.

More specifically, GEOSS will provide data and information relevant to: monitoring and forecasting fluctuations in hydropower, solar, ocean and wind energy sources; assessing and predicting the environmental impacts of energy-resource exploration, extraction, transportation and exploitation; and to informing energy-policy planning in both developing and developed countries.

Activities to strengthen the contribution of GEOSS to energy management are being carried out by the Energy Community of Practice, an international network of GEO members and participating organizations. The Community's current activities include providing online information and other resources, enhancing the interaction between various energy interests and between developed and developing nations, promoting training and education, integrating Earth observation data more firmly into the policymaking process, and engaging a wider array of stakeholders and professional societies in related fields such as sustainable buildings and carbon capture and storage.

Climate

Understanding, assessing, predicting, mitigating and adapting to climate variability and change will produce important benefits for every person on the planet. Virtually every economic sector, social activity and ecological system is affected by long-term climate change, natural climate variability, and extreme weather and climate events.

Improving the management of energy resources, a trillion-dollar economic sector that includes coal, oil and gas as well as solar, wind and hydropower resources, is of critical importance to all countries

A key function of the Global Earth Observation System of Systems, therefore, will be to improve: weather information, forecasting and warning; our understanding of the Earth's weather and climate system; and our ability to predict climate change, as well as to mitigate and adapt to climate change and climate variability.

Meeting the needs of the two societal benefit areas of weather and climate will require: strengthening capacities for observing and modelling conditions at the local, regional and global levels; improving weekly, seasonal, inter-annual and decadal forecasts; improving access to weather and climate data and forecasts, particularly in developing countries; upgrading emissions data for pollutants and greenhouse gases; and enhancing collaboration between the observation, research and user communities.

Achieving these goals poses a major challenge to both the research community and to GEOSS. Many aspects of the global climate system are still not fully understood. Because weather and climate are cross-cutting fields, stronger links are needed between the researchers specializing in weather or climate and researchers working on other Earth systems, natural hazards and socio-economic disciplines. More data from diverse sources (such as satellites and in situ instruments) needs to be integrated. Models must be improved. And information that is user friendly and relevant to the decision makers responsible for minimizing the societal, economic and environmental vulnerabilities of weather events and climate change, needs to be produced and disseminated more effectively.

The lead organizations in the implementation of the climate aspects of GEOSS are the World Meteorological Organization, the United Nations Environment Programme, the Intergovernmental Oceanographic Commission and the Partnership for Observation of the Global Oceans. Many of their climate-related activities are being coordinated through the Global Climate Observing System, the Global Ocean Observing System and the World Climate Research Programme.

Water

Improving water resource management through better understanding of the water cycle will reduce the risks of water scarcity and of floods and droughts. Freshwater is vital for life, and ever larger quantities of good-quality water will be needed for growing human populations over the coming decades. But today, more than 40 per cent of the world's population is faced with water scarcity. Water scarcity, drought and floods are the primary disasters threatening life and property.

Water continuously circulates between the atmosphere, the oceans and the land. The amount available for human consumption and for ensuring ecosystem services is affected by many variables. Unfortunately, current observation systems are inadequate for monitoring long-term changes in the global water system and

Weather and climate affect all societies and ecological systems, and improved knowledge of weather and climate changes underpins many societal benefit areas

their implications for people, the climate and biodiversity. Due to insufficient spatial coverage or inadequate monitoring capabilities, some of the major unknowns about the water cycle include precipitation, soil moisture, evapotranspiration, groundwater, surface runoff, storage in lakes and rivers, water quality, clouds and water vapour, snow cover, and much more.

Harmonizing the various in situ and remote-sensing instruments that monitor the water cycle, and integrating their data remains a work in progress. Greater coordination is needed between the water-cycle and water-resource-management communities, as well as amongst national meteorological and hydrological services and the agencies of the United Nations system. When this is achieved through GEOSS over the coming few years, the full range of water resource managers will have access to new and more powerful decision-support tools that will completely change the way they do their jobs.

Weather

Improving weather information, forecasting and warning will reduce the risks of extreme weather events while optimizing agricultural yields, water management and many other vital outputs and services. Weather forecasting is probably the most mature field of Earth observation, as suggested by the fact that the direct predecessor of the World Meteorological Organization was founded over 130 years ago, in 1873.

Led by the WMO and the national meteorological and hydrological services that constitute its membership, global cooperation on weather information has already contributed to the early achievements of GEOSS. The critical next step is to interlink weather data with the growing number of Earth observation data sets now emerging in the fields of biodiversity, health, energy and elsewhere. This in turn will greatly expand the range of uses to which weather information and forecasts can be put.

Ecosystems

Improving the management and protection of terrestrial, coastal and marine ecosystems will bring enormous societal, economic and, not least, environmental benefits. Greatly expanded and harmonized Earth observations are needed for both conservation and resource management. However, due to the complexity of ecosystems and the resulting challenges of monitoring them closely, many gaps and weaknesses currently exist. The successful implementation of GEOSS will dramatically change this situation.

GEOSS will pursue this goal by facilitating the production of spatial information on ecosystem changes, conditions and trends. This information is needed for confirming whether an ecosystem has the capacity to deliver sustainable services (such as flood control or sustainable timber harvests) and to meet societal needs. Information needs to be presented in the

Improving weather information, forecasting and warning will reduce the risks of extreme weather events

form of maps with sufficient resolution to support national and global decision-making. The kinds of details required could include ecosystem properties such as leaf area, phytoplankton bloom dynamics, primary production, net carbon exchange, energy and water exchange and supporting data such as topography, land use, geology and soils.

Achieving this breadth and depth of information will require the building of an expanded and coordinated network of land, ocean and coastal reference stations. More sensors and platforms are needed, such as synthetic aperture radar and hyperspectral imagers, airborne optical sensors, molecular tools for studying the microbial ecology of marine systems, self-contained flow cytometers for classifying phytoplankton and bacteria, and underwater laser imaging and scanning techniques for detecting terrestrial ecosystem structures. Many other sophisticated instruments are now available, or under development.

Finally, all of the existing and emerging instruments and systems that make up national, regional and global networks need to be interlinked through GEOSS, and their data and results need to be made more readily available in user-friendly formats.

Agriculture

Supporting sustainable agriculture and combating desertification is essential in a world where, according to the UN Food and Agriculture Organization, approximately 830 million people are chronically undernourished. The causes of this widespread malnutrition are complex but primarily linked to poverty. Increasingly variable climate conditions also play a role, particularly in the African subcontinent, where desertification and irregular rainfall combine with weak economies to exacerbate the spectre of hunger.

GEOSS will help to alleviate this continuing humanitarian crisis through the more rigorous monitoring of poverty, food supplies and the exploitation and management of productive lands and ocean areas. Improved environmental information will also enable international relief organizations to plan their activities more effectively. Other benefits will include the early warning of droughts and floods, more adaptive farming practices, and improved management of fisheries and grazing lands.

Although great strides have been made in recent decades with respect to the availability and accessibility of information, improvement is needed. In particular, there is a need for trained personnel and dedicated funding to support the integration of in situ and remote sensing data. The archiving of data in developing countries is also a critical need. Fortunately, the majority of monitoring requirements can be met through existing Earth observation systems.

New, relevant and comprehensive data products built around the flow of Earth observation data are also needed to assist policy makers as they analyse and plan for the future nutrition requirements of their populations. To respond to these challenges, GEO is coordinating efforts in four main areas: land resources (land use and degradation - crop production, soil characteristics and forestry assessment); freshwater resources

Reducing the loss of life and property from natural and human-induced disasters requires access to a wide range of environmental information

(irrigation monitoring, groundwater resources and aquaculture); ocean and coastal resources (aquaculture, shellfish and fish), and socio-economic conditions (population distribution, production intensity, food provision and cultural heritage).

With GEOSS in place, policymakers and farmers alike will be able to use Earth observations for routine and operational agricultural monitoring, yield prediction and risk management, thus ensuring sustainable agriculture and food security.

Biodiversity

Understanding, monitoring and conserving biodiversity is critical to ensuring the sustainable use of the world's biological resources. Key goals include protecting threatened and endangered species, combating invasive alien species and animal-borne diseases, and maintaining species diversity and genetic resources. Each of these specific objectives could be more effectively pursued if decision-making could be based on the ready availability of more accurate scientific data and rapid analyses of these relevant data.

The need to monitor the changes to animal and plant species and communities becomes ever more critical as biodiversity is put under increasing pressure from human activities, such as natural habitat conversion and climate change. New technologies for remote sensing and in situ observation, coupled with pattern recognition and modelling techniques, have opened up promising new means of monitoring species populations and understanding changes in biodiversity.

Implementing GEOSS will unify many disparate biodiversity-observing systems and create a platform for integrating biodiversity data with other types of information. Taxonomic and biological-information gaps will be filled, and the pace of information collection and dissemination increased. An important component of GEOSS will be the Global Biodiversity Observation Network. This network of interoperable biodiversity observation systems will also establish links with other ecological data sets.

Meanwhile, GEO members and participating organizations are working with interested partners to develop a biodiversity observation strategy based on geographic and thematic priorities. They are identifying ecosystems that are: unique or highly diverse; that support migratory, endemic or globally threatened species; whose biodiversity is of socio-economic importance; and which can support the 2010 Convention on Biological Diversity targets.

This brief survey of the societal benefits promised by GEOSS has attempted to set the stage for the articles that follow. While each of the activities and projects described in this chapter are unique, they all share one theme in common: they have been launched to meet the urgent and expanding needs of the human race in the early 21st century. These needs alone justify the large sums of money and energy that are being invested today on Earth observations and on the construction of the Global Earth Observation System of Systems.

Improved use of satellites for risk management

GEO DI-06-09 Steering Committee: Guy Séguin, Chair, Canadian Space Agency; Stephen Ambrose, NASA; Robert Backhaus, DLR; Jérôme Béquignon, ESA; Andrew Eddy, Athena Global; Jérôme Lafeuille, WMO; Francesco Pisano, UNOSAT; Giovanni Rum, GEO Secretariat and David Stevens, UNOOSA

In recent decades, both the frequency and impact of great natural disasters have been increasing. Great disasters are those that overtax the ability of regional authorities to respond, requiring international assistance. The increase in the world's population, increased development in coastal areas and increased vulnerability of modern societies have all contributed to the greater impact of disasters, particularly hydrological events such as typhoons and hurricanes, which are the most frequent hazards and, after earthquakes, the most costly in terms of loss of life.

Satellite contributions

Weather satellites have for many years made well-recognized contributions to disaster warning and prevention, particularly hydrological disasters. More recently, other Earth observation satellites are being used to improve the management of a broader range of natural disasters. This can be achieved through better assessment of risk before events take place, providing accurate warnings of where disasters will occur, assessing the situation of critical infrastructure after an event or supporting the recovery process long after the disaster is over. Dozens of Earth observation satellites orbit the world collecting imagery in the visible, near-infrared and even microwave spectrum. The images provide information about the effects of hazards derived from low and high-resolution data. The data from these satellites can be integrated into disaster warning systems to improve their utility, and may be used to generate maps and products that assist responders in determining the most affected areas and the status of infrastructure. Group on Earth Observation (GEO) members aim to improve access to these unique data sets for disaster managers and ensure that critical observations are sustained over the long term. In the context of GEO, member states are also examining how to ensure operational integration of data into disaster management decision support systems and develop capacity for improved use of satellite imagery.

Source: Courtesy of NASA

Hurricane Isabel from space

Regional initiatives

Following the UNISPACE III conference in July 1999, the European and French space agencies (ESA and CNES) initiated the international charter Space and Major Disasters (the Charter), whose membership now includes the Canadian Space Agency (CSA), US National Oceanic and Atmospheric Administration (NOAA) and US Geological Survey (USGS), Indian Space Research Organization (ISRO), Argentine Space Agency (CONAE), Japan Aerospace Exploration Agency (JAXA), British National Space Centre/DMC and the China National Space Administration (CNSA). The Charter provides a unified system of space data acquisition and delivery to emergency authorities affected by natural or man-made disasters through authorized users. This system has been activated over 150 times, with more than 30 calls in 2007 alone.

In Europe, the Global Monitoring for Environment and Security (GMES) programme of the EU and ESA has identified emergency response as a fast-track core service for implementation. The programme recently released a strategic implementation plan that outlines the context for emergency response, the services GMES will make available to responders, and the technology available to address these needs.

In parallel, 18 Asian countries have come together to form Sentinel Asia, a 'voluntary and best-efforts-basis initiative' led by the Asia-Pacific Regional Space Agency Forum. Sentinel Asia's role is to share disaster information in the Asia-Pacific region on the Digital Asia (Web-GIS) platform and to make the best use of Earth observation satellite data for disaster management in the region. It will initially be an Internet-based, node-distributed, information distribution backbone, eventually distributing relevant satellite and in situ spatial information on multiple hazards. The system will draw on satellite-derived products and imagery from all available Earth observing geostationary or low-earth orbiting satellites, including meteorological satellites. Sentinel Asia is also used to trigger dedicated data acquisitions through participating and cooperating space agencies during disasters in the region. Its initial focus has been on targeted observations in cases of emergency, wildfire monitoring using MODIS, flood monitoring, and capacity building for utilization of satellite imagery by disaster managers. The system is led by a joint project team comprised of 51 organizations including 44 agencies from 18 countries and seven international organizations.

In Latin America, another system provides broad operational support for Global Earth Observation System of Systems (GEOSS) goals, including disasters. SERVIR is a regional visualization and monitoring system for Mesoamerica that integrates satellite and other geospatial data for improved scientific knowledge and decision-making by managers, researchers, students and the general public. SERVIR addresses the nine societal benefit areas of GEOSS. For example, it can be used to monitor and forecast ecological changes and severe events such as forest fires, red tides and tropical storms. SERVIR headquarters are at the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) in Panama. A test bed and rapid prototyping SERVIR facility is managed by the NASA Marshall Space Flight Center. SERVIR implementing agencies include NASA, CATHALAC, the US Agency for International Development (USAID), the Central American Commission for Environment and Development, the World Bank, the Nature Conservancy, the UN Environment Programme and the Institute for the Application of Geospatial Technologies.

Added value and broadened scope

Recognizing the broad range of international activities being undertaken to use satellites in support of disaster management, and the strong potential such technologies offer, the UN has sought to establish a global system that offers broad access to data for all UN member states in support of all phases of disaster management. In its resolution 61/110 of 14 December 2006, the UN General Assembly agreed to establish the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) as a new programme within the Office for Outer Space Affairs (UNOOSA), with the following mission statement: "Ensure that all countries and all relevant international and regional organizations have access to and develop the capacity to use all types of space-based information and services to support the full disaster management cycle." The General Assembly recognized that space technology and its applications can play a vital role in supporting disaster relief operations by providing accurate and timely information and communication support, and also recognized the importance of coordinated applications of space technology in the implementation of the Hyogo Framework for Action. Whereas a number of initiatives in recent years have contributed to making space technologies available for humanitarian and emergency response, UN-SPIDER is the first to focus on the need to ensure access to and use of such solutions during all phases of the disaster, including the risk reduction phase which will significantly contribute to an increasing reduction in loss of lives and property.

GEO work under DI-06-09 has been closely coordinated with UN-SPIDER activities. In June 2007, representatives from GEO members met at UNOOSA headquarters in parallel to a UN-SPIDER meeting to discuss the data needs of risk managers and to begin planning the regular acquisition of a baseline data set. These acquisitions will support global disaster mitigation activities and facilitate the generation of damage maps after events. By increasing the number of satellites available to disaster managers and coordinating the access to data, a virtual constellation of satellites will supply all weather data at low and high resolutions in near-real time in support of disaster response, and baseline data in support of mitigation, warning, response and recovery. GEO member states and participating organizations are currently defining and facilitating the implementation of this constellation for multi-hazard risk managment.

Through GEO, it is hoped that successful systems can be taken one step further. For example, the GEO Secretariat is formulating a request to the Board of the International Charter to extend to all member states the right to directly activate the Charter and access data archives. In parallel, space agencies in the context of CEOS and DI-06-09 are currently discussing how to address needs for data during other phases of the disaster cycle: mitigation, warning and recovery. In order to do this, GEO members are compiling the first comprehensive requirements for satellite data for all disasters on a global basis. This work will build on extensive user requirements analysis in each of the disaster communities involved, as well as technical analyses undertaken by the Committee on Earth Observation Satellites, the Integrated Global Observing Strategy Partnership, the EU and others over the course of the last decade. From this analysis, priority observations will be identified and better coordinated, and mechanisms for broader data access will be established.

Current status and next steps

In the context of DI-06-09, user communities are working with satellite data providers to provide the first comprehensive statement of global requirements for Earth observations to support disaster management. These are compiled taking advantage of regional initiatives such as GMES, Sentinel Asia and SERVIR. Given that requirements aim to address a broad range of natural disasters at every phase of the disaster management cycle, the compilation of these has been demanding. This work includes defining global baseline data sets that meet the basic needs of disaster management communities for forecasts, warnings and recovery. Eventually, GEO members intend to create a virtual constellation of satellites that together can address all phases of disaster management. The initial system architecture is based on existing systems put together to collectively address needs. Future system architecture requirements will address critical gaps identified in the current system of systems. Users and satellite designers and operators will meet in autumn 2007 to validate initial requirements and establish a timeline for creating a system that marries existing, planned and future assets together in one operational service.

Disaster risk management: an investment in development

Maryam Golnaraghi, PhD and Jean-Baptiste Migraine, WMO Disaster Risk Reduction Programme

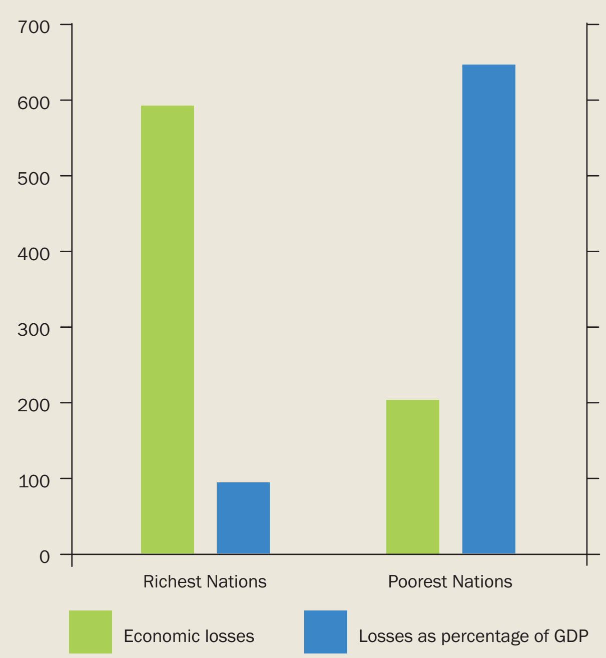
The adoption of the *Hyogo Declaration* and the *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters* (HFA) by 168 countries during the World Conference on Disaster Reduction (January 2005, Kobe, Japan) marked the beginning of a new era for disaster risk management. Over the last few years, a shift toward a more proactive and comprehensive paradigm, with a strong focus on prevention and preparedness, has emerged.

Every year disasters cause significant impacts around the globe. Disasters related to meteorological, hydrological and climate-related hazards such as floods, tropical cyclones, droughts and heat waves are the most frequent and extensive geographically, resulting in the largest share of overall impacts. During the period 1980 — 2005, over two million people were killed in 7,500 disasters caused by natural hazards worldwide.[1] During this period, about 90 per cent of all natural disasters were of meteorological or hydrological origin. These weather, climate and water-related hazards alone have accounted for 1.45 million lost lives and USD900 billion (respectively 72.5 per cent and 75 per cent of natural hazard impacts).

Disasters produce considerable impacts on life, livelihood and property. In developing and least developed countries, these impacts can set back socio-economic development by years, if not decades. While absolute economic impacts of disasters are higher in the richest countries, the impacts relative to gross domestic product are much higher for the least developed nations.

Potential increase in the risks associated with the changing patterns of hydrometeorological hazards (e.g. increasing frequency and severity of droughts, extreme temperatures, precipitation and storms) linked to climate change, as reported in the Fourth IPCC Assessment Reports, further stress a more immediate need for enhanced disaster risk management capacities.

Economic losses



Economic losses from disasters as an absolute, versus losses as a percentage of GDP in the richest and poorest nations

Source: Munich-Re, 1985-1999

Role of WMO and NMHS

Over the years, the World Meteorological Organization (WMO) has acted as an authoritative voice on weather, water, climate and disasters of hydrometeorological origin, and has promoted the importance of prevention and preparedness measures including risk assessment, early warning systems and sectoral planning, to reduce the impacts of weather, climate and water-related hazards. Through the coordinated networks of the national meteorological and hydrological services (NMHS) of its 188 members, WMO coordinates the Global Observing System, Global Telecommunication System and Global Data Processing and Forecasting System networks, providing a wide range of products and services based on observations, monitoring, hazard analysis, forecasting and warnings.

Since its establishment in 1950, one of WMO's core activities has been the consolidation of general requirements for global Earth observations and the coordination of consistent, systematic and continuous collection and archiving of hydrometeorological observations. Furthermore, through establishing standards, guidelines and procedures for data collection, quality control, formatting, archiving and rescue, WMO has assisted countries, through their NMHS, to enhance their capacity in this area. WMO continues to work toward ensuring consistent data quality and accessibility across national boundaries for the purpose of improving risk management capabilities at the regional and sub-regional levels.

Through the WMO Global Observing System, operated by the national meteorological services, data are collected from 17 satellites, hundreds of ocean buoys, thousands of aircraft and ships and nearly 10,000 land-based stations. More than 50,000 weather reports and several thousand charts and digital products are disseminated daily through the WMO Global Telecommunication System, which interconnects all meteorological centres around the globe.

The WMO Global Data Processing and Forecasting System involves three World Meteorological Centres (WMCs) and 40 Regional Specialized Meteorological Centres (RSMCs). They are all operated by NMHS, ensuring cooperation at global, regional and national levels to process data and routinely providing countries with analyses and meteorological forecasts, supporting early warning capacities through the national meteorological services. In addition, WMO supports 30 regional training centres, providing technical training for NMHS management and operations.

WMO's global network has proven highly effective for issuing tropical cyclone (including hurricanes and typhoons) early warnings over the past 20 years in the Atlantic, Pacific and Indian Ocean regions. Through the WMO coordinated observing network, atmospheric and oceanic data are collected via in situ and space-based instruments and distributed to six Regional Specialized Meteorological Centres dedicated to providing tropical cyclone analysis, forecasts and alerts in support of NMHS operational warning systems. These operational capacities are supplemented by five regional committees, involving NMHS forecasters, which ensure ongoing improvements in the tropical cyclone forecasting and warning systems. This has enabled availability of tropical cyclone warning capacities to all countries at risk.

Through the ten scientific and technical programmes of WMO, similar capacities have been developed and are being strengthened on an ongoing basis for monitoring and warning of droughts, floods, extreme temperatures, severe storms, wildland fires, air pollution, sand and dust storms, and transport of nuclear, chemical and biological pollutants related to man-made disasters. These capacities need to be further extended to all countries, particularly those with limited resources. However, WMO recognizes that only through strengthened coordination, collaboration and strategic partnership can these capacities be developed to improve safety of the communities and sustain socio-economic development.

A framework for disaster risk management

Disaster risk management strategies, as detailed in the HFA, can be framed under three main areas: Risk Identification, Risk Reduction and Risk Transfer. The HFA stresses that effective disaster risk management should be supported by effective governance, legislation, legal frameworks and institutional capacities at national to local levels, supplemented by effective information and knowledge sharing mechanisms among different stakeholders.

Risk identification

Risk identification involves understanding and quantification of risk through hazard, vulnerabilities and exposure patterns. It provides the first essential step for developing sound risk management strategies. A fundamental requirement for this is the availability of historical and real-time systematic and consistent observations of hydrometeorological parameters, complemented with other forecast products providing information on expected patterns of hazards from the next hour to longer timeframes. This must be complemented with vulnerability and exposure information as well as tools and methodologies for hazard analysis, mapping and sectoral risk assessment and modelling.

Hazard events are characterized by magnitude, duration, location and timing. Calculating the probability of hazard events in terms of these characteristics is key to fully documenting the hazard component of disaster impacts. These defining characteristics provide a basis for extracting information on hazard frequency and severity from observational datasets. The fundamental requirement is the availability of, and access to, high quality historical meteorological and hydrological data. This requires:

- Ongoing, systematic and consistent observations of hazard-relevant hydrometeorological parameters
- Quality assurance and proper archiving of data into temporally and geographically referenced, consistently catalogued observational datasets
- Ensuring that data can be located and retrieved by users.

Risk characterization would require that hazard information be complemented with socio-economic information related to the impact of disasters. Surveys and reports by UN and international development and financial institutions indicate that in most countries, the concept of risk identification needs to be mainstreamed in the development planning framework at policy to operational levels. In a recent capacity analysis survey conducted by the WMO, nearly 90 per cent of the 139 participating countries indicated the need to strengthen their observing networks; capacities for maintenance of standard hazard databases and metadata; maintenance of sectoral disaster loss data, and methodologies for risk modelling to support development planning in different economic sectors. Given the pervasive nature of hydrometeorological hazards and increasing levels of vulnerability, ability to manage these changes will require continuing and renewed commitment to maintaining the observing networks, basic data, and hazard forecasting capacities needed for identifying and managing risks.

Early warning systems for disaster risk reduction

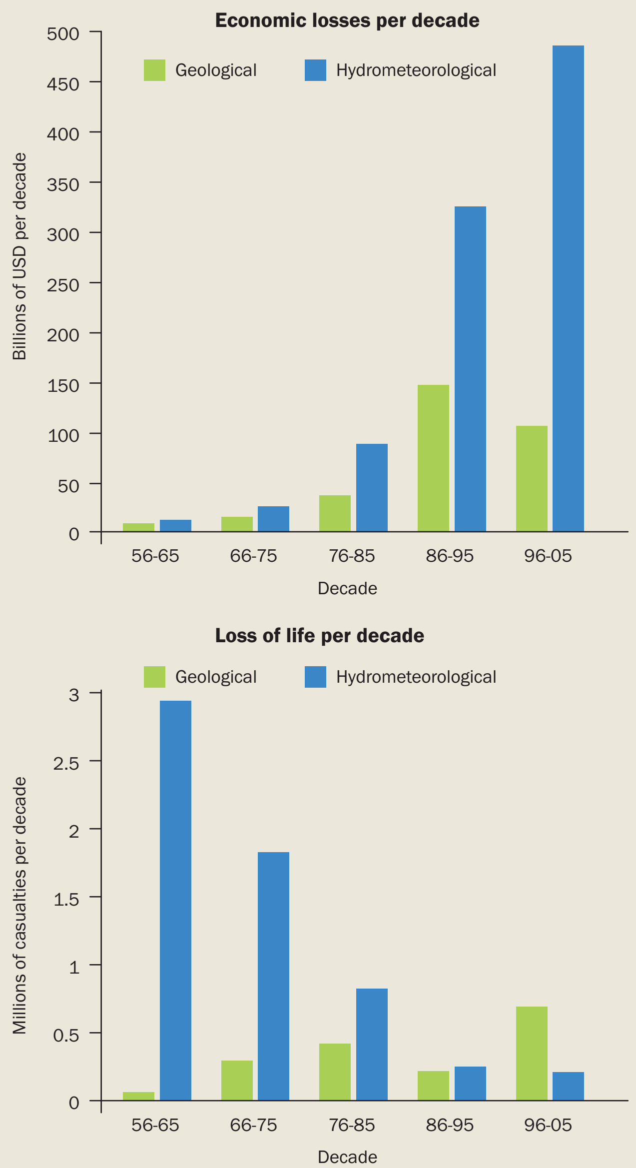
Risk reduction involves actions taken to reduce the overall risks associated with disasters. Such actions would include short-, medium- and long-term sectoral planning, early warning systems and emergency preparedness mechanisms.

The second priority for action in the HFA is to 'identify, assess and monitor disaster risks and enhance early warnings.' This stresses the importance of early warning systems as a critical component of disaster risk reduction. On the global scale, it is worth noting that while the number of disasters and related economic losses have increased steadily over the last five decades, the loss of life associated with hydrometeorological disasters has decreased by a factor of ten. This has been primarily attributed to the development of effective early warning systems, combined with emergency preparedness and response planning.

Effective early warning systems involve four components:

- Observing, detecting and developing hazard forecasts and warnings
- Assessing the potential risks and integrating risk information in the warning messages
- Distributing, rapidly and reliably, understandable warnings to authorities, risk managers and the population at risk
- Emergency preparedness and response to warnings at all relevant levels to minimize potential impacts.

Natural hazard impact trends



Trends in natural hazard impacts over the five last decades show increasing economic losses and decreasing loss of life associated with hydrometeorological hazards

Source: EM-DAT: The OFDA/CRED International Disaster Database

The concept of early warning systems has received significant international attention in the past few years.[2] Results of the *Global Survey of Early Warning Systems*, commissioned by the Former UN Secretary General Kofi Annan, together with national and regional capacity assessment surveys conducted by WMO, indicate that in many countries there is need for development of early warning systems as an integral part of national disaster risk reduction strategies. To be effective, these need to be supported by sectoral planning, legislative processes, institutional cooperation and coordination at national to local levels, to address linkages needed along their four components. Furthermore, in many countries there is a need for organizational, infrastructure and capacity development to support early warning systems.

Risk transfer

Financial risk transfer mechanisms, available through catastrophe insurance and bonds as well as weather risk management markets, enable distribution of the remaining risks associated with extreme events (e.g. floods, droughts, earthquakes and tropical cyclones), and deviation of meteorological conditions from 'normal' (e.g. late onset, warmer or cooler than normal seasons). These markets have primarily focused on developed countries, involving a wide range of standardized and customized financial products targeted at various sectors. However, under the new paradigm of disaster risk management, a number of international agencies including the World Bank, World Food Programme, WMO and the private sector are joining forces to facilitate the development of these markets in developing and least developed countries.

WMO initiatives in support of disaster risk management

WMO Disaster Risk Reduction programme — WMO, through its newly established Disaster Risk Reduction (DRR) Programme,[3] has developed a strategic work plan built upon strengthened cooperation and collaboration among its ten scientific and technical programmes, its members' NMHS and other international and regional partners, to leverage capacities for improved disaster risk management decision-making at national to international levels. WMO's strategic goals in DRR are derived from the HFA, pertaining to those high priority areas that fall under the mandate of WMO and NMHS.

The WMO DRR strategy is focused on:

- Strengthening of NMHS operational capacities in early warning systems with a multi-hazard approach
- Strengthening of hydro-meteorological hazard databases, hazard analysis and mapping and risk assessment tools
- Strengthening NMHS capacities to provide customer-driven products and services targeted at sectoral decision making

- Strengthening of NMHS cooperation with civil protection authorities and other economic sectors
- Capacity development and public awareness.

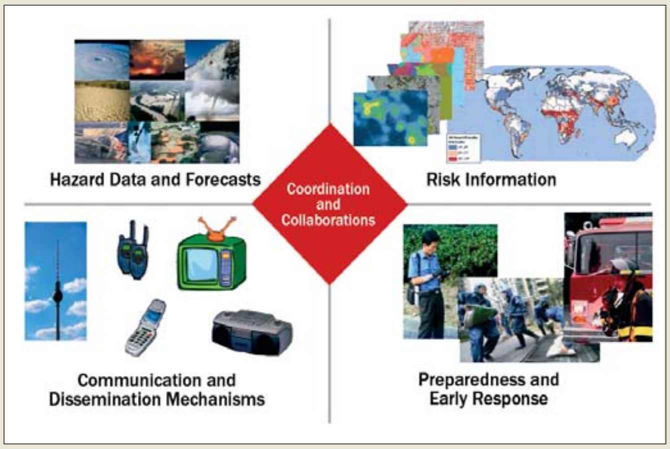
This strategy is being implemented through concrete operational national and regional projects initiated in nearly 30 countries. These efforts are supplemented with initiatives at political and institutional level to promote effective governance, legislation and legal framework for national to local disaster risk management planning; raise awareness to the benefits of hydrometeorological services and role of the NMHS in disaster risk management decision processes, and facilitate NMHS participation in related regional and national coordination mechanisms.

Specifically, WMO has initiated a number of projects in support of modernization of the observing networks and institutional capacities of the NMHS for disaster risk management; hydrometeorological risk assessment; early warning systems with a multi-hazard approach, and utilization of hydrometeorological information for sectoral planning with initial focus on catastrophe insurance and weather risk management markets, as well as humanitarian preparedness and contingency planning.

WMO, together with international development agencies such as the World Bank and its Global Facility for Disaster Reduction and Recovery, is working on modernization of NMHS in South-Eastern Europe and developing a four-year plan for modernization of an additional 20 NMHS.

In collaboration with the Global Risk Identification Programme (GRIP), a consortium involving UNDP, World Bank, Provention Consortium, Munich Re and international financial agencies, WMO will be leading major projects on flood, drought and tropical cyclone risk assessment. These projects involve a wide range of activities such as standardization of hazard databases and metadata, mapping and analysis tools and supporting national risk identification projects through facilitation of cooperation and capacity development of agencies involved in the process. This is complemented by ongoing improvements of regional and global flood, drought and tropical cyclone hazard and disaster impact databases.

Four elements of an end-to-end early warning system



End-to-end early warning systems must coordinate collaborative hazard data and forecasts; risk information; communication and dissemination mechanisms, and preparedness and early response efforts

Source: First WMO Symposium on Multi-Hazard Early Warning Systems (May 2006, Geneva) and Platform for Promotion of Early Warning System

Furthermore, in the area of early warning systems, WMO has initiated a number of projects such as severe weather forecasting in Southern Africa, flash flood guidance systems in Central America and Southern Africa, sand and dust storm warning systems in Middle-East and Northern Africa, drought monitoring and warning systems in South-East Europe and Sub-Saharan Africa, national integrated flood risk management programmes around the globe, and several projects (e.g. France, Shanghai, US/Canada transboundary) to demonstrate and share good practices of early warning systems, supported by strong governance, legislation, organizational and operational frameworks, particularly pertaining to the role of NMHS.

Finally, WMO, in close collaboration with partners from catastrophe insurance and weather risk management markets as well as humanitarian agencies, is developing concrete requirements of these sectors for weather-, water- and climate-related information.

Linkages to GEO and GEOSS

Currently, renewed efforts are underway to address limitations with respect to data quality and consistency, as well as availability and accessibility of relevant data for critical applications such as risk assessment on regional and subregional scales that can support risk identification, risk reduction and risk transfer decision processes. The goal of the international Group on Earth Observations (GEO) is to ensure comprehensive and sustained Earth observations. This initiative builds on, and adds value to, existing Earth observation systems by coordinating their efforts, addressing critical gaps, supporting interoperability, sharing information, reaching a common understanding of user requirements and improving delivery of information to users. This international initiative aims to establish a Global Earth Observation System of Systems (GEOSS) built upon existing capacities and new initiatives over the next decade. GEOSS is intended to achieve comprehensive, coordinated and sustained observations in order to improve monitoring of the state of the Earth, increase understanding of its processes, and enhance prediction of its behaviour. GEOSS seeks to meet the need for timely, quality, long-term global information as a basis for sound decision-making, and to enhance delivery of benefits to society for nine high-priority societal areas — of which one is reducing impacts from natural and human-induced disasters to life and property. WMO, through its DRR Programme, is leading activities in the GEO Work Plan, particularly related to early warning systems and risk assessment.

Governments that recognize the importance of disaster risk management can commit themselves by contributing to GEOSS. Actions include appropriate data-access policies, and legislation and measures to enhance the institutional capacity and operational services of their technical agencies such as NMHS. Furthermore, through close national, regional and international collaboration and exchange of relevant data and information, all countries can benefit from enhanced understanding of the hazards and their impacts, and forecasting capacities, contributing to all aspects of disaster risk management.

Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD): monitoring and early warning systems for wildland fire disaster reduction

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Fire is an increasingly prevalent disturbance on the global landscape with several hundred million hectares of vegetation being burnt every year. Wildland fires (including forest and land fires) occur annually in all vegetation zones, and most global fire is unmonitored and undocumented. Increasing trends in wildland fire activity have been reported in many global regions during the past one or two decades. Wildland fires can have many serious negative impacts on human safety,[1] health,[2] regional economies,[3] global climate change,[4] and fire-sensitive ecosystems. For all of these reasons, uncontrolled wildland fire can have disastrous effects with local to global impacts. In general, jurisdictions with the least capacity to cope with increasing wildfire threat, such as countries with developing economies, are at greater risk from wildfire disaster and its damaging impacts.

The overall damage by uncontrolled wildfires can be mitigated, and sometimes prevented, through fire management activities including fire prevention (e.g. road closures, media information, fire restrictions), pre-positioning and alert scheduling of suppression resources, detection planning, and the use of fire to reduce flammable fuel load. Fire management programmes are highly dependent on fire, weather, and fuels information. These data are used in operational decision-making to 1) establish the extent and activity of current ongoing fires, and 2) predict future fire occurrence and fire behaviour. Fire management occurs at many scales, from the local community to national and international levels. Data requirements range from simple to very complex, generally in proportion to the area of jurisdiction. Fuels (or vegetation) data are basically static for fire management timescales, but fire and weather data are highly variable over short (hourly) time periods. Therefore, these data require rapid transmission. Supplying information to the fire management community at national and international levels is very demanding because the datasets are very large and time-sensitive.

The international panel for Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) carries out several activities to link ground-based and satellite data collection networks in support of global near-real time wildland fire monitoring and early warning. The activities are included in the work of the Group on Earth Observations (GEO). Specifically, work plan task DI-06-13 includes the development of a globally coordinated early warning system for vegetation fires (wildland fires), including the development of improved information products and risk assessment models.

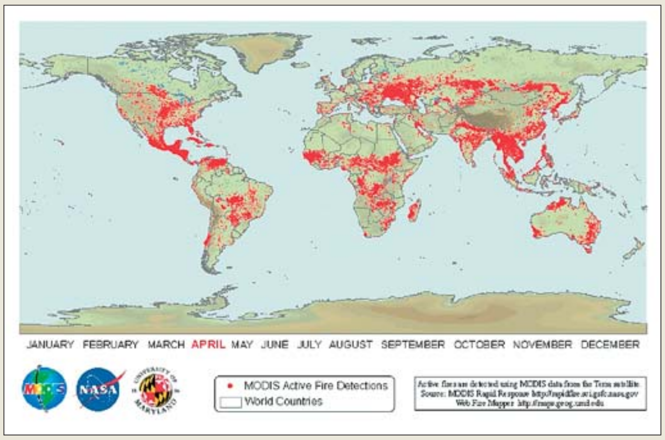
Global near-real time wildland fire monitoring

Polar orbiting systems

GOFC-GOLD-Fire programme is aimed at establishing operational polar orbiters with fire monitoring capability by providing operational moderate resolution long-term global fire products and enhanced regional products.

The polar systems with full operational status are the NOAA Polar Orbiting Environmental Satellites (POES) and the EUMETSAT Polar System (EPS), operating Advanced Very High Resolution Radiometer (AVHRR). Many of the existing national or regional operational systems for detecting active fires rely on AVHRR data downloaded from direct readout stations. The NASA Moderate Resolution Imaging Spectroradiometer (MODIS) research instrument has demonstrated the value that improved spatial resolution, radiometric calibration, geolocation accuracy, and an extended suite of spectral bands can bring to fire remote sensing.[5] Data from the ESA (Advanced) Along-Track Scanning Radiometer ((A)ATSR) have been processed to produce global compilations of night time active fire and burn scars.[6] The US Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) can detect fires at night via low light imaging in the visible wavelength region.[7] GOFC-GOLD-Fire programme is currently focusing on ensuring fire detection capabilities from future systems, such as

MODIS rapid response fire detections for 2005



Global distribution of MODIS active fire detections for April 2005 from the FIRMS system

Source: The Fire Information for Resource Management System (FIRMS)

Photo: Canadian Forest Service, Natural Resources Canada

Northern boreal forest fire

NPP/NPOESS Visible Infrared Imagery Radiometer Suite (VIIRS) and sensors on Global Monitoring for Environment and Security (GMES) Sentinel satellites.

To maximize the societal benefit of these systems to support natural resource management and decision-making, there needs to be a continued emphasis on ensuring that the data are converted to usable information and made available in a timely fashion. This process is becoming easier with advances in web technology and improved access to broadband Internet. Recent advances in information technology make it easier to integrate remote sensing products and GIS data within web-based GIS systems to provide resource managers with information that is timely, accurate, and delivered in a readily accessible format. Technologies already exist to create interactive web maps that incorporate data from a wide range of servers in different locations; a key obstacle to improving these maps for active fire managers is finding suitable data that are up-to-date, accurate, readily available and consistent across regions.

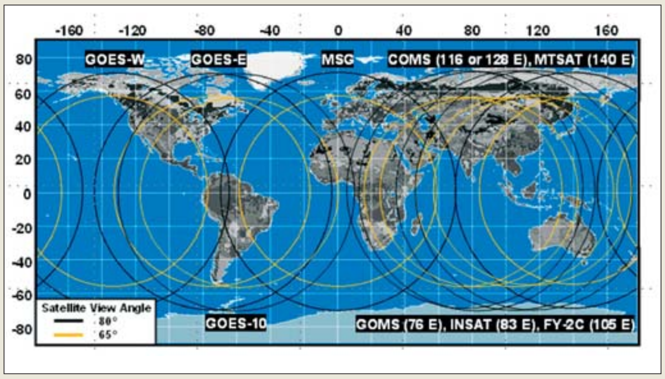
An example of web-based fire information systems is the Fire Information for Resource Management System (FIRMS),[8] developed at the University of Maryland with funding from NASA. FIRMS uses data transmitted from the MODIS instrument on board NASA's Terra and Aqua satellites. These data are processed to produce images and text files pertaining to active fire locations. These are ingested into a geo-database and disseminated to users using web mapping services (known as Web Fire Mapper), e-mail alert and SMS/Text messages, and downloadable files that allow users to access the latest fire locations using GIS software, Google Earth or NASA World Wind. FIRMS works with regional networks to customize the web mapping services; in this way users are able to integrate fire information with local geospatial information (such as park boundaries and roads), enabling them to place MODIS active fires in their geographic context. FIRMS currently provides MODIS active fire data to natural resource managers, scientists and policy makers working in 58 countries.

Geostationary systems

The NOAA series of Geostationary Operational Environmental Satellites (GOES) have had the necessary spectral bands to monitor active fires since the early 1980s, although with limited capability until the implementation of the GOES-8 Imager in 1994. With the launch of the European Meteosat-8 Spinning Enhanced Visible and Infrared Imager (SEVIRI), the Chinese FY-2C stretched Visible and Infrared Spin Scan Radiometer (S-VISSR), and the Japanese Advanced Meteorological Imager (JAMI) on the Multifunctional Transport Satellite (MTSAT-1R), almost global geostationary fire monitoring is possible.[9] Although these geostationary sensors have a reduced spatial resolution (4-5 km in the IR) compared to polar orbiters, they offer enhanced temporal resolution (full disk every 15 minutes with Meteosat-9), providing valuable diurnal information that is complementary to polar orbiting fire products. Over the past ten years, the use of geostationary satellite-derived fire products has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change, emissions monitoring, aerosol and trace gas transport modelling, air quality and land-use and land-cover change detection. The user community includes government agencies, resource and emergency managers, fire managers, educational institutions and the general public.

A specific goal of the GOFC-GOLD-Fire programme is to develop and foster the implementation of a near real-time operational global geostationary fire monitoring network using current (GOES, MSG, MTSAT, FY-2C) and future geostationary platforms (Indian INSAT-3D, Russian GOMS Elektro L MSU-GS, Korean COMS). This effort also supports GEOSS activities and the GEO 2006 work plan, which calls for the initiation of 'a globally coordinated warning system for fire and monitoring for forest conversion, including the development of improved information products and risk assessment models (DI-06-13)' and the expansion of 'the use of meteorological geostationary satellites for the management of non-weather related hazards (DI-06-09).'

Components of a global geostationary fire monitoring system



Current and future network of operational geostationary meteorological satellites with active fire detection capabilities

Source: University of Wisconsin-Madison SSEC/CIMSS

In an effort to coordinate international geostationary fire monitoring efforts, the GOFC-GOLD Fire Monitoring and Implementation Team and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) hosted two workshops on geostationary fire monitoring and applications in Darmstadt, Germany in 2004 and 2006. The 2006 workshop was attended by over 45 representatives from 18 countries in Europe, Africa, Asia and the Americas.[10] This workshop included many presentations on current research and applications of GOES, Met-8, FY-2C, and MTSAT-1R, demonstrating the capabilities of these instruments for fire detection and monitoring. The use of Met-8 SEVIRI data for fire applications has grown significantly throughout Europe and in Africa. FY-2C and MTSAT-1R were launched in 2004 and 2005. Over the past two years, FY-2C and MTSAT-1R have been used to some extent for fire detection and monitoring in Asia and Australia. Furthermore, several operational agencies (e.g. NOAA/NESDIS, EUMETSAT, INPE, UK Met Office, China Meteorological Administration, and India) plan to develop or expand existing geostationary fire detection and monitoring programmes. NOAA/NESDIS and the UK Met Office plan to implement a real-time global geostationary fire monitoring system in 2008 and 2009, respectively. Furthermore, fire detection and monitoring is a requirement for the next generation GOES-R Advanced Baseline Imager (ABI) and the Meteosat Third Generation geostationary platforms.

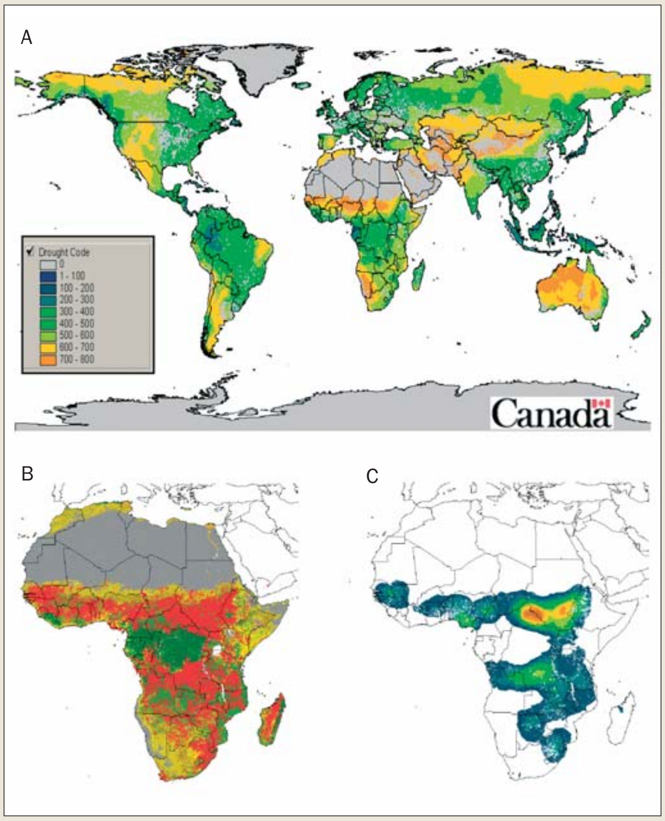
One of the primary recommendations from the 2006 workshop addressed the need to become more closely connected to international working groups and inter-agency efforts to gain better insight into the needs of the global user community, to enable better coordination of data sources and products, and to provide input for future missions. Both international and inter-governmental activities provide suitable forums for reaching a consensus on sensor and algorithmic requirements. In particular, the relationship between the GOFC-GOLD-Fire Global Geostationary Network, the Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observation Satellites (CEOS) was discussed. CGMS, primarily through its working groups, promotes standardization and coordinated operational production by operational agencies. The recently emerged CEOS constellations are aimed at fostering the international planning process for space-based observations. Major elements of the concept include a clear and common statement of requirements defined by the target user communities, definition of a series of virtual satellite constellations that satisfy these requirements, definition of a series of standards for a mission to be included in the constellation, and a process for recognition and acceptance. The standards include requirement of sensor capabilities, calibration and validation and data production and distribution. Many elements of the CEOS constellation process should be adapted by the geostationary fire monitoring network. A strong relationship with the CEOS Working Group on Calibration and Validation also needs to be maintained to ensure ongoing cal/val activities in the community.

Global early warning system for wildland fire

The success of fire management programmes in reducing or preventing wildfire disasters is highly dependent on the ability to predict and prepare for those situations. To do this, forest and land management agencies, as well as landowners and communities, require an early warning system to identify critical periods of extreme fire danger in advance of their occurrence. Early warning of these conditions, with high spatial and temporal resolution, allows fire managers to implement fire prevention, detection, and pre-suppression plans before fire problems begin. Considering that most uncontrolled and destructive wildfires are caused by humans as a consequence of inappropriate use of fire in agriculture, pastoralism and forestry, it is crucial that international wildland fire early warning systems are developed to complement relevant national fire danger warning systems where they exist, to provide early warning where national systems do not exist, and to enhance warnings applied or generated at the local community level. This will ensure delivery of targeted information reflecting specific local conditions and allowing the involvement of local communities in wildland fire prevention.

Fire danger rating is a mature science and has long been used as a tool to provide early warning of the potential for serious wildfires. Fire danger rating systems (FDRS) use basic daily weather data to calculate wildfire potential. FDRS early warning information is often enhanced with satellite data, such as hotspots for early fire detection, and with spectral data on land cover and fuel conditions. Normally, these systems provide a four to six-hour early warning of the highest fire danger for any day for which the weather data is supplied. However, by using forecasted weather data, as much as two weeks of early warning can be provided, depending on the length of the forecast. Ensemble weather prediction systems through multiple realizations of forecasts provide distributions of weather forecasts and capture the inherent predictability and uncertainty associated with such forecasts.

A Global Early Warning System prototype for wildland fire



Examples of potential early warning products, including a) global fire danger using the Drought Code (DC) component of the Canadian Forest Fire Weather Index System (Van Wagner 1987); b) DC overlaid by hotspot data (red), and c) spatial fire threat as assessed by DC and hotspot density

Source: Canadian Forest Service, Natural Resources Canada

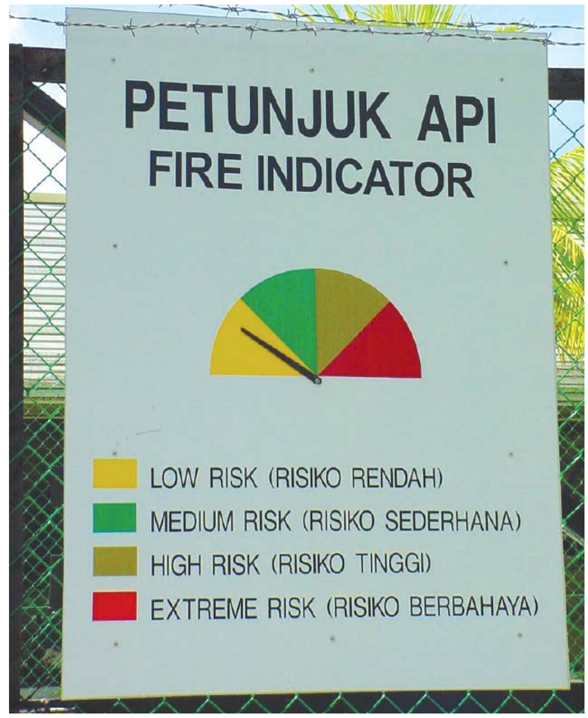


Photo: Canadian Forest Service, Natural Resources Canada

Fire danger sign (Sabah, Malaysia)

FDRS tools for early warning are highly adaptable and have demonstrated their application to a wide range of users, from independent remote field stations (for making local fire suppression and preparedness decisions) to global and regional fire information centres (for large-scale decision making, such as resource sharing across jurisdictions). There are many examples of current operational systems using GIS technology and computer modelling of landscape-level fire danger[11] that process and transfer early warning information very quickly via the World Wide Web.

While the scientific knowledge and technical capability to develop large-scale operational FDRS for early warning exists, a global system has yet to be established. The GOFC-GOLD Fire Implementation Team is leading development of an operational global early warning system for wildland fire through a collaborative international effort by numerous partner agencies.[12] The goal of the early warning project is to establish a scientifically supported, systematic procedure for assessing and predicting international fire danger that can be applied from local to global scales. By integrating existing ground-based and earth observation data networks, the early warning system will meet three primary objectives:

- Support existing national fire management programmes by providing longer-term predictions of fire danger based on advanced numerical weather models
- Provide early warning capability for countries where financial and institutional capacity to develop national systems do not exist
- Provide a common international metric for implementing international resource-sharing agreements during times of fire disaster.

A pilot study, or prototype of the global early warning system is being developed for sub-Saharan Africa.[13] The prototype includes products to support fire management decision-making at national (Ghana), regional (western Africa), and pan-Africa levels. It includes the integration of data from a global network of fire weather data with satellite hot spot data over Africa to display spatial fire threat based on Drought Code[14] and hotspot density. As an early warning product, it can be used to implement a range of fire management activities such as prioritising values at risk, mobilizing resources to the most threatened areas, and enhanced prevention and detection in the critical regions.

Fire management programmes can limit or prevent the damaging effects of uncontrolled wildland fire by implementing fire prevention, detection, and suppression action plans. Operational decision-making is based on the knowledge of current fire activity and early warning of future burning conditions. GOFC-GOLD supports the provision of this information through global monitoring of active wildfires in near-real time using polar orbiting and geostationary systems, and by leading development of a global early warning system for wildland fire using new fire weather forecasting models and remotely sensed fire and vegetation data.

The advanced fire information system

Philip Frost and Dr Bob Scholes, South African Advanced Fire Information System

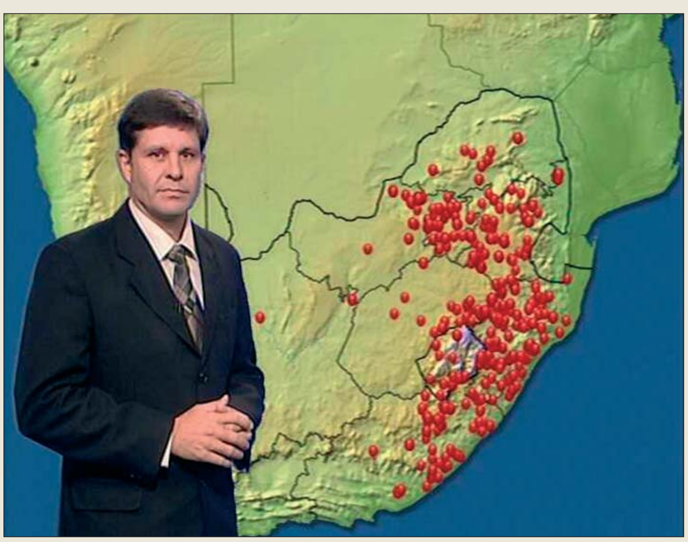
The South African Advanced Fire Information System (AFIS) is the first near real-time satellite-based fire monitoring system in Africa. It was originally developed for, and funded by, the electrical power utility Eskom, to reduce the impact of wild fires on regional electricity supply.[1] Fires underneath the 28,000 km of power lines can cause flashovers which severely affect electricity supply. The loss of life and destruction of property caused every year by wildfires further emphasised the need to develop an operational, early warning fire information system that could alert the disaster management, firefighting, farming and forestry communities on the location and trajectory of blazes, as well as capturing information on the frequency and distribution of fires for researchers. In 1999 the Terra polar-orbiting satellite was launched, with Aqua following in 2002. Both have a MODIS sensor on board that can detect fires with high precision four times a day. These data are coupled with observations from Meteosat Second Generation (MSG), a geostationary weather satellite that provides slightly coarser and less sensitive fire location information every 15 minutes. Eskom implemented AFIS in June 2004, scanning every 15 minutes within a buffer of 5 km along all transmission lines, searching for any fire hotspots. With the detection of a fire, e-mail and SMS text messages are immediately sent to affected parties. AFIS was first implemented using propriety GIS technology, but has now been reengineered as an Open Geospatial Consortium-compliant Sensor Web application which is currently being developed.

Hotspot detection

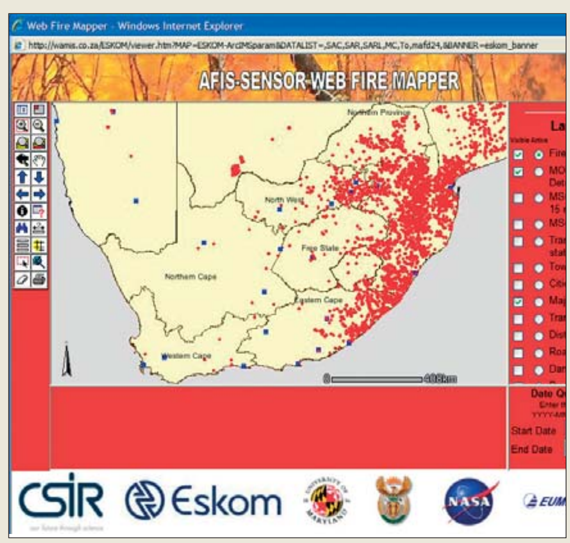
AFIS currently relies on contextual algorithms for hotspot detection using the two MODIS sensors and the SEVERI sensor aboard the geostationary METEOSAT-8 satellite. Though the SEVERI provides almost near real-time hotspot detection, it can only resolve large hotspots (five hectares or more in extent), whereas MODIS can resolve hotspots less than a hectare in size.

The hotspot detection algorithm was originally developed for the Advanced Very High Resolution Radiometer (AVHRR) sensor flown aboard the TIROS satellites. The algorithm uses the short wave infrared and thermal bands to discriminate fire pixels from background pixels. The algorithm first classifies a pixel according to a fixed threshold, e.g. $T > 310K$, to identify potential fire pixels, and the remaining pixels are called background pixels. The neighbourhood of this pixel is then searched for background pixels, growing the neighbourhood if necessary to ensure that at least 25 per cent of the neighbourhood pixels are background pixels. From this set

Advanced fire warnings



The MODIS active fires are incorporated into the weather report once a week on national television



The AFIS web mapper enables people to view fire locations via the Internet

A grass fire burning underneath an Eskom transmission line

of background pixels, the mean and standard deviation statistics are calculated from the difference between the mid-infrared and thermal band. The pixel under consideration is then classified as a hotspot if its mid-infrared value exceeds the background mean by some multiple of the standard deviation. A similar test is performed on the mid-infrared and thermal band difference.

Hotspot detection success rate

The success of AFIS as a management tool within Eskom is measured by its ability to detect fires close to transmission lines before flashovers occur. MODIS was able to detect an average of 44 per cent of all flashover fires during 2003-2005, while MSG detected 46 per cent of all flashover fires during the same period. By combining the detection accuracy of MODIS and MSG within one system (AFIS), the detection rate rose to 60 per cent.[2] The statistics of the MODIS and MSG detections clearly demonstrate the limitations of each of these sensors as a detection tool on its own. The MODIS sensor was able to detect many of the smaller fires, but due to its infrequent revisit time, was unable to detect short-duration fires. The MSG sensor struggled to detect smaller fires but picked them up when they grew big enough to be seen by the current algorithm. The 2 per cent higher detection accuracy calculated for MSG with its lower resolution and less advanced detection algorithm shows the importance of frequent observations.

In order to further improve the detection rate a new, more sensitive non-contextual hotspot algorithm is under development for the SEVERI sensor. The basic approach is to build a general model of the diurnal cycle of the thermal and infrared bands, and then to fit this model to the observed data of the last 24 hours. The model can then be used to generate accurate estimates of the expected background temperatures. If a statistically significant difference between the current observed temperature and the predicted background temperature is observed, then the pixel in question is classified as a hotspot. The first implementation of this algorithm relied on a Kalman filter to provide the estimates of the background temperature. Initial results indicate that this method is significantly more sensitive, particularly in cases where the background temperature is below 300K e.g. early morning.

Extending AFIS functionality

The intention is to shift the emphasis from simple fire detection to more sophisticated fire risk management. This requires a good understanding of what controls wild fire behaviour. The Meraka Institute is currently building domain ontology for wild fires. The ontology will capture key concepts in the wild fire domain such as combustion properties, fuel load, burning regime, fire weather, fire suppression methods and topographical controls. The aim is to use the Sensor Web to observe specific fire-related phenomena described in the wild fire ontology and employ machine reasoning to determine fire risk and issue more useful fire alerts.

Disaster monitoring using ASTER and PALSAR data

Dr Hiroji Tsu, Managing Director, Earth Remote Sensing Data Analysis Center (ERSDAC), Japan

Earth observation from space is a powerful tool for detecting and monitoring the effects of natural disasters such as earthquakes, tsunami, volcanic eruptions, flooding and landslides, as well as manmade effects, such as pollution and land subsidence caused by drawing excessive groundwater or underground mining. As a consequence, information from Earth observation systems has the potential to greatly assist decision makers managing the appropriate disaster response.

ERSDAC is responsible for the scheduling, collection, processing, archiving, distribution and application science of Earth Observation data, including that from the space-borne Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Phased Array type L-band Synthetic Aperture Radar (PALSAR) imaging sensors. Both of these space-borne sensors were funded by the Ministry of Economy, Trade and Industry (METI) of Japan.

ASTER data applications

The ASTER instrument provides 14 spectral bands in the visible to thermal infrared spectral regions for a 60 kilometre wide area, at a pixel spatial resolution of 15-90 m, depending on wavelength region. ASTER also has a downward and backward pointing band suitable for generating digital elevation models.

ERSDAC examined the images ASTER collected prior to and after the devastating magnitude 9.0 earthquake, which centered in the Indian Ocean, west of Aceh in west Sumatra on 26 December 2004. ASTER produced data that showed the land use type prior to the impact of the Tsunami. Such information is valuable for restoration planning.

The infrared bands of ASTER can provide information about surface temperature suitable for applications like volcano monitoring, especially lava and pyroclastic flows, as well as forest fires and the thermal discharge from power plants. In this way the eruption of the Merapi volcano in the Central Java, 2006 was monitored. At shorter ASTER wavelength bands (VNIR: Visible and Near Infrared) clouds of ash and water vapor clearly were caught, but the related lava and/or pyroclastic flows were not evident. In contrast, the longer wavelength ASTER bands (SWIR: Short Wave Infrared) see through the clouds to detect the high temperatures associated with the flows/vent.

Analysis of the time series of ASTER images revealed that the volcanic crater was filled with lava on 14 May and that the lava overflowed in two directions, namely to the southwest and south-southeast, on 30 May. On 6 June, the lava changed flow direction again and proceeded down in a southwest direction, thus extending its area.

The shape of the land surface is one of the most fundamental geophysical measurements of the Earth, and is dominant controlling factor in virtually all natural process that occur on the land surface. Topography of the land surface also significantly influences processes within the overlaying atmosphere, as well as reflecting the processes in the underlying lithosphere. Consequently topographic information is important across the full spectrum of Earth Sciences.

ASTER has acquired nearly 1.5 million stereoscopic image pairs since its launch, including an ASTER derived digital elevation model of the Mount Fuji region. ERSDAC and NASA are currently collaborating on a project to use this archive of stereoscopic data to gener-

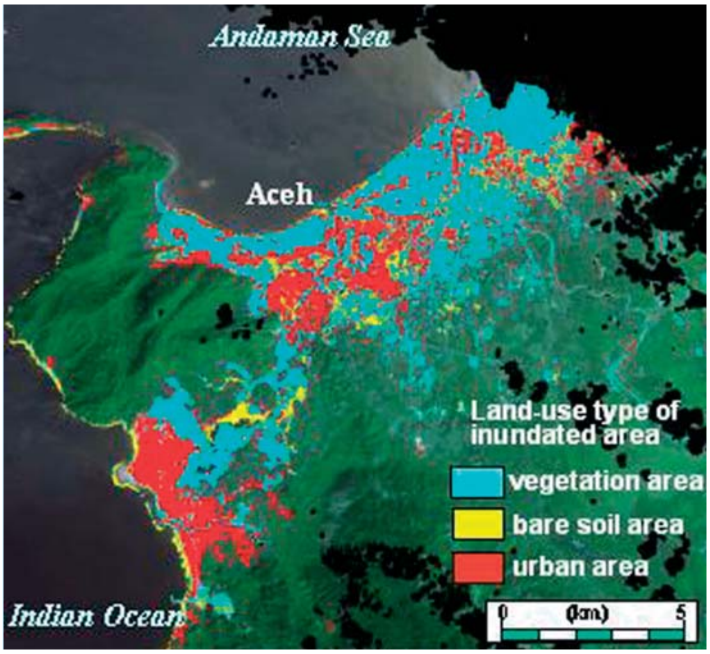


Photo: METI/NASA retain ownership of ASTER data. Processed by ERSDAC

Tsunami affected area and its land-use type in and around Aceh, North Sumatra ate a Global Digital Elevation Model (ASTER G-DEM), which will comprise a seamless global mesh at 30x30m resolution that extends up into high-latitudes to cover even the most inaccessible mountainous regions.

ASTER G-DEM could be used to provide topographic information on entire drainage basins, which in turn could be used to inform water management, irrigation for agriculture and hydroelectric power generation for industries, as well as flood control planning. Topographical data could also be applied to infrastructure design, including roads, railways and pipelines for oil, gas and water. Specifically such data could be used to plan the best route or pass, establish any necessity for tunnels or bridges and, in general, to estimate the amount of work necessary to complete a project.

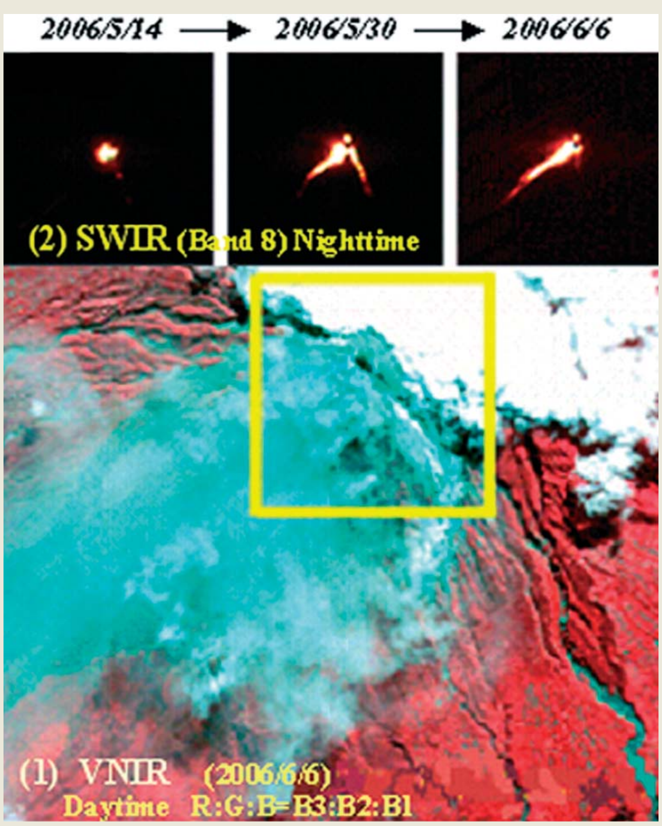
Furthermore, through contribution to Global Earth Observation System of Systems, ASTER G-DEM is expected to make substantial contributions to understanding the Earth and its processes, including water resource management, ocean and marine monitoring, agricultural land use and mineral and energy resources.

Application of PALSAR data

PALSAR is an L-band interferometric sensor suitable for detecting the three-dimentional movements on a land surface. It is capable of detecting changes of as little as ten centimetres between different dates of image acquisition. This interferometric capability is useful for monitoring subtle movements prior to earthquakes as well as volcano ballooning prior to eruption, landslides and land subsidence.

PALSAR was used to monitor land subsidence related to exploration drilling for hydrocarbons at Sidoarjo, East Java. The drilling triggered the development of a mud volcano on 29 May, 2006. The PALSAR interferometric data showed the level of ground subsidence during a 46-day period from October to November 2006. The interferometric fringes, which are colored cyan, magenta and yellow, indicated the subsided area. There were seven cycles of fringes with the maximum subsidence calculated as approximately 90 centimetres. Areas of wet mud are insensitive to interferometry analysis and thus produce the black tones spatially associated with areas of subsidence. Monitoring the Sidoarjo area using PALSAR allowed for assessment of whether the land subsidence was increasing or decreasing with time, which helped the local administrative authorities to manage the rehabilitation process.

ASTER captured image of volcanic activity, Mt. Merapi, Central Java



VNIR image captured the volcanic fumes and ash-fall damages. SWIR images captured the overflow of hot lava

Source: METI/NASA retain ownership of ASTER data. Processed by ERSDAC

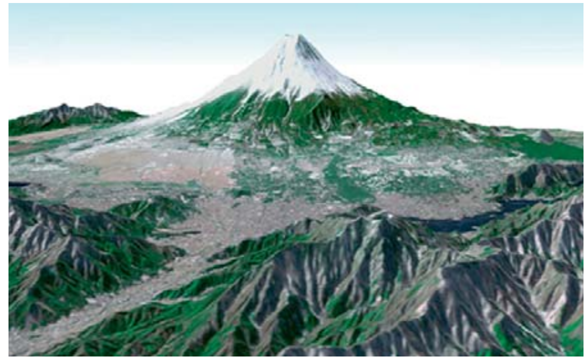


Photo: METI/NASA retain ownership of ASTER data. Processed by ERSDAC

Three dimensional image of Mt. Fuji derived from ASTER VNIR image and ASTER G-DEM

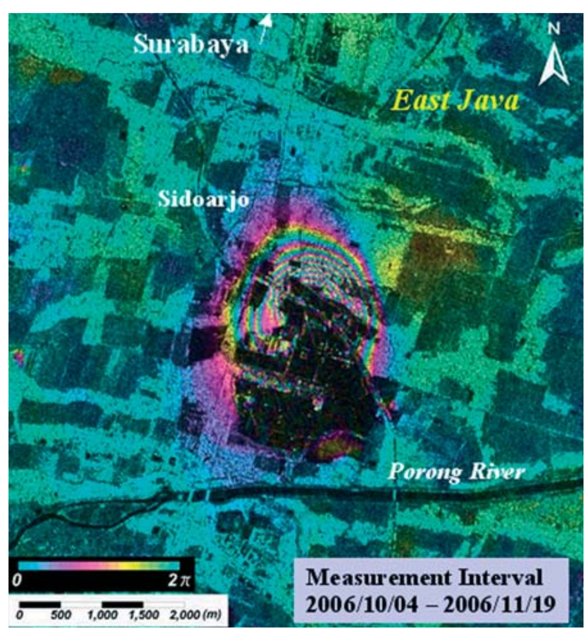


Photo: METI/JAXA retain ownership of PALSAR data. Processed by ERSDAC

Interferogram derived from a pair of PALSAR data. The circular fringe pattern corresponds to the area affected by land subsidence

Contribution of the International Federation of Digital Seismographic Networks (FDSN) to the Global Earth Observation System of Systems

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Rhett Butler, Incorporated Research Institutions for Seismology (IRIS), USA;
Domenico Giardini, Swiss Seismological Service;
Tim Ahern, Data Management Center, (IRIS)

The International Federation of Digital Seismographic Networks (FDSN) is an integrated system of seismological observatories. The data stemming from the seismographic observatories that are part of FDSN are linked to a structured system of networked data centres that make available the information generated to all interested users. FDSN is one of the early contributors to the Global Earth Observation System of Systems (GEOSS), providing high-quality, timely and reliable data to the Group on Earth Observations (GEO) on earthquakes of all sizes that occur anywhere on the globe.

FDSN is a signatory of the ten-year implementation plan of GEO. FDSN provides GEO with an existing and fully functional global infrastructure for the acquisition of seismological information, its transmission to the data centres and its distribution to interested users in a free and open manner. The contribution of FDSN and the seismological information that it collects, stores and distributes has been recognized to be essential to one of the fundamental societal benefits enunciated in the mission of GEO: the reduction of the loss of lives and properties due to natural disasters; in particular, FDSN contributes to the prevention and reduction of losses due to earthquakes and tsunamis.

The data produced by the seismographic stations that are part of the federation has an important impact in understanding the natural processes and phenomena that are responsible for the occurrence of large earthquakes. Over the past 25 years, the scientific use of the data generated by FDSN has been of fundamental importance to understand the seismicity of the Earth, the global dynamic processes that are responsible for this activity and the internal structure of our planet. Seismological data stemming from FDSN stations are routinely used to estimate seismic and tsunami hazard at the regional, local and global level. Here again, the Federation answers an additional societal benefit of GEO: understanding the environment that affects human health and well-being.

Description of the FDSN: structure and membership

The FDSN is an international organization of true global scope instituted in 1986 with the mission of bringing together operators of seismographic stations and networks. Membership in the FDSN is voluntary and there are no fees or contributions. All members participate in the activities of FDSN in a cooperative manner, volunteering their time and resources. The main goal of the FDSN is the collection, archiving and distribution of high-quality seismological observations; all of which is made available to interested users in a timely, free and open manner.

FDSN is formed by 65 organizations from 53 countries that contribute data to the three main data centres in the United States, Europe and Japan. One of the main objectives of FDSN is to encourage the transmission of information in real time. A subset of the stations that are part the FDSN is sent in real-time to the Data Management Center (DMC) of the Incorporated Research Institutions in Seismology (IRIS) consortium. Data from this real-time network are crucial to the determination of the seismic parameters of large earthquakes in a very short time after their occurrence and to support the efforts of institutions that are responsible for disaster relief or prevention.

FDSN promotes the installation of broadband seismographic instruments. This type of seismographs record seismic signals with high fidelity over a very broad range of frequencies, allowing scientists to observe on scale the very small displacements produced by the bell-like oscillations of the whole Earth after a great earthquake, as well as the strong and high-amplitude seismic signals observed at regional distances after major earthquakes. The FDSN serves as a coordinating entity to plan the installation of future seismic stations and networks in order to ensure a homogenous global distribution. Also, FDSN developed and encourages the use of common data format and protocols for data distribution and exchange.

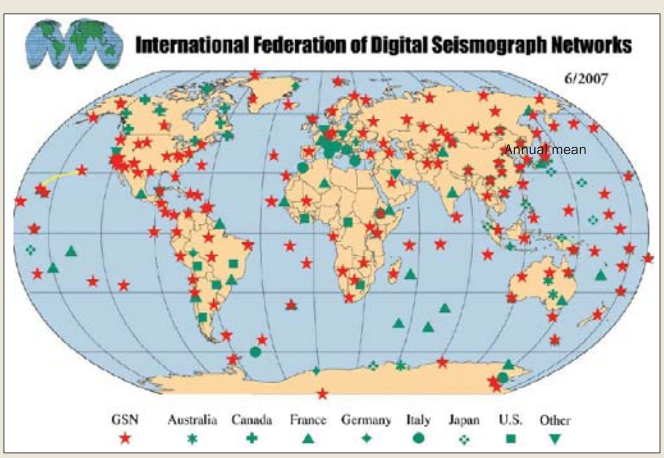
To date, over 6,000 stations contribute data to the three main data centres of the Federation: the DMC in Seattle, Washington; a European consortium called Observatories and Research Facilities for EUropean Seismology (ORFEUS) in de Bilt, the Netherlands, and the Institute for Frontier Research on Earth Evolution (IFREE /JAMSTEC) in Japan. In the exchange of data a common format called Standard for the Exchange of Earthquake Data (SEED) was developed by one of the working groups of the federation, and its use is strongly recommended. This format, however, is not compulsory and members of the federation may transmit their data in a different manner. FDSN has also developed software, which it also distributes freely, to convert into and from SEED most of the formats used today. Common software developed by the federation for data mining and retrieval from all data centres is also freely and openly accessible to users and network operators.

The seismographic networks that contribute data to the federation can be categorized into two main levels. There are global networks that install and maintain a large number of seismographic observatories distributed globally. The Global Seismographic Network (GSN) of IRIS, GEOFON of Germany, GEOSCOPE of France and Pacific21 of Japan, are examples of these global networks, and they all operate state-of-the-art seismological observatories. These networks adhere strictly to the recommendations of the FDSN of using broadband seismic instrumentation to faithfully record the full spectrum of seismic signals with high fidelity. The mission of these global networks is mainly scientific and they all contribute and participate actively in the tsunami warning and disaster prevention efforts at all levels.

Other seismographic networks that are also part of the FDSN are of national, regional or local extent. These networks generally do not have the production of data for scientific research as their main priority. Instead, they are tasked to monitor seismicity and to contribute to the evaluation of seismic hazard in their national territories or regions. These operators are less demanding in the use of broadband seismic instruments and data distribution, and exchange with other users or operators is often controlled by their available technical and financial resources. More and more of these operators, however, are now contributing data to the FDSN data centres both in real time and in archival exchange. The global exchange of seismic data is measured in tens of terabytes per year.

The coverage of seismic observatories around the world is unfortunately not homogeneous. The FDSN is collaborating with national and international agencies and seismological network operators to improve the number and quality of stations in those regions of the world where station distribution is less than ideal. Some examples of regions where seismographic coverage is improving are Latin America, Africa and some parts of Asia. The federation has given high priority to encouraging and supporting the installation of stations on the bottom of the oceans. The Earth, being essentially an oceanic planet, has large areas where the installation of seismological observing stations is restricted to islands. Several international efforts are underway, using cutting edge technology to install seismographic stations in the various ocean basins.

Geographic distribution of FDSN 'Backbone' stations



The FDSN 'Backbone' stations' data are archived at the Data Management Center of IRIS and distributed in real-time by FDSN members. The different symbols indicate the different parent networks contributing the data

Source: Incorporated Research Institutions for Seismology (IRIS)

FDSN and GEOSS: a fruitful interaction

In February 2005, the FDSN subscribed the ten-year implementation plan of GEO. In this manner, FDSN embraced the goals of GEO by contributing seismological data of the highest quality available, which may be distributed openly for the benefit of society. As mentioned above, the federation has encouraged for many years the transmission and distribution of data in real time, another of the main goals of GEOSS. In fact, FDSN is probably the most developed and integrated system of in situ observatories now contributing to the GEOSS effort.

Within GEOSS, the FDSN offers the participation and representation of a global community of seismographic network operators in a coordinated and structured manner. Additionally, the federation has contributed routinely to GEO its expertise in the real-time transmission of data and in the development of common formats and protocols for the transmission, archiving, exchange and retrieval of data.

One of the main goals of GEOSS is the production and distribution of information that allows the future development of sustainable communities and societies. One of the important elements for this is the prevention and reduction of the loss of lives and property caused by natural disasters. FDSN provides GEOSS with the global infrastructure that is crucial to meeting the societal benefit enunciated by GEO of reducing disaster losses in the realm of earthquakes and tsunamis.

The experience of the Sumatra and Indian Ocean tsunami, which claimed over 300,000 lives in 2004, eloquently illustrates the importance of strengthening and improving the timely processing and distribution of relevant data to support the efforts of international agencies and governmental organizations in disaster relief and prevention. Although the primary mission of the FDSN is not disaster prevention, it is well aware of the importance of the data that it produces for these efforts and strives to maintain a close collaboration with those agencies responsible for these tasks. Thus FDSN has offered its own resources and its close collaboration and synergy with other institutions like the US National Earthquake Information Center, the European Mediterranean Seismological Center and the Intergovernmental Oceanographic Commission of UNESCO (IOC), to actively contribute to two of the goals of the ten-year implementation plan of GEO: the reduction of losses due to natural disasters and the understanding of our environment as it may affect human lives and well-being.

Sentinel Asia: supporting disaster management in the Asia-Pacific region

Mr Hideshi Kozawa and Mr Kazuya Kaku, Japan Aerospace Exploration Agency

The Sentinel Asia initiative is a new kind of collaboration between space agencies and disaster management agencies, applying remote sensing and Web-GIS technologies to assist disaster management in the Asia-Pacific region. Its aims are:

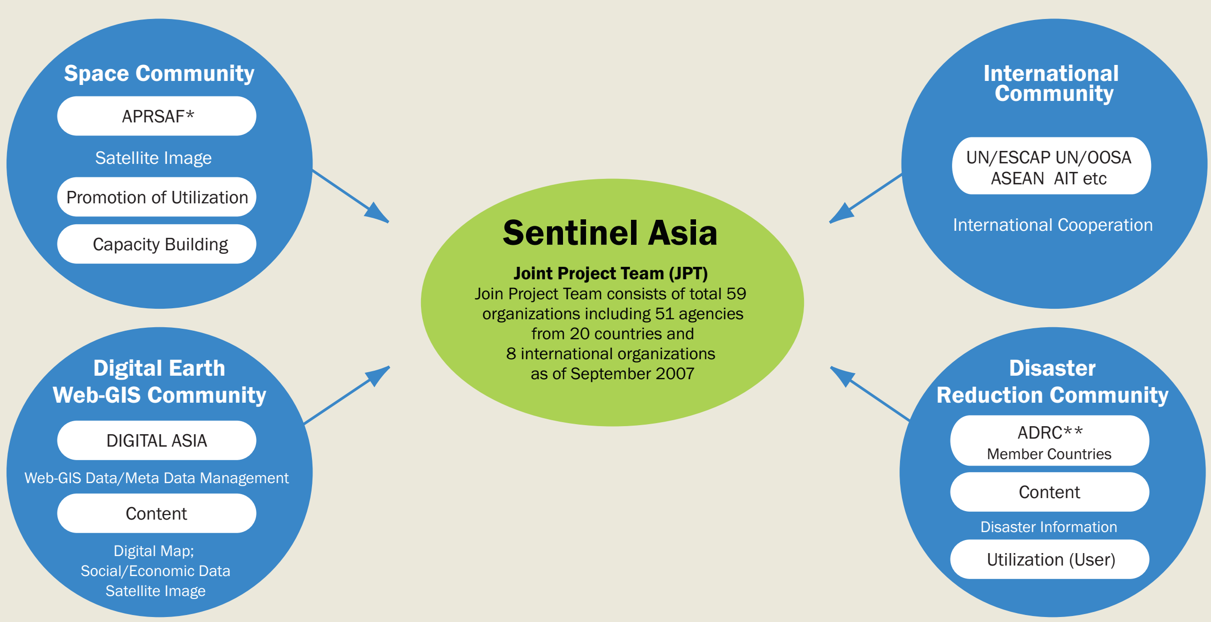
- **To improve safety in society using ICT and space technology**
- **To improve the speed and accuracy of disaster preparedness and early warning**
- **To minimize victims and social/economic losses.**

Sentinel Asia is a voluntary initiative led by the Asia-Pacific Regional Space Agency Forum (APRSAF) to share disaster information in near real time across the Asia-Pacific region, using primarily the Digital Asia (Web-GIS) platform. Its architecture is designed to operate initially as an Internet-based, node-distributed information distribution backbone, eventually distributing relevant satellite and in situ spatial information on multiple hazards in the Asia-Pacific region.

A step-by-step approach for implementation of this dissemination system has been adopted as follows:
Step 1: Implementation of the backbone Sentinel Asia data dissemination system as a pilot project, to showcase the value and impact of the technology using standard Internet dissemination systems (February 2006—December 2007)
Step 2: Expansion of the dissemination backbone with new satellite communication systems (2008 and onwards)
Step 3: Establishment of a comprehensive disaster management support system.

According to statistics, the Asia region has been seriously damaged by natural disasters, compounded by its high levels of population (close to three billion).[1] For

Framework of Sentinel Asia Step 1



*Asian-Pacific Regional Space Agency Forum
**Asian Disaster Reduction Center

example, the number of disasters in Asia is 37 per cent of those across the world, whereas the region has 57 per cent of the global fatalities associated with such disasters, and victims amount to 89 per cent.

In view of these circumstances, APRSAF proposed a new project called Sentinel Asia (SA) in 2005, to showcase the value and impact of Earth observation technologies, combined with near real-time Internet dissemination methods and Web-GIS mapping tools for disaster management support in the Asia-Pacific region. The APRSAF was established in 1993, in response to the declaration adopted by the Asia-Pacific International Space Year Conference (APIC) in 1992, to enhance the development of each country's space programme and to exchange views toward future cooperation in space activities in the Asia-Pacific region. APRSAF was originally designed to provide opportunities for regional space agencies and associated governmental bodies to exchange technical views, opinions and information on national space programmes and space resources.

Framework

Sentinel Asia is promoted under cooperation among the space community (APRSAF), international community (UN/ESCAP, UN/OOSA, ASEAN and AIT etc.), disaster reduction community (Asian Disaster Reduction Center and its member countries) and the digital Asia community (Keio University etc.). To support the implementation of the Sentinel Asia project, a joint project team (JPT) was organized. Membership of the JPT is open to all the APRSAF member countries, disaster prevention organizations and regional/international organizations that are prepared to contribute their experience and technical capabilities and wish to participate in technical aspects of disaster information sharing activities.

Activities

Sentinel Asia consists of two kinds of activities. One is to provide disaster-related information in the Asia-Pacific region, such as satellite imagery and satellite data products through a website. The other is a capacity building project to develop human resources and a human network to utilize the information provided by the website.

The main activities of Sentinel Asia are as follows:

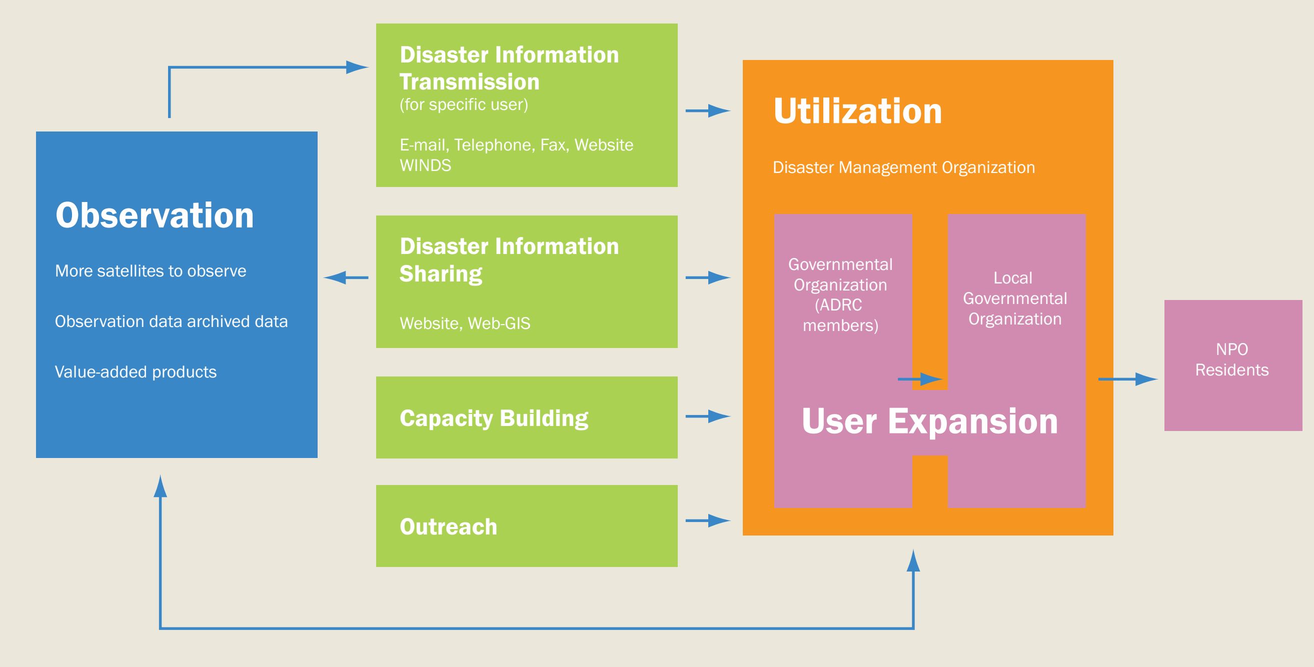
- Emergency observation by Earth observation satellites in case of major disasters, via the observation requests of JPT and ADRC members
- Wildfire monitoring and flood monitoring
- Capacity building for utilization of satellite images for disaster management.

Current status

Sentinel Asia Step 1 began in October 2006 with the opening of its website.[2] The JPT consists of 51 organizations from 20 countries and eight international organizations. The Japan Aerospace Exploration Agency (JAXA) is a secretariat of the JPT.

Currently, a website dedicated to Sentinel Asia is open to the public, providing five areas of information and resources: recent disasters and emergency observation; hotspot data for wildfire monitoring; accumulated precipitation data for flood monitoring in cooperation with the Global Flood Alert System (GFAS); MTSAT imagery in cooperation with the Japan Meteorological Agency (JMA), and capacity building.

Concept of Sentinel Asia Step 2, to expand utilization



Emergency observation in case of major disasters in the Asia-Pacific region has been carried out by JAXA's Advanced Land Observing Satellite (ALOS). The Indian Space Research Organization (ISRO) has agreed to provide Indian Remote Sensing Satellite (IRS) imagery to Sentinel Asia. The Geo-Informatics and Space Technology Development Agency (GISTDA) has also planned to provide imagery from the Thailand Earth Observation System (THEOS), which is scheduled to launch late in 2007.

At the time of writing, emergency observations by ALOS have been activated and images from the onboard sensors have been provided through the website in the context of Sentinel Asia's emergency observation activities.

Records of the recent activations are as follows:

February 2007 — PALSAR (Phased Array type L-band Synthetic Aperture Radar) images were provided for the flood in Jakarta

March 2007 — AVNIR-2 (Advanced Visible and Near Infrared Radiometer type-2) images were provided for the earthquake in West Sumatra, Indonesia. The International Disaster Charter was also activated in this time

April 2007 — AVNIR-2 and PALSAR images were provided for the earthquake in the Solomon Islands. The International Disaster Charter was also activated in this time

May 2007 — AVNIR-2 images were provided for blizzards in Nepal

June 2007 — PALSAR images were provided for flooding and landslide in Bangladesh, and for flooding in Pakistan. The International Disaster Charter was also activated in this time

July 2007 — AVNIR-2 and PALSAR images were provided for earthquake and landslide in Tajikistan. PALSAR images were also provided for floods in Indonesia and Bangladesh.

September 2007 — AVNIR-2 and PALSAR images were provided for the earthquake in Indonesia.

Through operations since October 2006, a good human network has been built between the space community and the disaster reduction community. At the same time, some issues need to be worked on with greater attention, for example narrowband areas in Asia, which make it difficult to see information via the Internet.

Future plans

Sentinel Asia Step 2, which will begin in 2008, is currently being studied by JPT. The concept of Sentinel Asia Step 2 is as follows:

- To promote the use of disaster-related information obtained by space, remote sensing technology and ICT
- To expand users in cooperation with international organisation represented by UNESCAP
- To utilize every possible means for information transmission, taking into consideration different Internet environments in Asia besides websites — for example, e-mail, fax and communication satellites such as the Wideband Internetworking engineering test and Demonstration Satellite (WINDS), which will be launched early in 2008 by JAXA.

The plan and concept of Sentinel Asia Step 2 proposed by the JPT will be discussed in the forthcoming APRSAF-14 in November 2007.

User expansion

The Sentinel Asia Step 1 system has already been established, and services have been opened. However, lessons were learned in the first stage regarding utilization from the users' point of view. It was found that the system was open to any people in the region, but that it had been utilized only among the limited user communities that were close to the regional space agencies or disaster related organizations participating in the project. Of course, there are technical reasons for this, such as the difficulty of downloading satellite imagery in a narrowband Internet environment. However, the largest issue is how to establish links to end users such as regional local government and non-governmental organizations, which are expected to act as core organizations in an actual disaster situation. Step 1 has seen Sentinel Asia contributing, to some extent, to activities in the event of real disasters. However, for Step 2 it is necessary to increase use of the system, and to encourage the development of regional user communities, for example using UN human networks such as UNESCAP, in order to expand Sentinel Asia.

APRSAF has a lot of experience and expertise in system development, while international organizations have broad, strong connections with various communities in the Asia-Pacific region. Some of them will be potential end users of Sentinel Asia.

It is also important to consider how Sentinel Asia can be enhanced for regional communities, and to design a new model of international cooperation between space agency communities and international organizations such as UNESCAP. Looking around other areas of the world, many similar initiatives or cooperative relationships such as UNSPIDER have been conducted and are progressing. If Sentinel Asia achieves successful growth, it is willing to provide its model on the basis of international cooperation, and to extend its lessons and experience worldwide, for example to expand to Africa or South America. Cooperation between JAXA and UNESCAP is key to this, as these organizations are engines for the expansion of Sentinel Asia activities.

Contribution to GEOSS

The Sentinel Asia initiative contributes to the Global Earth Observation System of Systems (GEOSS) task on wildfire warning, and also potentially to the GEONETCast project. This kind of approach could be extended to a worldwide initiative such as 'Sentinel Earth', to include Africa and the Amazon under the overall GEOSS initiative.

A new model of international cooperation is needed between space agency communities and international organizations, in order to expand Sentinel Asia activities. JAXA is at the forefront of such cooperaive efforts

Sea-level rise and vulnerable coastal populations

John A. Church, CSIRO Marine and Atmospheric Research, Antarctic Climate and Ecosystems Cooperative Research Centre; Thorkild Aarup, Intergovernmental Oceanographic Commission, UNESCO; W. Stanley Wilson, US National Oceanic and Atmospheric Administration and Philip L. Woodworth, Permanent Service for Mean Sea Level, Proudman Oceanographic Laboratory

The coastal zone changed profoundly during the 20th century, primarily due to growing populations and increasing urbanization. In 1990, 23 per cent of the world's population (1.2 billion people) lived both within a 100 km distance and 100-metre elevation of the coast at densities about three times higher than the global average. By 2010, 20 out of 30 megacities will be on the coast, with many low-lying locations threatened by sea-level rise. With coastal development continuing at a rapid pace, society is becoming increasingly vulnerable to sea-level rise and variability — as Hurricane Katrina recently demonstrated in New Orleans. For example, in Europe the storm surge of 1953 had a major impact with the loss of over 1,800 lives in the Netherlands and 300 deaths in southeast England. In the Bay of Bengal, there have been 23 surge events since 1737, with over 10,000 people killed in each. The most severe impacts were felt in 1737 (300,000 people killed), 1864 (100,000 people killed), 1876 (100,000 people killed), 1897 (175,000 people killed), 1970 (300,000 people killed) and 1991 (about 140,000 killed and ten million made homeless).

Rising sea levels are felt most acutely through the increased frequency and intensity of extreme storm surges and flooding, even if hurricane intensities do not increase in response to the warming of the oceans. For example, a 100-year coastal flooding event could become a ten-year event at some locations before the end of the 21st century. Increases in the frequency of extreme sea levels of a given height have already been observed in a number of locations around the world, particularly in the Pacific Ocean and along the east coast of North America. Data from Australia's east and west coasts indicates that high sea levels of a given value occurred about three times as often in the latter half of the 20th century compared with the first half. Many coastal megacities are built on deltaic regions where significant sinking is occurring, making these cities particularly vulnerable to these extreme events. Unless such change is taken into account, design criteria for existing coastal structures can become out-of-date and lead to catastrophic flooding such as experienced in New Orleans with Hurricane Katrina. Moreover, the possibility that severe weather events may become more frequent and/or intense with our changing climate can only make matters worse.

Rising sea levels will also contribute to the erosion of the world's sandy beaches, 70 per cent of which have been retreating over the past century, with less than ten per cent prograding. Sandy-beach erosion commonly occurs at tens to hundreds of times the rate of sea-level rise and will degrade or remove protective coastal features such as sand dunes and vegetation, further increasing the risk of coastal flooding. Low-lying islands are particularly vulnerable to sea-level rise.

An improved understanding of sea-level rise and variability will help reduce the uncertainties associated with sea-level rise projections, thus contributing to more effective coastal planning and management. Adaptation measures, including enhanced building codes, restrictions on where to build, and developing infrastructures better able to cope with flooding, should help to minimize the potential losses.

Rising sea levels

Since the beginning of high-accuracy satellite altimetry in the early 1990s, global mean sea level has been rising at a rate of about 3.2 mm/year, compared to a rate of 1.7 mm/year over the previous century. About a third to a half of the sea-level rise during the first decade of the altimeter record can be attributed to thermal expansion due to a warming of the oceans; the other major contributions include the combined effects of melting glaciers and ice sheets. Changes in the storage of water on land (such as the depletion of aquifers and increases in dams and reservoirs) remain very uncertain.

The Intergovernmental Panel on Climate Change (IPCC) provides the most authoritative information on projected sea-level change. The most recent IPCC report projected a sea-level rise of 18 cm to 59 cm by 2095, plus an additional 10-20 cm to allow for a potential response of the ice sheets to global warming, making a total range of 18 to 79 cm by 2095. The report also stated that "larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea-level rise."

There is increasing concern about the stability of ice sheets. For Greenland, this concern is based on measurements indicating an increasing contribution from the ice sheet, and melt water possibly finding its way to the base of the ice sheet, facilitating rapid sliding of glaciers and thus contributing to a more rapid sea-level rise. Much of the West Antarctic Ice Sheet is grounded below sea level, and the penetration of warmer water beneath the ice shelves to the base of the ice sheet and the subsequent dynamic response could also lead to a more rapid rate of sea-level rise. However, the current suite of ice sheet models does not adequately represent many of these processes and thus projections of ice sheet contributions to both 21st century and longer-term sea-level rise may be underestimated.

Concern that the sea-level projections may be biased low has been reinforced by a comparison showing that since 1990, observed sea level has been rising more rapidly than the central range of the IPCC projections. It is now at the very upper end of those projections.

To address these uncertainties, 163 scientists from 29 countries attended the Workshop on Understanding Sea-level Rise and Variability, hosted by the Intergovernmental Oceanographic Commission of UNESCO in Paris (6-9 June, 2006). The workshop was organized by the World Climate Research Programme (WCRP) to bring together all relevant scientific expertise with a view to identifying the uncertainties associated with past and future sea-level rise and variability, as well as the research and observational activities needed for narrowing these uncertainties.[1] The Workshop was also conducted in support of the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan.[2] As such, it helped develop international and interdisciplinary scientific consensus for those observational requirements needed to address sea-level rise and its variability, especially GEOSS activities focused on climate and hazards.

Reducing uncertainties

Improving our understanding of sea-level rise and variability, as well as reducing the associated uncertainties, critically depends on the availability of adequate observations, as proposed under GEOSS. These requirements include sustaining existing systematic observations, as well as the development of new and improved observing systems.

An overarching observational requirement is the need for an open data policy, together with timely, unrestricted access for all. Using the Argo and Jason policies[3] as a guide, this access would include real-time, high-frequency sea-level data from the Global Sea Level Observing System (GLOSS) tide gauges and co-located GPS stations, as well as data from satellite missions and in situ observing systems. Further requirements include the need for appropriate data archaeology — retrieving and making accessible historical, paper-based sea-level records, especially those extending over long periods and in the Southern Hemisphere. It's important to note that an immediate priority for paper records is electronic scanning and making them available for subsequent digitization. Moreover, satellite observations need to be as continuous as possible, with overlap between successive missions. There also needs to be a corresponding collection of appropriate in situ observations for calibration and validation. In general, ongoing satellite and in situ observing systems should adhere to the Global Climate Observing System (GCOS) observing principles.[4]

The existing systems that should be sustained include those observing sea level — the Jason series of satellite altimeters, as well as completing the GLOSS network of approximately 300 gauges (each with high-frequency sampling, real-time reporting, and geodetic positioning). Together these satellite and in situ observations enable the measurement of both absolute and relative changes in sea level. In order to estimate the change in sea level by ocean thermal expansion, the Argo array of profiling floats needs to be completed and sustained to observe the upper-ocean in ice-free areas. To estimate the contribution to changes in sea level from melting ice caps and glaciers and changes in terrestrial water storage, observations of the time-varying gravity field from the Gravity Recovery and Climate Experiment (GRACE) need to be sustained.

Photo: Bruce Miller

The Gold Coast, Australia. Coastal development is continuing around the world

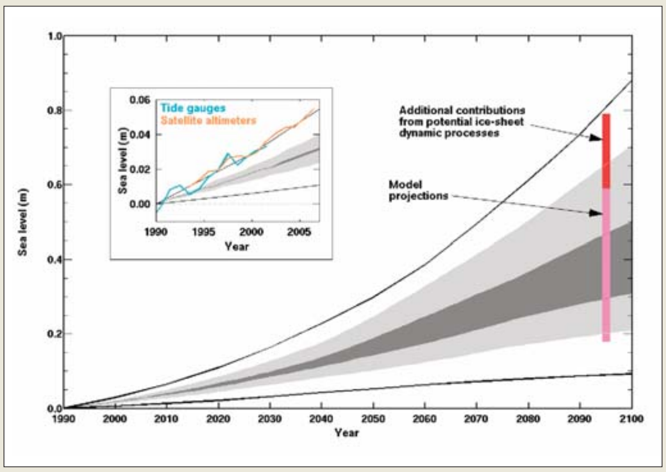
Additional existing systems to be sustained are those to observe changes in ice sheet and glacier topography and thickness — satellites utilizing radar (e.g. Envisat, GFO and Sentinel-3) and laser (ICESat and, once launched, CryoSat-2) altimeters, complemented by aircraft and in situ observations. All of these measurements require that the International Terrestrial Reference Frame (ITRF), which integrates the geodetic components — SLR, VLBI, DORIS, and GNSS (GPS, together with GLONASS and Galileo once launched), must be made more robust and stable. Finally, observations of the time-invariant gravity field from GOCE, once launched, and other stand-alone missions are needed to determine the precise geoid.

New and improved observing systems which need to be developed include those directed at changes in the ocean volume, specifically extending the Argo-type capability to enable the collection of similar observations under the sea ice, as well as the design and implementation of an effort to obtain observations for the deep ocean. Based on experience gained with radar and laser satellite altimeters, the development of a suitable follow-on capability is needed to improve observations of ice sheet and glacier topography. Access to InSAR data and ongoing InSAR missions are needed to observe flow rates in glaciers and ice sheets. Finally, the development of an advanced wide-swath altimeter is needed to observe sea level associated with the oceanic mesoscale field, coastal variability and marine geoid/bathymetry, surface water levels on land and their changes in space and time, and surface topography of glaciers and ice sheets.

Conclusions

Sea-level rise during the 20th century was much faster than in the previous few centuries and millennia. In situ and satellite data indicate an increase in the rate of rise since 1870, and that sea level is currently rising at a faster rate than at any time during the last 130 years. Sea level is projected to continue to rise at an increasing rate during the 21st century and beyond.

Projected sea-level rise for the 21st century



The projected range of global averaged sea-level rise from the IPCC 2001 Assessment Report for the period 1990 to 2100 is shown by the lines and shading. The dark shading is the model average envelope for all SRES greenhouse gas scenarios; the light shading is the envelope for all models and all SRES Scenarios, and the outer lines include an allowance for an additional land-ice uncertainty. The updated AR4 IPCC projections (90 per cent confidence limits) made in 2007 are shown by the bars plotted at 2095 – the magenta bar is the range of model projections and the red bar is the extended range to allow for the potential but poorly quantified additional contribution from a dynamic response of the Greenland and Antarctic ice sheets to global warming. The inset shows the 2001 projection compared with the observed rate estimated from tide gauges (blue) and satellite altimeters (orange)

Photo: Courtesy Eastern Daily Press

The flooding at Sea Palling, Norfolk, UK due to the storm surge of 31 January – 1 February 1953. This storm surge resulted in major investment in coastal protection along the east coast of the UK and in the Netherlands

Over the last several decades, including the period of the IPCC projections since 1990, models indicate a slower rate of sea-level rise than observed, thus raising concern about the accuracy of projections for the 21st century and beyond. Significant further work is required to understand adequately 20th century sea-level rise and thus improve projections for the future; a fundamental aspect of that work is the need to sustain and enhance a suite of ongoing satellite and in situ observing systems. To the extent that we are able to sustain these observations, research programmes utilizing the resulting data should significantly reduce uncertainties of our understanding of historical sea-level rise and thus narrow projections of future sea-level rise.

There are significant regional variations in the rate of sea-level rise. However, the current generation of climate models does not yet provide robust projections of regional patterns of sea-level rise. As a result, the global-averaged sea-level rise should be considered for planning purposes, with some allowance for a potentially larger contribution as a result of the regional pattern of sea-level rise.

The impacts of sea-level rise are being felt now, they will be felt during the 21st century and in the longer term and society will need to adapt to the effects of these rising sea levels. These effects include coastal inundation and its consequences, and increased rates of coastal erosion. Impacts will be felt most acutely during extreme events. Coastal flooding events will become more severe and events of a given height will occur more frequently; indeed analysis to date indicates that there has already been an increase in frequency of these flooding events. The least developed countries and the poor are most at risk. Adaptation requires local and regional planning to avoid the impacts of the most severe events.

A major question is whether we will pass a critical point, during the 21st century, that will lead to an ongoing and possibly irretrievable melting of the Greenland or West Antarctic ice sheet and a sea-level rise of several metres. Our current understanding of ice-sheet dynamics is insufficient to predict whether any such large rise would occur in a century or two or over many centuries or millennia.

Environmental refugees already exist as a result of extreme sea-level events, and their numbers will increase as a result of sea-level rise during the 21st century and beyond. It is not a matter of if there will be major coastal flooding events, but more a matter of when and where these events will occur and how we will respond.

To address sea-level rise and its impacts requires partnerships between science, government, business and community sectors. These partnerships are required now and will need to be strengthened during the 21st century. Appropriate strategies can lead to a significant amelioration of the impacts of sea-level rise through both mitigation of our emissions and also plans to adapt to the inevitable consequences of sea-level rise.[5]

Earth Observation System response to disaster reduction in Thailand

Dr Darasri Dowreang, Deputy Director, GISTDA

In Thailand, catastrophes such as floods, drought, massive landslides and forest fires occur from time to time. Space technology such as remote sensing technology serves human beings as a crucial tool for disaster monitoring, mitigation and prevention. The Geo-Informatics and Space Technology Development Agency (GISTDA) is the public organization responsible for development of space technology and geo-informatics in Thailand including remote sensing and geographic information systems. GISTDA has been conducting several activities concerning disaster management as follows:

Floods

Thailand is influenced by the tropical monsoon, and has suffered annually from several tropical storms. In the middle of 2006, the 'Pra Pirun' depressions reiterated by 'Chang San' caused severe and catastrophic damage nationwide. At the beginning, heavy rainfall caused massive landslide in Utaradit, a northern province where hundreds of people were killed, not to mention losses of properties and psychological impact. Immediately after this, a massive water mass from the north overwhelmed agricultural areas in the central part of Thailand.

To protect the Bangkok metropolitan, a massive amount of water was drained into paddy fields which became a vast destination area for inundation in 2006. People from all walks of life living in the affected area suffered from this deluge. More than 100 scenes of satellite imagery both from optical and SAR sensors were acquired. Flood detection and inundation maps were produced by GISTDA and then provided to agencies concerned with flood management and mitigation. As for rapid response, GISTDA has provided a geo-information package for the Thai government, the E-Flood Map, comprising flood maps derived from satellite data, the GIS database, and high-resolution satellite images, both pre- and post-flood, for decision makers. The E-Flood Map plays a crucial rule not only in the process of compensation, but also rehabilitation at local level.

Coastal erosion

Extreme natural force also affected Thailand's shoreline during late 2006, by the southwest and northeast monsoons. The high waves and strong winds in the Gulf of Thailand were the main causes of coastal erosion. Wave magnitude varied according to additional factors influencing the seasonal monsoon, and records from the study period show that strong high air pressure from China prevailed continually over the southern area and the Gulf of Thailand. During 20-23 December 2006,

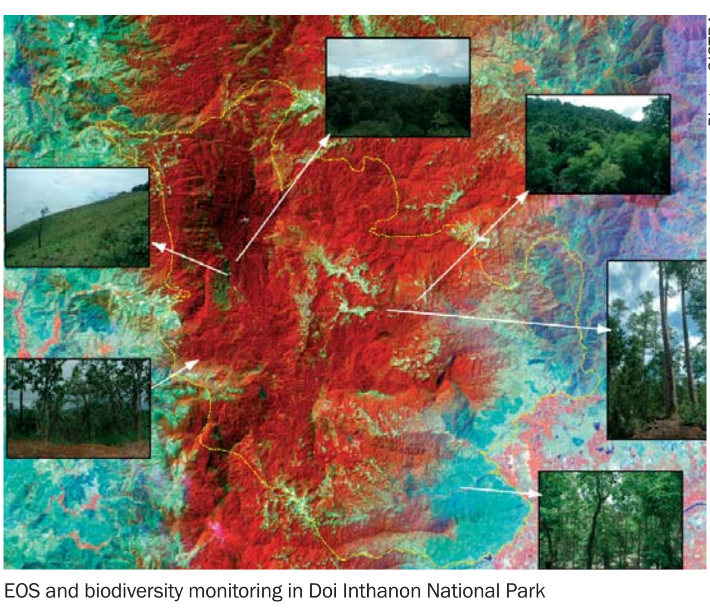


Photo: GISTDA

EOS and biodiversity monitoring in Doi Inthanon National Park

Photo: GISTDA

E-Flood Map, comprising flood maps derived from satellite data, the GIS database, and high-resolution satellite images

Photo: GISTDA

Remote sensing technology is crucial for disater monitoring, mitigation and prevention

severe erosion driven by high waves occurred along the shorelines of the southern provinces of Chumporn, Suratthani, Nakhon Si Thammarat, Songkhla, and Narathiwas. GISTDA conducted a study on the high wave impact by using satellite images from SPOT4 and SPOT5 satellites. The study focused on detection of shoreline changes, incorporating oceanographic and meteorological data. It was found that the severity of erosion varied according to coastal topography and location.

Forest fires

While the southern part of the country is under the influence of the monsoon, the northern part of Thailand faces the threat of forest fires. During late 2006 and early 2007, slash-and-burn cultivation was accelerated by high temperatures and dry conditions, causing severe forest fires in the upper part of Thailand. The smoke and haze from forest fires totally covered the northern provinces. For months, the hazy condition affected the respiratory systems of people living in the area. To monitor the situation, daily MODIS data both from TERRA and AQUA were used for the detection of hotspots and smoke plumes. Subsequently, high-resolution satellite data from SPOT and LANDSAT were used to locate the fire front over the critical area. Furthermore, to validate the position of the burning area during the peak of the fire season, a forest fire validation team was sent into the field to carry out field investigations.

EOS and biodiversity

The Earth Observation System (EOS) also plays an important role in the study of biodiversity, which represents the very foundation of human existence and has become part of our daily lives. In Thailand, a project has been initiated for monitoring biodiversity in Doi Inthanon National Park, which has a unique environment, a complicated human society and rich biodiversity. In the first phase, a geospatial database of the study area has been designed to respond to dynamic ecosystem changes due to global warming. Next, the team will develop an algorithm to extract information from EOS data as an input into a dynamic ecosystem change model of the area that impacts biodiversity. The final goal of the study is the operational use of EOS for biodiversity monitoring.

Human health and biodiversity: making the connection

Gary Foley, Montira Pongsiri and Aaron Ferster, US Environmental Protection Agency

For centuries, people have been able to alter landscapes and natural systems with seemingly little consequence, tapping a variety of 'ecosystem services' unabated. In the last 50 years, however, things have changed. We have altered the environment to such a degree that entire ecosystems are at risk, and the loss to biological diversity is mounting at an alarming rate. In addition to pollution, increased erosion, and flooding, studies strongly suggest that another consequence of land use is the emergence and re-emergence of disease.

The Global Earth Observation System of Systems (GEOSS) is being developed to allow people to access and provide the right information, in the right format, at the right time, to the right people, to make the right decisions. The US Environmental Protection Agency (EPA) is contributing to this effort in the health societal benefit area with a focus on emerging disease, by conducting research on the use of earth observations on biodiversity and ecosystems to reduce the incidence of vector-borne diseases.

The United Nations, through the Millennium Development Goals, recognizes the fundamental links between biodiversity conservation and health and well-being. However, there is a lack of available tools that decision makers can use to better understand how changes we make to the environment can affect our health. If we can better understand how environmental factors and peoples' behaviour contributes to infectious diseases, we may be able to make better decisions to reduce, and perhaps, prevent disease.

There are new tools, both remote and in situ, that provide information on earth systems, or 'earth observations'. These tools include instruments aboard space satellites that orbit the earth, collecting information over the entire earth's surface, on weather and such features as land cover and vegetation.

What if we could use information from these new tools to better understand how man made changes to the environment, along with natural factors, are related to disease emergence? Imagine a world in which we can predict where the next outbreak of malaria, SARS or West Nile virus is likely to hit. Imagine a world in which we can also understand how to manage the biodiversity, specifically the diversity or numbers of animal hosts or disease-carrying vectors, in ecosystems so that the services they provide can prevent or minimize the extent of disease outbreaks.

Making the link: biodiversity and disease

The World Health Organization (WHO)'s estimates of the global environmental disease (see figure opposite) burden do not include how changed or damaged ecosystems are associated with disease. Senior scientist Richard Ostfeld of the Institute of Ecosystem Studies is working on a regional scale to show that WHO estimates may be low. His cutting-edge research is illuminating the link between biodiversity, specifically the diversity of animal hosts, and the risk of Lyme disease.

Through field experiments and modelling, Ostfeld has suggested that a greater diversity of mammalian hosts native to healthy forests could help decrease the risk of people getting Lyme disease. People acquire the Lyme disease agent through tick bites, but ticks acquire the Lyme disease agent by feeding on mammals such as mice and squirrels. Not all mammals are equally effective or efficient in transmitting the disease agent to ticks when fed upon. For example, mice are better, more efficient "hosts" of the Lyme disease agent than squirrels. So, it's thought that a greater diversity of mammalian species, with varying degrees of transmission efficiency, could 'dilute' the rates that ticks get infected with the Lyme disease agent. With lower rates of tick infection, there would be lower rates of human infection. The 'dilution effect' may apply to other infectious diseases as well.

There is also a connection between diversity of animal hosts and the landscape in which they live. Studies suggest that the makeup of these host communities is largely determined by how intact the forest habitat is. Forest fragmentation and destruction in the US have been shown to reduce mammalian species diversity and to increase populations of the white-footed mouse, the most efficient host of Lyme disease. Greater numbers of efficient hosts and greater numbers of ticks that become infected from feeding on them could mean higher risk of Lyme disease for people.

In the tropics, malaria is a major problem. Changes in biodiversity through deforestation can have adverse effects on the risk of malaria. This was demonstrated for the first time by Amy Vittor and her colleagues in the Peruvian Amazon. Her group found that not only the numbers, but also the human biting rates, of the most effective malaria-transmitting mosquito species were higher in deforested areas compared to forested areas. This was unrelated to human population density.

The links between changes in ecosystems, biodiversity and infectious diseases are complex. Such links may involve other social and global environmental changes, such as climate change, which occur over different scales of space and time. This means that there could be many ways in which these factors interact to affect human disease. A better understanding of the role that changes in biodiversity plays in human health, particularly for diseases that continue to

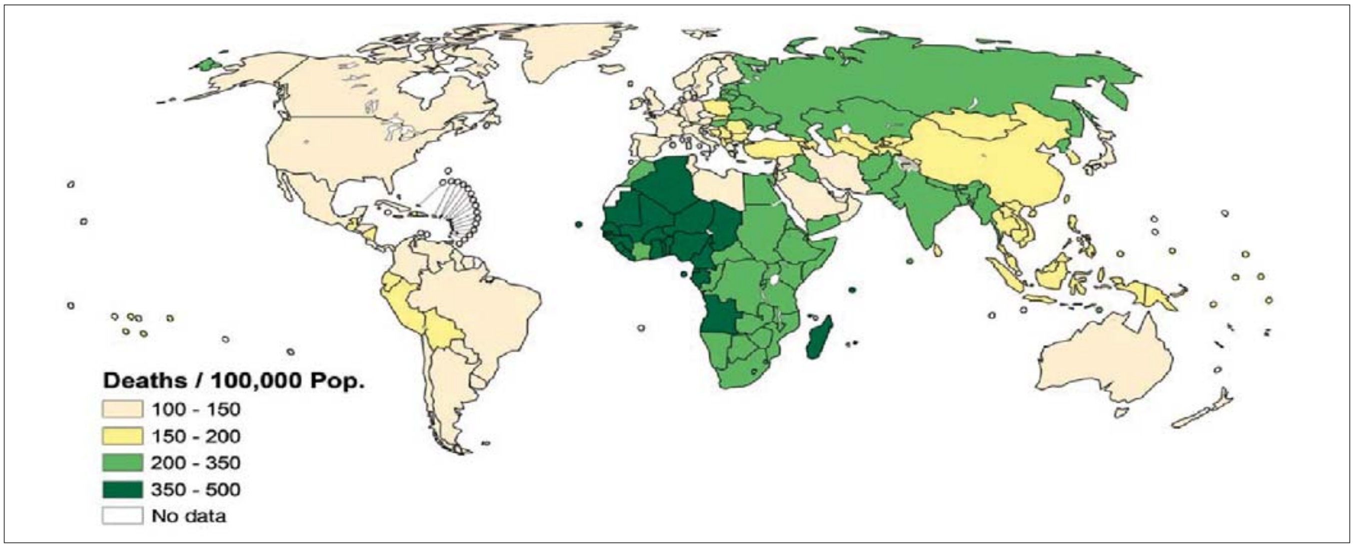


Figure reproduced from 'Preventing Disease Through Healthy Environments,' by A. Pruss-Ustun and C. Corvalan, World Health Organization, copyright 2006, with the permission of the World Health Organization

be problems in certain parts of the world, can reveal social and environmental factors that are important contributors to disease. These factors present new opportunities to reduce disease through improved policy and management.

A unique GEOSS approach: US EPA's interdisciplinary initiative

While studies indicate that changes in biodiversity can affect infectious disease transmission to humans, more research is needed if decision makers are to consider biodiversity change as a factor in predicting risks to human health. In response, the US EPA has added to GEOSS a new interdisciplinary program to better understand the scientific relationship between human stressors (such as climate change and deforestation), changes in biodiversity and disease transmission to humans.

In September 2006, in co-sponsorship with Yale's Center for EcoEpidemiology, the Smithsonian Institution, and the World Conservation Union, GEO and the US EPA launched the 'Biodiversity and Health initiative' by bringing together researchers, practitioners, and decision makers in ecology, public health, social sciences and the earth sciences. This is one of the few international programs that brings together these various disciplines and encourages the coordination of earth observations with experimental field data in order to study biodiversity and health.

Every discipline constitutes a vital contribution. For example, ecologists and population biologists can help describe the environmental factors affecting animal hosts and vectors of disease. Earth scientists can play an important role in understanding animal and vector population density related to land cover features through the use of real-time Earth observations. Epidemiologists can contribute knowledge on disease life cycles and how diseases spread to and among humans. Social scientists can identify the human behaviour that affects biodiversity and health as well as strategies to encourage human behaviour to protect the environment and human health. Economists can put a monetary value on biodiversity as it relates to disease reduction.

This innovative approach built on multidisciplinary collaboration can lead to better and faster uses of new knowledge to reduce disease and protect the environment. The US EPA is working with US Federal partners and international organizations to advance this work.

Environmental Disease Burden

The map above shows the estimated global disease burden, measured in deaths per 100,000 population for the year 2002. The largest difference between regions is in infectious diseases, with the burden suffered as a result of environmental factors 15 times greater in developing countries than in developed countries. The World Health Organization (WHO) has estimated that 24 per cent of the global disease toll and 23 per cent of all deaths can be attributed to environmental factors such as poor water quality, air pollution, man-made climate change, and policies and practices regarding water resource management. These environmental factors are considered 'modifiable' in that they can realistically be changed using existing technologies, policies, and preventive and public health measures. This analysis does not include how changed or damaged ecosystems may contribute to disease, so these global estimates are likely to be conservative.

(Source: World Health Organization)

We live in a fast-paced, dynamic period of globalization. Along with the increasing interdependence of economies, politics, and technology, we are also experiencing the rise of emerging and re-emerging disease. International travel and commerce, human behaviour and manmade changes to the environment all together contribute to the current problem of emerging and re-emerging diseases.

Not long ago, we thought that DDT was the silver bullet that would wipe away malaria, but today, it continues to affect more than 300 million people and cause more than a million deaths every year. We need new approaches and solutions to this and other age-old problems. The US EPA is taking an interdisciplinary approach that looks at the wider picture of human-environment-disease interactions, and we hope, providing one new, positive way forward.

Applications of remote sensing technologies for monitoring human health

Pietro Ceccato, Michael A. Bell, Tufa Dinku, Stephen J. Connor,
International Research Institute for Climate and Society (IRI), Columbia University

As a primary aspiration of human development, good health remains a focus in all aspects of society. Depending on its stage of socio-economic development, however, one society may experience different types of health problems to another. As a result, health problems facing rural African communities today differ from those facing urban populations in the developed world.

In sub-Saharan Africa, the greatest burden of disease morbidity and related mortality stems primarily from infectious disease. Specifically, HIV-AIDS, Tuberculosis (TB) and Malaria, as a group, have come to be seen as a significant constraint to Africa's development prospects. Calls have been made for massive investment in health services and control programmes in the most affected countries. Since its establishment in 2002 the Global Fund for AIDS, TB and Malaria has mobilized significant financial, technical and political resources toward the fight against these three diseases alone.[1]

The high profile of health in development objectives is apparent in the Millennium Development Goals (MDGs) for 2015, where three of the eight goals are directly related to health care intervention and outcomes. With Global Fund grant commitments and disbursements now underway, attention is beginning to focus on a large group of diseases confined to the 'other' category by health policy makers and politicians. These so-called neglected diseases are the viral, bacterial, and parasitic infections, together with acute respiratory infections and diarrhoeal diseases, which are all too common in the poorer countries of the world. Despite the availability of cost-effective, successful control interventions, large numbers of the world's poorest people remain afflicted or at risk from this group of diseases.

Photo: R. Taddei/IRI

Many diseases are associated with rainfall anomalies which favour the development of parasites and vectors

Climate and environmentally sensitive diseases

Certain diseases are associated with particular environmental conditions, season and climate. This was recognized by the ancient writers of Vedic literature, by Hippocrates, and is the focus of considerable research today.

The World Health Organization (WHO) has targeted a number of 'climate-sensitive' diseases, including Malaria, and several of the so-called neglected diseases. WHO acknowledges that this list does not include several respiratory and non-communicable diseases which may also be climate-sensitive.

While the implications of future climate change are not known, we can be sure that health will remain a major factor in social well being. If we are successful in helping vulnerable communities to benefit from significant investments in health services and improved management of climate sensitive disease in the immediate future, then we will at least face the potential impacts of climate change with a lower baseline of infections.

Earth observation to monitor climate and environment

Satellite sensors developed in the United States, Europe, Canada, Japan, India, and emerging countries by the remote sensing community have contributed to a better understanding of the ecology of environmental diseases. The history of remote sensing and its application to vector-borne diseases has been recorded over time in a

Climate sensitive diseases targeted by WHO

Diseases	Biological Agent	Vector	Climate Sensitive
Malaria	Plasmodium sp (protozoa)	Anopheles sp. (mosquito)	Rainfall, Temperature, Humidity
African Trypanosomiasis	Trypanosoma sp. (protozoa)	Glossina sp. (tsetse fly)	Rainfall, Temperature, Humidity
Leishmaniasis	Leishmania sp. (protozoa)	Plebotomus sp., Lutzomyia sp. (sand fly)	Rainfall, Temperature
Yellow Fever	Flavivirus sp. (virus)	Aedes sp. (mosquito)	Rainfall, Temperature
Cholera	Vibrio sp. (bacteria)	Zooplankton	Rainfall, Temperature
Meningitis	Meningococcal meningitis (bacteria)	No vector, transmission from person to person	Rainfall, Temperature, Humidity, Dust
Dengue	Flavivirus sp. (virus)	Aedes sp. (mosquito)	Rainfall, Temperature
Rift Valley Fever	Phlebovirus sp. (virus)	Aedes sp. (mosquito)	Rainfall, Temperature, Humidity
West Nile Virus	Flavivirus sp. (virus)	Culex sp. Mosquito	Rainfall, Temperature, Humidity
Japanese Encephalitis	Flavivirus sp. (virus)	Culex sp. Mosquito	Rainfall, Temperature, Humidity
St. Louis Encephalitis	Flavivirus sp. (virus)	Culex sp. Mosquito	Rainfall, Temperature, Humidity
Murray Valley	Flavivirus sp. (virus)	Culex sp. Mosquito	Rainfall, Temperature, Humidity
Ross River Virus	Alphavirus sp. (virus)	Aedes sp. (mosquito)	Rainfall, Temperature, Humidity
Influenza	Influenzavirus sp. (virus)	No vector, transmission from person to person	Temperature

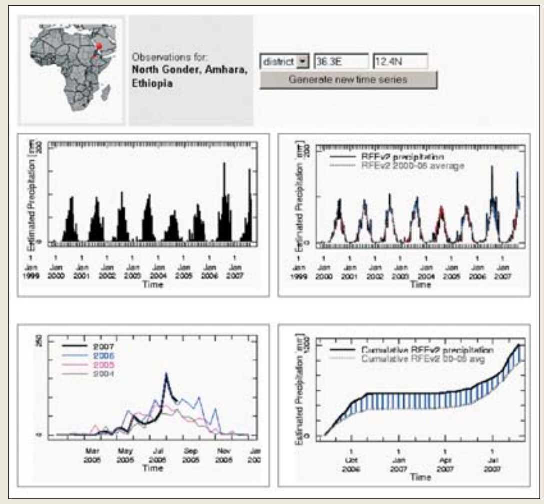
Source: adapted from the WHO 2005

series of review papers. Yet, despite 30 years of successful research on the potential applicability of remote sensing technologies to control diseases, these tools are only now beginning to have an impact on policy and practice in operational control of Malaria in affected countries.

Operational use of remotely sensed images has taken a long time to be implemented in technologically developing regions due to prohibitive image and processing software costs. This problem is now diminishing because of lower-cost computer processing and data storage facilities, free access to high spatial resolution satellite images via the Internet and the availability of processing tools such as Healthmapper (Geographical Information System tool) to the user community at no cost by organizations such as WHO. The recent availability of free images and processing tools has enabled the rapid development of applications using remote sensing and GIS for operational purposes.

The International Research Institute for Climate and Society (IRI) has developed operational tools for Botswana and Eritrea. Using Malaria cases from health facilities in both countries, the relationship between rainfall, vegetation development and Malaria epidemic

Rainfall observations



Four time-series graphs are generated providing an analysis of recent rainfall with respect to that of recent seasons

Source: IRI Data Library Map Room

was first established. The use of remote sensing images to monitor rainfall and vegetation was then proposed as follows.

Monitoring rainfall

Using satellite rainfall estimate products updated every ten days, IRI developed a Web-based Malaria Early Warning System (MEWS) interface which enables the user to gain a contextual perspective of the current rainfall season by comparing it to previous seasons.

The interface takes the form of an online 'clickable map', which displays the most recent ten-day (dekadal) rainfall map.[2]

Dekadal rainfall can be spatially averaged over a variety of user-selected areas. Upon the selection of this sampling area and a specific location of interest (by clicking on the map), four time-series graphs can be generated. These graphs provide an analysis of recent rainfall with respect to that of recent seasons and long-time series.

These graphs allow the users to automatically see whether the area of interest is wetter (blue colour) or drier (red colour) than normal and decide whether risks are associated with vector developments.

Monitoring vegetation and water bodies

In Eritrea, the relationship between the development of vegetation and epidemics of Malaria has been established in specific areas. The presence of surface water also provides the habitat for the juvenile stages (egg, larvae and pupae) of Malaria vectors.

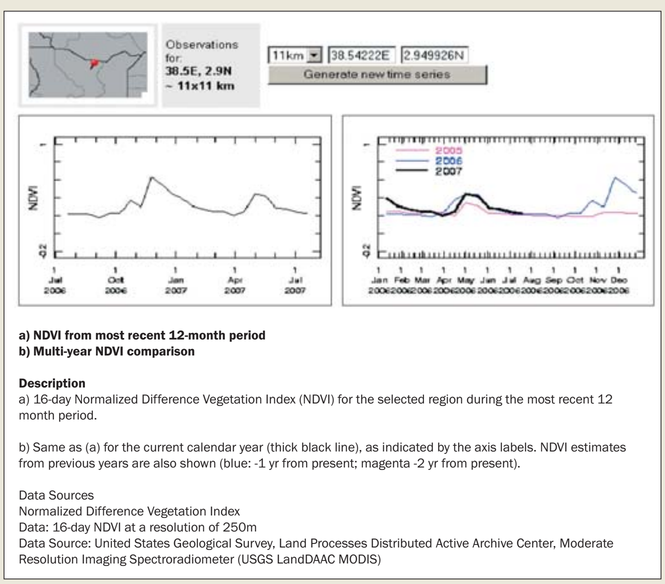
To monitor vegetation and water bodies, TERRA-MODIS images provided by the National Aeronautics and Space Administration (NASA) are used. Frequent images at high spatial resolution (250m) are made available free of charge. The products are provided to the user community via the IRI Data Library web site.[3] Users can remotely:

- Visualize a colour composite where the vegetation appears in green, the bare soils in brown and the water in blue
- Compute long-term series of vegetation indices and compare them with historical data.

Here, we select a location in North Kenya to display the evolution of the Normalized Difference Vegetation Index (NDVI). This index provides information on the vegetation status. The time-series for years 2005, 2006 and 2007 indicates that November to December 2006 and January 2007 had vegetation index values greater than those in 2005. The development of above normal vegetation in that region during November to December 2006 was associated with an outbreak of Rift Valley Fever.

Similarly, the National Malaria Control Program (NMCP) from the Ministry of Health based in Asmara, Eritrea, monitors the development of vegetation in the northern part of Eritrea along the Red Sea Coast. Between December 2006 and April 2007, the NMCP noted an increase in vegetation. Despite good environmental conditions, the number of Malaria cases in the region remained under control. However, the development of vegetation also created the perfect conditions for the development of Desert Locusts. The same information provided by IRI was used by the Food and Agriculture Organization (FAO) of the United Nations and the Ministry of Agriculture in Asmara to direct survey teams to the area. Subsequently Desert Locusts were found, and an alert was issued by FAO to the Ministries of Agriculture in countries potentially affected by the locusts and to the donor community via the FAO Locust Watch website.[4]

NDVI analysis



NDVI interface with time series extraction of any particular location of interest – here, a location in North Kenya. The time-series for years 2005, 2006 and 2007 indicates that November to December 2006 and January 2007 had NDVI values greater than those in 2005. The development of vegetation in that region was correlated with an outbreak of Rift Valley Fever

Source: IRI Data Library Map Room

While monitoring environmental conditions using remotely sensed data plays an important role in assessing the risk of epidemics, it is important to stress that socio-economic, demographic and immunological factors also play an important role in the vulnerability of communities to the diseases. Early Warning Systems that integrate all these factors must be implemented to help health services to manage diseases more effectively.

Integration of remote sensing to produce early warning systems

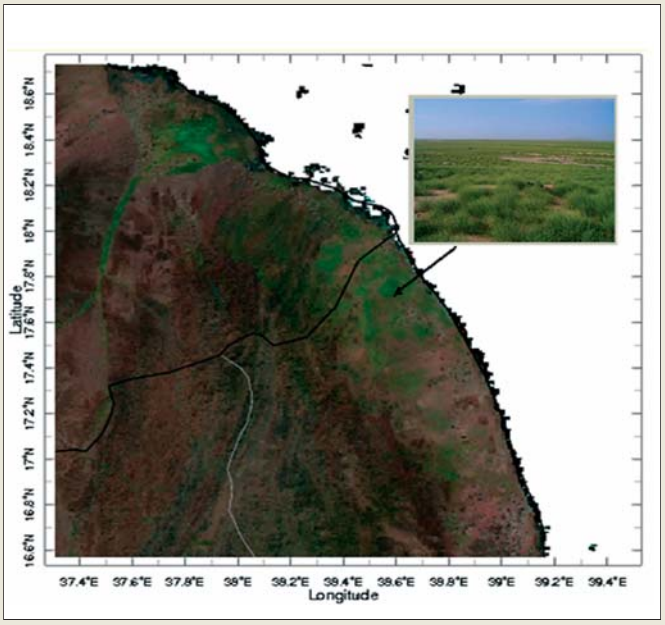
The concept of an early warning system for the prediction of epidemics predates satellite technology by many decades. In fact an early warning system in response to the massive malaria epidemics that occurred periodically in pre-independence India was routinely operated in the Punjab from the early 1920s until the early 1950s. S. R. Christophers observed that between 1868 and 1908 severe and explosive 'fever' epidemics of two-to-three month duration (August-October) were common in the region.[5] In particular he noted that the worst of the epidemics, which had a periodicity of seven-to-eight years, coincided with high grain prices and famine. Christophers saw this 'human factor' as an 'essential requirement' which undermined the population and resulted in high death rates as a result of the epidemics.

Despite this example, much of the interest in early warning systems for Malaria epidemics was lost during the Global Malaria Control/Eradication Era. It was not until the 1990s that renewed interest was stimulated by a number of epidemics reported from the East African highlands and a regional epidemic in Southern Africa. At its launch in 1998 the Roll Back Malaria partnership recommended the development of a framework to establish Malaria Early Warning Systems (MEWS) in sub-Saharan Africa. The MEWS framework sets out a series of activities which together form the basis of an integrated monitoring process to identify changes in epidemic potential and increased risk of transmission.

In the MEWS framework, the first step involves consideration of the dynamic factors which make populations more vulnerable to severe epidemic outcomes. Drought, inadequate food security and nutritional/economic status, increasing levels of drug or insecticide resistance, reduction in health service provision or a high burden of other diseases such as HIV/AIDS, compromise any immunity and increase vulnerability to epidemics. While these factors are unlikely to give an indication of when an epidemic might occur, they do provide warning of the severity that can be expected if one does occur and is not prevented.

The second MEWS monitoring process considers the forthcoming season's climate. Will it be a drier, normal, or wetter season? A number of years of drought may disrupt populations, lower immunity and make populations more susceptible when higher, or even normal rainfall levels occur. The use of climate forecasts to predict Malaria epidemics has been demonstrated in Botswana, where climate forecast products predict the occurrence of Malaria epidemics months in advance.

MODIS image along the Red Sea Coast



A MODIS image taken in February 2007, showing in green the vegetation along the Red Sea Coast

Source: IRI Data Library Map Room

Malaria response

A Malaria poster developed through collaborations between many agencies and programmes (SAMC, SADC DMC, DEMETER, The European Centre for Medium Range Weather Forecast, ENSEMBLES, IRI, Meteo France, UK Met Office, USAID and WHO). The poster is distributed to the epidemic-prone districts in Southern Africa to illustrate the decision support process

Source: Da Silva and Marx in Da Silva et al., 2004, Malaria Journal

The third MEWS process is monitoring the weather as it occurs. Are temperatures unusual for this time of year? Is the rainfall higher than would normally be expected? The latter is now freely monitored through satellites as shown in the section above.

The fourth monitoring process is epidemiological surveillance. While the detection of an epidemic through a rapid increase in the number of cases would be the most reliable, it is unfortunate that routine case reporting systems are at present, especially in sub-Saharan African countries, unable to detect epidemics in sufficient time to enable an effective response.

Integration of early warning systems into decision-making processes

Early warning systems do not prevent diseases if the infrastructure, contingency plans and financial resources are not available. The case of the Desert Locust crisis in 2004-2005 is a good example. Despite regular warnings and several appeals issued by FAO, meetings organized with donors, and exact knowledge of the progression of Desert Locusts towards breeding areas in the Sahel where countries had fewer financial resources to implement control measures, the donor community was slow to respond. Locusts captured the public attention during the crisis in June-July 2004 and funds started flowing after numerous swarms had already invaded agricultural zones in Mauritania, Senegal, Mali and Niger, reducing the crop production and putting millions of people at risk of food shortage.

In order to overcome this problem, different solutions must be investigated to optimise reactions to potential disaster. In the case of Malaria, an integrated framework of actions has been developed to translate the results of the early warning system into early action. A poster was developed in collaboration with several agencies and programmes that summarizes a series of actions (i.e. managing the distribution of bednets, distribution of anti-Malaria drugs, mosquito control) to be taken when early warning systems indicate a possible outbreak of Malaria.

The current momentum and investment in strengthening health systems and reducing disease in sub-Saharan Africa allows this framework to become operational. The launch of initiatives to reduce Malaria such as Roll Back Malaria, Millennium Development Goals and the Global Fund to Fight AIDS, Tuberculosis and Malaria provide a platform to help the transfer of these new technologies toward the most affected countries. Data and good intentions alone, however, are not sufficient. Assistance is also required in the process of technology transfer and in structuring national decision-making processes. An important requirement is the training of Ministries of Health on how to use the new technologies issued for remote sensing. People working in Ministries of Health are not expert in remote sensing and do not have time to become so. It is therefore important to provide easy-to-understand and easy-to-access information. This is often a problem overlooked within the remote sensing community and requires an interdisciplinary approach in order to provide the right level of information to the right decision-makers.

The importance of Earth observations in the assessment of malaria, respiratory and ocular diseases in South Asia

A. P. Mitra, National Physical Laboratory, India

South Asia is a unique region. It has only three per cent of the total world land area, yet in 2002, more than 22 per cent of the world population lived there.[1] This region consists of developing countries like Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, which are predominantly inhabited by resource-starved populations trying to achieve economic well-being for their respective countries. This region is also one of the most densely populated, ranging from about 250 people per square kilometre in Nepal to about 800 persons per square kilometre in Bangladesh.

Human health is of significant importance for South Asia, as it affects the overall productivity and thus impacts the development process of the region. The total per-capita expenditure on health care in 2001 ranged from USD58 for Bangladesh to USD122 for Sri Lanka, which is less than one-fifth of the global average of USD629, indicating a poor affordability of health care systems in the region.[2] Earth observation systems have great potential in assisting measures to address human health concerns in the region, as can be seen from their importance in the context of malaria, respiratory and ocular diseases.

Malaria

Malaria is endemic in all parts of the South Asian region, except in areas of higher elevation and some coastal areas. Developing countries, where the health system is yet not geared up to meet the needs of all sections of society, especially the tribal population living in forest areas and poor people living in urban slums, are prone to be adversely affected by malaria outbreaks. Within the vulnerable communities, those most affected are children, senior citizens, the chronically ill, the disabled, people living off the land, people living on islands, and pockets of overcrowded and poorly-serviced settlements in urban and rural areas which are a potential breeding ground for disease hosts such as mosquitoes, rats, mice and flies. Communities surrounded by these poverty belts also become more vulnerable to disease outbreaks.

The three main climate factors (i.e. climate determinants) that affect malaria generation and its transmission are temperature, precipitation and relative humidity. Climate predicts, to a large degree, the natural distribution of malaria. Therefore, the network of meteorological stations available in the South Asian region can contribute very significantly by providing quality data for understanding the links between climate determinants and malaria occurrence. The modelling of future climate scenarios and their impacts on malaria occurrences will also help in the allocation of appropriate resources to priority areas for the effective control of malaria incidences in the region. In South Asia, the systemic meteorological data collection process is overseen mainly by government agencies, through their respective networks of meteorological stations.

In India, a study has been carried out to assess the climate parameters governing malaria transmission and the likely extent of malarial activity in the future due to climate change, using empirical relations.[3] This study revealed the dominant role of temperature and relative humidity in malaria transmission, leading to the development of a new set of transmission windows (named as class I, II and III) that govern the transmission of P. vivax and P. falciparum in India. Using the transmission window criteria thus developed, malaria has been found to be endemic in the central and eastern Indian regions of the country, covering states like Madhya Pradesh, Jharkhand, Chhattisgarh, Orissa, West Bengal and Assam in the current climate.

Applying the same criteria under the climate change conditions for the period 2050s as derived from HadRM2 using the 1S92a scenario, it has been projected that malaria is likely to persist in Orissa, West Bengal and southern parts of Assam, bordering north of West Bengal. However, it may shift from the central Indian region to the southwestern coastal states of Maharashtra, Karnataka and Kerala. Also the northern states, including Himachal Pradesh may become malaria-prone in the future climate change regime. The duration of the transmission windows is also likely to widen in northern and western states and shorten in the southern states in India. This study is not conclusive by itself as the influence of other factors like socio-economic, environmental and vector related parameters could not be included in this study. Therefore, there is a need to undertake comprehensive studies on malaria in South Asia using region specific data and models to help in designing the most effective policy and technological interventions in order to minimize the malaria incidences and increase the region's productivity.

Respiratory diseases

Rapid urbanization is exposing increasingly high populations to outdoor pollution with serious health consequences, especially related to pulmonary health in South Asia. The coexistence of old and new technologies in the transport and industrial sectors, which are considered to be the prime sectors responsible for pollution in urban areas, masks the efficacies of policy interventions implemented for amelioration of the ambient air quality in the region. The increasing consumption patterns, commensurate with the changing socio-economic status, further contribute to deterioration of air quality.

The World Health Organization (WHO)[4] has estimated that urban air pollution is responsible annually for approximately 800,000 deaths and 4.6 million lost life years worldwide, and almost two-thirds of these numbers are accounted for by Asia. But the fact that these estimates are based mainly on the extrapolation of research results carried out in mainly non-Asian countries underlines the importance of undertaking such studies in South Asia. These estimates may entail significant ambiguities for the Asian region because the nature of air pollutants, conditions and magnitude of exposure, health status and health care facilities are different in Asia compared to other regions of world. Limited studies of air pollutant impacts on human pulmonary health are available for the developing world, which are mainly carried out in China with some studies carried out in India, Singapore and Hong Kong.[5]

The urban population of South Asia is growing at a very fast rate, especially in the megacities where, for example, a growth rate of more than 20 per cent per year has been observed between 1950 and 2000 for Delhi, Kolkata, Karachi and Dhaka. The ambient air quality in most of these megacities is in poor shape, mainly due to the presence of high suspended particulate matter (SPM). For example, average concentrations of SPM have been reported to be in range of 148-259 $\mu g/m^3$ for Delhi; 260-380 $\mu g/m^3$ for Kolkata; 233-318 $\mu g/m^3$ for Karachi; 663 $\mu g/m^3$ for Dhaka and about 250 µg/m3 for Kathmandu. These are much higher than the normal prescribed values, with Indian standards identifying >210 g/m^3 SPM concentration as the critical level for residential areas. The deterioration of ambient air quality is occurring in South Asian countries due to human-induced developmental activities, which are energy intensive and result in the emissions of a number of trace gas species and particulate matter. WHO has estimated that exposure of humans to ambient air with more than a 100 $\mu g/m^3$ concentration of SPM can cause cardiovascular mortality, respiratory mortality, lung cancer and mortality due to acute respiratory infections in children.

Emissions of particulate matter directly impact human health by affecting respiratory system. It is well established that exposure to pollutants like SPM, SO, NO_x, CO, O_3, benzene etc. can have a range of health effects,[6] especially if serious pollution episodes occur. Both the physical (such as particle size) and chemical compositions (e.g. presence of sulfate, nitrate, organic acids, metals, black carbon, lead etc.) of aerosols are responsible for their impacts on human health. The total SPM can travel deep into the human respiratory system, depending on particle size. Different kinds of aerosols have different effects — for example, sulfate aerosols have been found to be highly toxic. These SPM particles also carry toxic substances (like toxic metals), which on the particles that enter the human respiratory organs. Generally, it is believed that particles having sizes less than 10 m (PM_{10}) can travel to the thoracic region, and particles with a diameter of less than 2.5 m can travel to alveolic areas of the lungs. It is estimated that there is an increase of three per cent in respiratory diseases and of 0.5 per cent in mortality per 10 $\mu g/m^3$ increase in PM_{10} exposure. However, these values need to be investigated for developing countries as they are based on studies carried out in developed world.

In South Asia, systematic air pollution monitoring is being carried out by designated country government agencies through their respective ambient air quality monitoring networks established in representative areas. These networks primarily monitor criteria pollutants (like oxides of nitrogen and sulfur, SPM, PM_{10},

Photo: Dr. R.C. Dhiman, NIMR

Insecticide spray team for malaria mosquito control in an Indian village

Photo: Dr. R.C. Dhiman, NIMR

Social workers display a mosquito net for malaria control surface ozone etc.) depending upon the available national capacities. Some other science and technology institutes and universities are involved in the episodic measurement of ambient air quality in the region for meeting their research requirements. Air pollution, as a local issue, has also been partially addressed by legislation in most of the countries of South Asia. However, a holistic action to deal with this issue in the region is still lacking because the scientific understanding about the linkage of observed pollution levels with human health effects is still in its preliminary stages. Therefore, there is a need to undertake appropriate research activities in the region, to get an in-depth understanding of these linkages.

In this direction, a research project, the Assessment of the Effects of High Particulate Pollutants on Pulmonary Health Status in Selected Megacities of South Asia has been undertaken since late 2005, supported by the Asia Pacific Network for Global Change Research (APN) to develop scientific capacity in the region. This project aims to investigate the impacts of high particulate matter concentrations on human respiratory health in selected megacities of South Asia, where the particulate matter loading in ambient air is, in general, very high due to various anthropogenic activities. Through this project, multi-disciplinary country teams consisting of health and aerosol experts are carrying out a study in target areas in selected megacities: Colombo, Delhi, Dhaka, Kathmandu, Kolkata and Lahore.

For this project, common protocols for health studies and air pollution monitoring have been developed and are being followed by all the country teams. In the first year, a sample survey of health status of target population was carried out using common protocols for both acute and chronic symptoms. The ambient air quality in the target locations has also been monitored. The lung function tests of the identified subjects in the target locations are also being carried out using peak flow meters and/or Spirometers. This project is expected to generate useful scientific insights about the linkages between the air pollution and health status in South Asia.

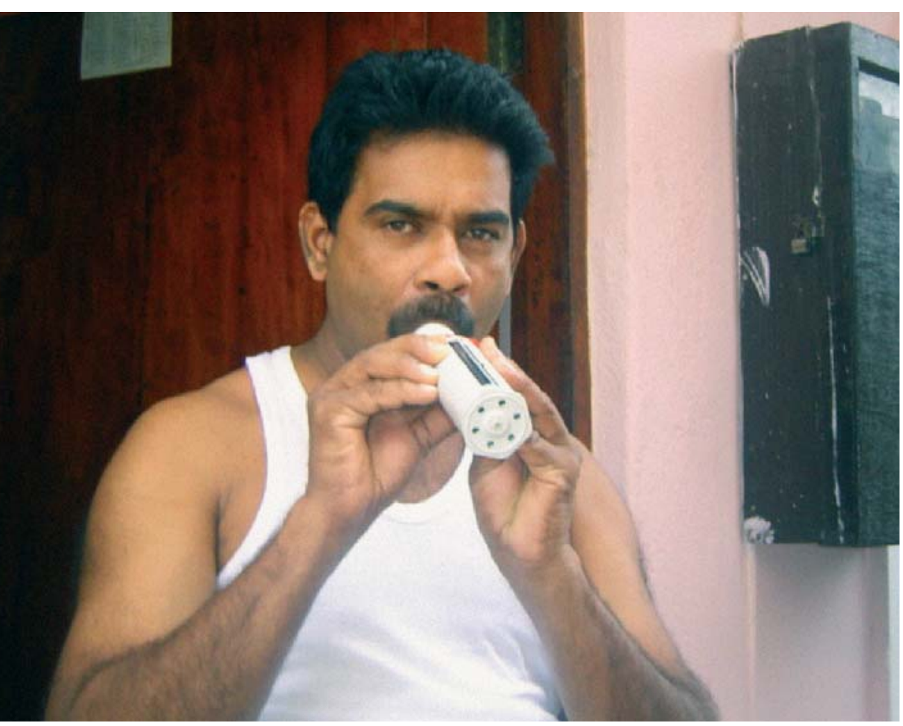


Photo: Dr. J. Ratnasiri, APN South Asian Health Project Team Coordinator for Sri Lanka

Lung function tests are carried out using peak flow meters and spirometers. Here, one of the subjects in Sri Lanka takes a peak flow test

Ocular diseases

The human body is exposed to sunlight that contains radiations ranging between UVB (wavelength ranging from 280–315nm), UVA (wavelength ranging from 315–400nm), visible (wavelength ranging from 400–800nm) and infrared (IR; wavelength ranging from 800nm to 1mm). UVB wavelengths <295nm and UVC (100–280nm) radiations are totally filtered by the stratospheric ozone layer. However, UVA is not absorbed by the stratospheric ozone and reaches the Earth's surface virtually unattenuated through clear atmosphere. UVB radiation, being more energetic, is more damaging to the eye and is absorbed by the cornea and lens. UVA radiation has lower energy, but penetrates much deeper into the eye and may cause injury to the retina. Epidemiological investigations have reported a higher prevalence of cataracts in regions with high levels of UV exposure. Various ocular disorders induced and exacerbated by UV radiation (UVR) include cataract, dry eye, pterygium, allergic diseases, photokeratitis, ocular surface squamous neoplasia, corneal degenerative changes and age-related macular degeneration. Globally, excessive solar UVR exposure is estimated to have caused a loss of about 1.5 million disability-adjusted life years (DALYS), and 60,000 premature deaths in the year 2000.[7]

The South Asian region predominantly lies in the low stratospheric ozone belt because of its geographical location near the equator. Hence this region, in general, receives higher dosages of UVR. The UV levels have been found to be over 1,000 times higher at the equator compared to the poles and levels increase further with altitude. So, the high altitude and equatorial regions are the real hotspots for UV exposure. However, no concerted scientific efforts have so far been mounted in the South Asian region to assess the impacts of higher UV radiations on human health. In India, however, efforts have been mounted to generate UVR maps[8] which revealed higher UVB dosages over the Indian subcontinent.

The path ahead

In view of the limited resources and national capacities available in South Asia, major thrust is needed to strengthen the observational networks for generating data that is quality controlled and quality assured. The development of user-friendly data products and their timely distribution for use by health and other sector experts is also a major challenge in the region. The institutional and individual capacities are still inadequate in the South Asia region, and need to be further strengthened to enable the generation of observational data and their effective use for the proper assessment of health impacts.

AIRNow: the beginning

Phil Dickerson, AIRNow Programme Director, US EPA

The average adult breathes 13,000 litres of air each day, making air quality a critical public health issue. Air is all around us, yet invisible. Poor air quality is an insidious problem that is difficult to sense and impossible for the public to measure. In an attempt to counter this problem the US Environmental Protection Agency (EPA) created the AIRNow programme in 1995.

AIRNow was founded upon the principle of protecting public health by offering real-time air quality data and forecasts. Based upon that vision, EPA developed AIRNow from a small regional programme with three data polls each day, to a nationwide programme featuring hourly data, hundreds of maps, forecasts and information on air quality.

The Air Quality Index

To make real-time data meaningful to the general public, EPA developed the Air Quality Index (AQI), a colour-coded scale that ties air quality concentrations to health effects.

AIRNow-International

Air quality is a worldwide problem. Developing countries are installing air quality monitoring networks and beginning to forecast air pollution levels to help address this challenge. Equally important is developing methods to effectively communicate information and educate the public about air quality conditions.

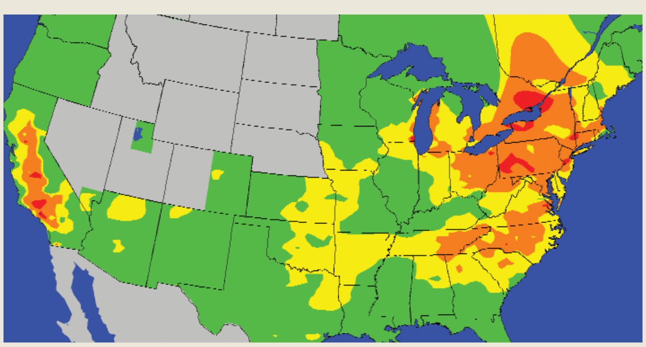
This educational effort is consistent with the World Health Organization's guidelines for air quality, which state that public information systems are playing an increasingly important role in raising awareness, warning of pollution episodes and advising susceptible population subgroups. An especial problem facing air quality agencies in developing countries is a lack of software and knowledge about how to effectively communicate this information to the public.

The EPA's AIRNow programme has been shown to be a successful model for communicating air quality conditions and forecasts to the public. It has become the national resource and focal point for decision makers, the media and the public to access air quality information. AIRNow displays air quality conditions using animated maps with colours that correspond to the AQI.

These maps are shown on the programme's website (www.airnow.gov) along with information about health impacts from air pollution and suggestions about what individuals can do to improve air quality. In addiion, EPA has developed training, outreach and educational materials about the health effects of poor air quality and guidance on public health protection.

Several countries have expressed interest in the AIRNow system; however, the current system is a customized collection of software programs and data-

Air quality conditions relating to AQI values



15 August 2007

Air Quality Index (AQI) values	Air quality conditions	Corresponding colours
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for sensitive groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very unhealthy	Purple
301 to 500	Hazardous	Maroon

Good – The AQI value is between 0 and 50. Air quality is considered satisfactory, and air pollution poses little or no risk.

Moderate – The AQI is between 51 and 100. Air quality is acceptable, though for some pollutants there may be a moderate health concern for a very small number of people.

Unhealthy for sensitive groups – When AQI values are between 101 and 150, members of sensitive groups may experience health effects. For example, people with lung disease are at greater risk from exposure to ozone, while people with either lung or heart disease are at greater risk from exposure to particle pollution. The general public is not likely to be affected when the AQI is in this range.

Unhealthy – Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.

Very unhealthy – AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.

Hazardous – AQI values over 300 trigger health warnings of emergency conditions. The entire population is likely to be affected

Source: EPA

Photo: EPA

Real-time information about the quality of the air they breathe will enable people to make decisions to protect themselves from harmful air quality

bases that are not easily distributed. One way to address this distribution issue is to provide a simpler, easier-to-install version of the AIRNow software. It would include data processing, quality control, system monitoring and mapping. This AIRNow-International (AIRNow-I) software package would provide the basic features of the AIRNow program based on AIRNow's technology.

Benefits of AIRNow-I

The benefits of AIRNow-I are simple, yet far-reaching. AIRNow-I will bring the immense experience EPA gained in real-time data gathering, processing and distribution to the rest of the world. AIRNow-I will offer air quality information to the public in areas across the world that do not currently have such access.

Armed with this knowledge, the public can begin to make decisions to protect themselves from harmful air quality. In addition, the data sharing capabilities that AIRNow-I provides can be of tremendous use to the air quality research community. As different local entities begin to share air quality information, new discoveries can be made about the behaviour and causes of regional air pollution.

Furthermore, AIRNow-I sets the stage for an international dialogue on real-time data standards, methods, applications, and more. AIRNow-I has the potential to become a catalyst for worldwide integration and standardization of real-time air quality data. In addition, AIRNow-I contributes to bringing international equity to the availability of public information regarding air quality. This is especially important in developing countries where air quality can be an immense public health issue.

By supporting existing real-time data efforts in other countries, AIRNow-I will serve to bolster those established systems, while also allowing less developed countries to apply AIRNow technology. With established standards for sharing data, AIRNow-I could interface seamlessly with existing systems and allowing for worldwide sharing of air quality data. This worldwide availability of data would foster air quality research, while also giving the public access to an important health resource.

GEO societal benefits

AIRNow-I delivers the key GEO societal benefit of 'understanding environmental factors affecting human health and well-being'. Within that benefit area, two key topics are air quality and the urban environment. AIRNow-I supports both, with air quality as its primary focus. As for the urban environment, AIRNow-I will provide the data and tools needed to both measure air quality in urban areas and, more importantly, inform the residents in those areas. As such, AIRNow-I will deliver great benefit to both key GEO topics.

AIRNow-I is a critical infrastructure and public information piece within the larger GEO framework. Using the AIRNow framework will allow GEO to measure and report air quality on a global scale. Furthermore, the AIRNow-I real-time data and reporting concept could be extended to other media, such as water, and could also be used as a basis for emergency environmental alerts. This has already been done in parts of the US with the EnviroFlash e-mail alert system.

In addition, the AIRNow-I project dovetails nicely with several other GEO initiatives. In particular, the AIRNow team plans to support the Common Alerting Protocol (CAP) to integrate air quality alerts into CAP's all-hazards, all-media approach.

Call to action for GEO

In the GEOSS ten-year implementation plan, the health societal benefit is described thus: "GEOSS will improve the flow of appropriate environmental data and health statistics to the health community, promoting a focus on prevention and contributing to the continued improvements in human health worldwide."

This passage illustrates precisely the need for a system such as AIRNow-I. In the air quality arena, the only prevention available is through knowledge of when and where poor air quality exists. In many developing nations, that information is simply not available to the people that so desperately need it.

GEO provides the necessary tools for countries around the globe to measure, evaluate and distribute air quality information – information that can be used to further research, but more importantly, to protect public health.

The Air Quality Health Index: using Canadian Earth observations for health protection from air pollution

Dave Henderson, Policy Advisor, Air Issues and Sean Daley, Program Officer, Business Policy, Meteorological Service of Canada, Environment Canada; David M. Stieb, Medical Epidemiologist, Healthy Environments and Consumer Safety Branch, Health Canada

Extensive studies around the world have linked air pollution to a variety of adverse health effects including premature mortality, and both respiratory and cardiovascular morbidity. These studies also indicated that certain populations are more vulnerable to those adverse health effects, namely children, the elderly, and people with pre-existing cardio-respiratory disease. Individuals who exercise or do strenuous activities outdoors are also more susceptible to the negative effects of air pollution.

For nearly three decades Canadians have relied on an Air Quality Index (AQI) to inform them of measured and forecast air pollution conditions. It is recognized that these indices are inadequate for personal health protection because they are:

- Based on thresholds which imply a safe level of single pollutant concentrations and can not convey that adverse health effects can be experienced by sensitive members of the population at relatively low pollutant concentrations
- Not designed to reflect a realistic assessment of the mixture of gases and particles that we breathe
- Inconsistently applied and communicated across Canada, resulting in the absence of a true national picture of daily air quality, which limits national media exposure and comparability for travelling.

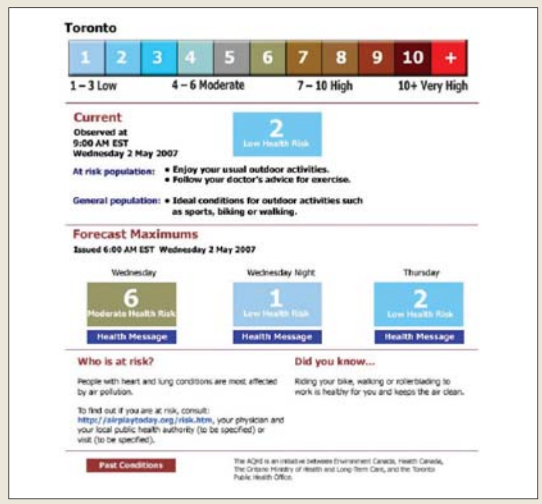
The move toward an Air Quality Health Index

Health Canada (HC) and Environment Canada (EC) collaborated with national air quality stakeholders representing health and environmental expertise from provinces, municipalities and non-governmental organizations. Together they developed a national, health-based approach to presenting air quality information to Canadians.

Modelled after the successful, Canadian-developed index for ultraviolet radiation (UV index), the Air Quality Health Index (AQHI) was designed to provide Canadians with local air quality information and forecasts combined with health and environmental messages, on a daily basis. The AQHI is a personal communications tool designed to increase public awareness of air quality as a community health issue in Canada.

The index follows the principles established by the Group on Earth Observations (GEO), as it combines observations and information across sectors to provide a value-added product to society; in this case information related to human health. The index will be used to enable Canadians to take appropriate measures to protect their health in response to changing air quality conditions and to help motivate them to take actions to reduce emissions.

Air Quality Health Index



The Air Quality Health Index provides Canadians with local air quality information and forecasts combined with health and environmental messages

Source: Environment Canada, 2007

The science of the AQHI

As an alternative to linking air quality information to air pollution standards or guidelines, the AQHI is founded on the statistical analyses of mortality risks associated with air pollution for ten large Canadian cites. Through exhaustive analyses of the 20-year, day-to-day health impact of air pollution for each location, Health Canada analysts developed a new health-based formulation derived from mortality statistics. This methodology better characterizes the community health risk associated with an air pollution mixture composed of ground-level ozone, particulate matter, and nitrogen dioxide. The science underlying the new index has been published in the peer-reviewed literature and undergone two additional scientific peer reviews.

Presentation of the AQHI

The AQHI uses a colour scale of 1 to 10+ to represent the health risks posed by the air pollutant mixture for current and forecast conditions. The scale is divided into categories that describe the relative health risk as low, moderate, high or very high. For each category there are associated health messages that provide concrete advice on how to reduce those risks. Two sets of messages have been developed; one for the general public and the other for those at greater risk, as noted in the introduction. The presentation elements are integrated into an informative graphic, which is updated hourly and made available on the Internet as new air pollution monitoring data are captured, processed and linked to the appropriate forecast period. Using this approach the data collected are transformed into a communication tool.

Data acquisition

The delivery of the AQHI to Canadians is built upon real time air quality data from Environment Canada's rural-based Canadian Air and Precipitation Monitoring Network (CAPMoN) and the largely urban-based Canadian National Air Pollution Surveillance (NAPS) network, in partnership with the provinces and municipalities. These data are captured at the Canadian Meteorological Centre and used in the production of forecast products and in providing real-time AQHI conditions. The integration of data from disparate networks is a fundamental thrust to the GEO initiative.

User interface — implementation

Environment Canada is responsible for environmental stakeholder relations on the implementation of the AQHI. Operational tests conducted in the provinces of Nova Scotia in 2006 and in British Columbia in 2005 and 2006, have resulted in several improvements to the new index. More importantly, these tests confirmed the appetite for such a personal health protection tool. The success of these pilots laid the foundation for a national introduction of the AQHI, which began in July 2007 in Toronto. This will expand in 2008 to the Greater Toronto Area, which comprises 15 per cent of Canada's population.

The collaboration among environment and health departments at all levels of government, non-governmental organizations and the communications industry which characterized the development phase, will be an ongoing feature of the implementation of the index over the coming years. The presentation of the index will be adapted to requirements set by local and provincial health authorities. Building capacity within the health sector jurisdictions to respond to public interest in the AQHI is a focus for the approach.

Lessons learned

Testing of the index to date has shown that it raises interest in not only health aspects of air quality, but also on measures one may take to reduce personal contributions to community air pollution. Support will be made available to non-governmental organizations to develop strategies that use the AQHI as a tool to encourage reduced air pollutant and greenhouse gas emissions.

The pilots in Nova Scotia and British Columbia suggest that the public want to have the AQHI 'pushed' to them; their preference is not to access websites or phone systems to receive this information. In the Toronto introduction of the index, local and national media are willingly carrying the AQHI in limited regional feeds and they will also be enthusiastic participants as the index is rolled out across Canada.

The future of the AQHI

Environment Canada will continue to support the expansion and transition from the existing single-pollutant, threshold-based forecast to the new multi-pollutant prediction requirements for the AQHI. Implementing the index across Canada over the coming years will necessitate the development, testing and implementation of new models and techniques to assist forecasters with issuing AQHI forecasts.

EC will expand its Internet presence to support dynamic dissemination of the AQHI through the 'Weatheroffice' website (www.weatheroffice.ec.gc.ca) which receives up to 1.7 million visits daily. EC will continue to develop and maintain the AQHI information website (www.ec.gc.ca/cas-aqhi) and base improvements on user feedback. National implementation of the AQHI in major urban centres is expected to be completed over the next four years.

The AQHI demonstrates how Canadian expertise in health science, air quality forecasting and earth observations networks can merge to produce societal benefits. It also illustrates how improved understanding of environmental factors affecting human health and well-being may lead to an information tool which has the potential of improving the health of all Canadians. Like the Canadian developed UV index, the AQHI provides an easy to understand, informative package with specific recommendations on how to reduce the risk associated with air pollution in a community. The potential benefits to society of a nationally implemented AQHI include improved health, better quality of life and economic returns through reduced health care costs and fewer absences from work.

Photo: Richard Tanabe – July 2007

The Canadian Air and Precipitation Monitoring Network

Informing decision making in the energy sector using NASA spaceborne observations and model predictions

Richard S. Eckman and Paul W. Stackhouse, Jr., NASA Langley Research Center

Adapting global sets of spaceborne observations — often made for diverse research purposes — to enhance end-user decision making remains a challenge for the Global Earth Observation System of Systems (GEOSS). The US National Aeronautics and Space Administration (NASA) Applied Sciences Program (the Program) seeks to identify innovative uses for NASA-derived spaceborne observations and model predictions and connect with end users to enhance their ability to make management and policy decisions. The Applied Sciences Program's Energy Management application extends NASA Earth science research results to improve decisions and assessments for energy production and energy efficiency, by interacting with partners to benchmark NASA research datasets derived from the analysis of historic and current observations and models to meet energy sector needs. These partners are other government agencies (both domestic and international), academia, professional organizations and the private sector. These activities support the goals of the GEOSS energy societal benefit area.

The Energy Management Program focuses its activities on several energy sector themes by integrating NASA-sponsored spaceborne measurements and mathematical models to produce value-added datasets which can be directly used by energy decision makers. These themes include renewable energy, energy efficiency (sustainable buildings), bioenergy, climate change impacts on the energy sector, supply and load forecasting, and space weather impacts on the energy sector.

Key to the success of the uptake of Earth observations is the creation of datasets in readily accessible formats, in units consistent with the end-user's needs, and delivered via the web. NASA researchers integrate observations from multiple data sources and models to produce value-added products for the energy sector. In the following sections, we describe some recent Program activities.

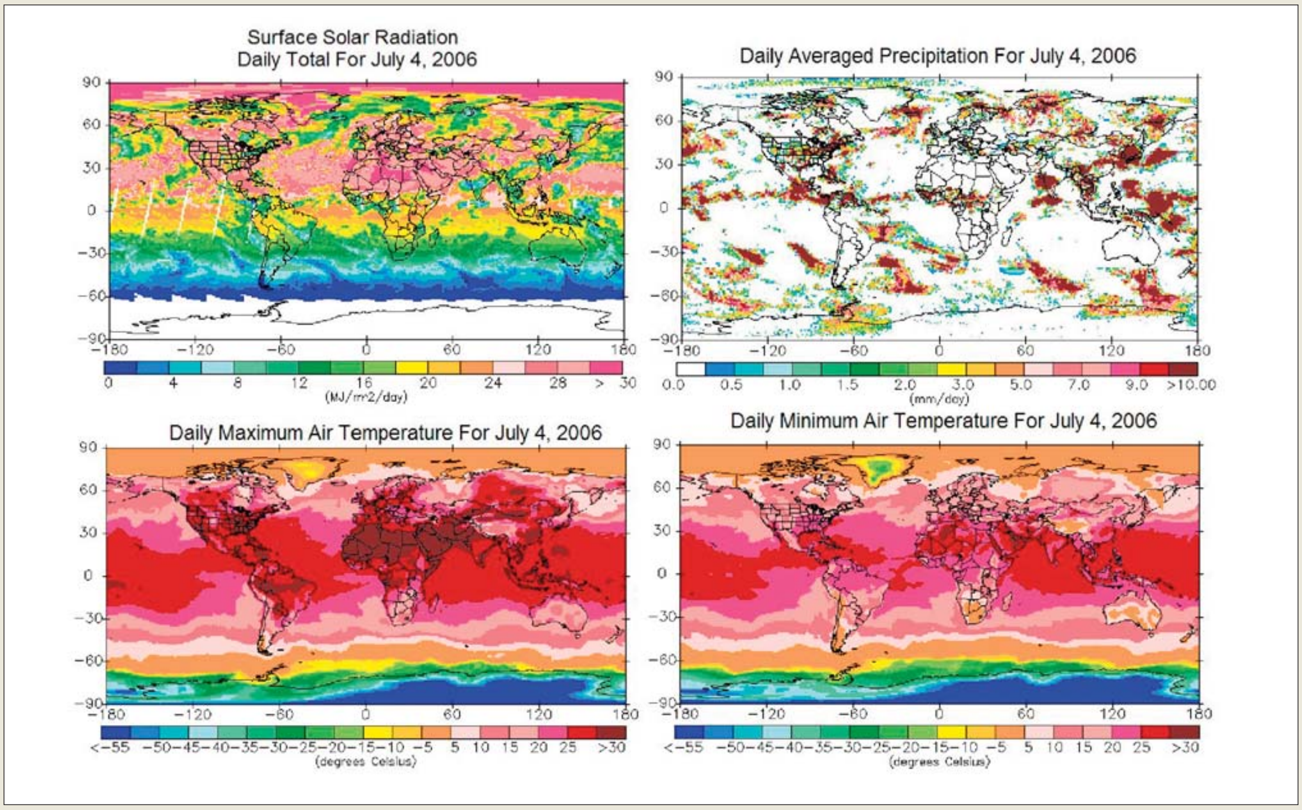
Renewable energy

In the renewable energy sector, NASA has developed partnerships with Natural Resources Canada (NRCan) and the US National Renewable Energy Laboratory (NREL) to enhance their project analysis tools using NASA-derived datasets of surface solar energy and meteorological parameters derived from assimilation models. This product, the Surface Meteorological and Solar Energy dataset (SSE), contains over 200 satellite-derived meteorology and solar energy parameters monthly averaged from ten years of data on a 1° x 1° global grid. These data are derived from a variety of NASA measurements and NASA-sponsored programmes including the Earth Radiation Budget Experiment (ERBE), International Satellite Cloud Climatology Project (ISCCP), Surface Radiation Budget (SRB), Global Modeling and Assimilation Office (GMAO), Goddard Earth Observing System (GEOS) meteorological analysis model, and Langley Research Center FLASHFlux project providing near-real time surface radiative flux.

RETScreen (www.retscreen.net) is a clean energy decision support system, developed by NRCan's CANMET Energy Technology Centre, which enables end users to better assess the feasibility of renewable energy and energy efficiency projects, their costs, and greenhouse gas mitigation benefits. Surface solar energy measurements available from ground observations are often sparse or unavailable in the developing world. NASA's satellite-derived global observations and historical datasets of meteorological parameters can be integrated by the RETScreen decision-making tool to enhance its utility where ground-based inputs are unavailable. RETScreen has over 120,000 registered users in the developed and developing world. We have also partnered with NREL's HOMER micropower optimization tool for distributed power by making available similar NASA-derived products. Both RETScreen and NREL access the NASA data through via the Internet; thereby providing convenient access to the most recent parameter estimates available. Studies by both partners, presented at the 2006 American Solar Energy Society annual meeting, confirm the utility of the NASA SSE dataset in enhancing the ability of their decision support systems for the adaptation and mitigation of energy production and efficiency to changing environmental conditions.

The Energy Management Program has also participated in the United Nations Environment Programme Solar and Wind Energy Resource Assessment (SWERA) project. The goal of SWERA is to enable the delivery of accurate solar and wind energy resource assessment information globally. The project initially focused on 13 pilot countries in the developing world. Working together with our decision support tool partners, the Program has been active in supporting SWERA's activities. NASA's Energy Management Program has recently initiated a project to further the SWERA goals by enhancing the availability and

NASA Earth Science products for energy decision support



Sample solar irradiance and meteorological products from NASA science research adapted for testing in crop models. In the example, daily averaged parameters for 4 July 2006 are presented for solar irradiance, average precipitation, and daily maximum and minimum temperatures

Source: NASA

distribution of global data sets of these resource assessment products in collaboration with the US Geological Survey.

We are collaborating on an International Energy Agency (IEA) task entitled 'Solar Resource Knowledge Management.' This activity uses satellite-derived datasets to add value to the standardization and structure (e.g. improved spatial and temporal coverage) of energy products for use worldwide and which are easily accessible to end users. The project's goals are inherently consistent with the GEOSS 10-year Implementation Plan for solar irradiance data sets. The task is establishing standardized methods for evaluating satellite based solar energy information and developing advanced methods to disseminate that information, while fostering the development and improvement of the capability for current and future satellite systems to provide such information. Planned outcomes of this activity will reduce the cost and planning of solar energy system deployment and improve efficiency of solar energy systems by more accurate and complete resource information.

Biofuels

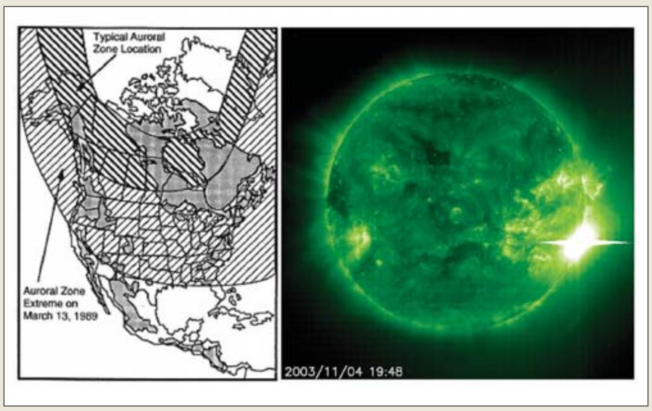
NASA has partnered with two universities and with the US Department of Agriculture-Agricultural Research Service to integrate NASA-derived measurements into wheat and maize crop yield models to test from improvements to their predictive capacity. These agricultural decision support systems typically require timely access to meteorological parameters such as solar irradiance, temperature and precipitation, and have previously relied on ground-based networks. The Program delivered its first version of a website dedicated to providing agricultural industry access to climatological information not readily available on a consistent basis worldwide. Solar parameters were adapted to units used in agricultural modeling for ease of use by end users. The prototype project conducted earlier this year was deemed successful and further work is planned. Given the rapid expansion of ethanol production in the US, this collaboration can contribute to the optimization of corn-based ethanol production and to balancing the demand between food, feed and fuel with other crops.

Energy efficiency

The Energy Management Program is working to support the sustainable buildings design and engineering industry by collaborating with partners and developing new parameters from NASA derived datasets specifically designed to meet engineering needs. A Sustainable Buildings website was delivered in 2006 (http://power.larc.nasa.gov/buildings). This interface contains new plots and figures that architects and heating, ventilation and air conditioning engineers may use in the energy efficient design of buildings. Also, specialized statistics including US Department of Energy consistent climate zones were defined from the datasets.

NASA researchers have participated in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) meetings and in its Meteorology and Climate subcommittee. Sample datasets were made available for evaluation by committee members. These datasets specifically address unmet data needs for clear-sky solar flux information for the building design community.

Geomagnetically induced current events



Power systems in areas of igneous rock (grey) are the most vulnerable to the effects of intense geomagnetic activity because the high resistance of igneous rock encourages geomagnetically induced currents (GICs) to flow in the power transmission lines situated above the rock. (Left) Shown in cross-hatching are the auroral zone and the extremes that the aurora can reach during severe disturbances such as 13 March 1989. (Right) NASA provides solar and near-Earth environment data sets used by models to predict GIC events

Left image: J. Kappenman, EOS, 29 January 1997, p. 37. Right image: NASA

NASA's spacecraft constellation monitoring the Earth-Sun system

Observations from many of these spacecraft have been used to inform decision making in the energy sector by providing Earth radiation, solar, and near-Earth environment datasets

Source: NASA

Climate change impacts

In the energy market forecasting and climate change impacts community, integrated assessment models are increasingly used to assess policy options for climate change mitigation and adaptation. The US Pacific Northwest National Laboratory's (PNNL) MiniCAM market forecast model is one such integrated assessment model. MiniCAM has a detailed representation of energy technologies for energy supply and end use. NASA has provided surface solar energy datasets specifically designed to meet input needs of MiniCAM's renewable energy module. The impact of the NASA inputs is currently being evaluated and we plan to provide additional datasets for use by MiniCAM and other integrated assessment models.

The Program conducted a stakeholder's workshop in early 2007 which engaged other US Government agencies, electric power utilities, and the private sector to understand user requirements and assess how NASA-derived measurements could meet some of these needs. Stakeholders expressed a strong interest in understanding future climate change impacts, especially considerations such as land use, temperature, and reducing uncertainties in forecasts to enable adoption and mitigation. The Program will begin assessing the utility of downscaled global climate model predictions to inform regional climate change impacts in the Energy sector.

Space weather impacts

Enhanced solar activity can cause disruptions to electric power transmission systems. A notable example was the major X-class solar flare on 13 March 1989, and its resultant geomagnetic disturbance which led to instability in Hydro-Quebec's electric power grid, leaving six million people without power for nine hours. The Energy Management Program has partnered with the Electric Power Research Institute's (EPRI) SUNBURST network to enhance its capability for predicting geomagnetically induced currents (GIC) and their impacts on the power transmission system using NASA observations of the near-Earth environment (including the Solar and Heliospheric Observatory (SOHO), Solar Terrestrial Relations Observatory (STEREO), Advanced Composition Explorer (ACE), Wind and Geotail) together with a suite of models that predict the ground-based impact of these solar disturbances. SUNBURST predictions may be used by electric power companies to better predict the potential for damaging GIC events.

By developing data products using NASA spaceborne measurements and model predictions in close cooperation with decision makers, using consistent units, and delivered in easy-to-use interfaces, the NASA Applied Sciences Program Energy Management application advances the uptake of Earth observations and models to improve decision-making in the Energy sector worldwide. The Program works closely with the Group on Earth Observations (GEO) Energy Community of Practice to ensure that our activities are aligned with GEO Energy work plan goals to improve the management of energy resources.

Space for solar energy

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It is widely recognized, both scientifically and politically, that the increase of atmospheric CO_2 has led to the increased speed of the greenhouse effect and, as such, warrants concern with regards to climate change. Following the IPCC report in 2007, it is now clear that climate change is partly induced by humans and the use of fossil fuels. Today, solar energy is receiving increasing attention as a clean and renewable energy alternative to oil or coal. The future contribution of solar energy to a sustainable energy supply strongly depends on its availability, in other words the solar resources.

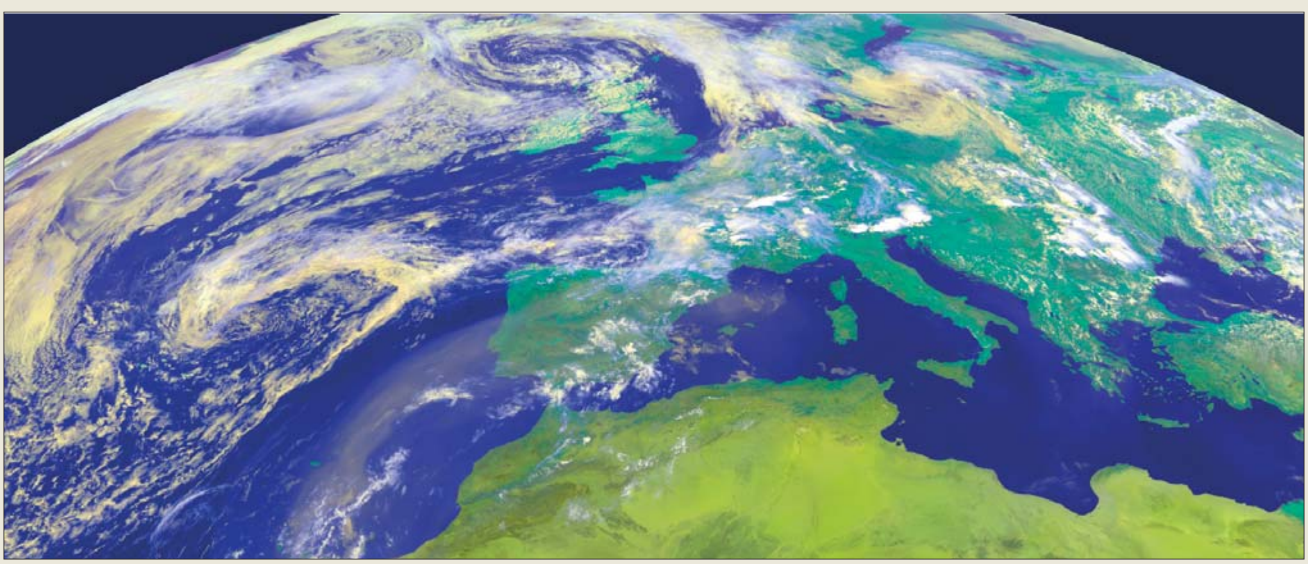
The general expectation for the world's solar energy market is a sustained growth, based on incentives and preferential tariffs. During this transition phase, with the solar energy market changing from an idealistic/incentive driven market to a financially driven one, investment assurance is necessary. This is provided by services in the different phases of investment decision-making in the planning stage, and in plant management during the operations phase. In both phases, the spatial distribution of Global Earth Observation System of Systems (GEOSS) information constitutes an advantage over ground-measured data, and helps to develop sustainable solar energy production.

Apart from these market segments, another emerging and promising segment of the market is the load and production forecasting for utilities. Because of liberalized markets and the higher penetration of renewable energies, an accurate load and production forecast is necessary to secure energy supply with intermittent renewable energy resources. For this segment, temperature and irradiance, as the major environmental influences on electricity demand and solar energy production, become indispensable variables in forecasting.

Role of space technologies

Earth observation products and services have proven to be helpful for the resource assessment, monitoring and forecasting of fluctuating energy sources like solar energy. Solar energy resources are currently assessed mainly in situ and through satellite-based measure-

METEOSAT image



Clouds and aerosols as seen from the METEOSAT satellite series on 23 July 2004, 12:00 UTC

Source: Copyright DLR/EUMETSAT

Irradiance image

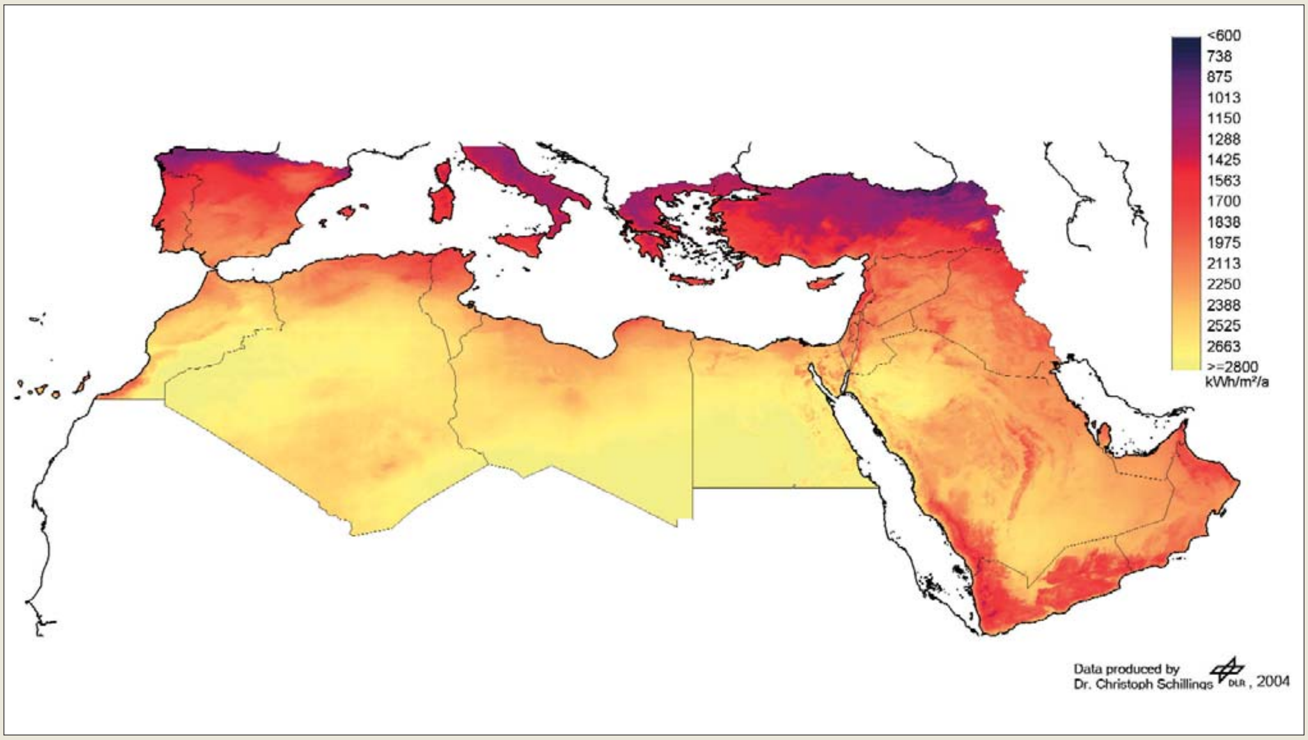


Image showing annual sum of direct normal irradiance for 2004

Source: DLR

ments. Basic information for solar energy users includes the amount of incoming solar radiation measured at ground level. Global, diffuse and direct irradiance are needed for the different technical systems. Spectral distribution of irradiance will be required in the future, for example, in the use of spectrally more sensitive thin film photovoltaic (PV) technologies.

Earth observation allows the provision of surface solar irradiance services specifically adapted to users' needs in the solar energy sector. In particular, the temporal and spatial resolution of geostationary satellites in the GOES and the METEOSAT series are essential for this application.

An important function of meteorological geostationary satellites is detecting cloud fields and monitoring their evolution in time over extended regions of the world. Clouds are the main modulator of daily and hourly solar irradiance, thus radiance measurements from space represent a unique data source for geographically continuous assessments of the solar resource at the earth's surface.

In addition to cloud information, detailed knowledge about atmospheric substances like aerosol particles, water vapour, trace gases and air molecules involved in the scattering and absorption of sunlight is a further necessity. Such information is taken from climatologies, atmospheric modelling and atmospheric satellite measurements.

Space-based services

Services for investment decision — Site assessment allows the investor to find the best site for a planned power plant and to optimise the financial yield. Site analysis and optimisation is based on maps of the average long-term radiation available. If a site is found, time series are needed for the power plant technical design phase. For larger project developments, hourly resolved time series of up to ten years are necessary, for smaller projects monthly mean values are sufficient. GEOSS satellites provide such long-term time series over a large geographical area.

Services for plant management — A service line for plant management is needed once a solar energy system is built. Automatic fault detection and performance control allow reliable alarm issuing and assure the validity of the investment, while a performance check for smaller plants gives first estimates of performance and failures. Through comparison between the effective energy production and the corresponding solar energy at the array plane, the proper functioning of the solar power plant can be monitored in defined time intervals. Hourly values are used for error analysis, comparing typical patterns of energy loss and the profile of the actual failure.

Services for utilities — Both energy supply and demand require information on the solar resource. The scheduling of large power plants and overall grid management necessitates precise knowledge of the expected load. Beside temperature, irradiance has a major environmental influence of up to ten per cent on electricity demand. For this reason solar irradiance needs to be forecasted as well load. On the supply side, electric power transmission systems collect power from conven-

Photo: Enecolo AG

Photovoltaic system Jasminweg in Zürich. The Jasminweg photovoltaic system is operated by Edisun Power AG using plant monitoring services based on satellite information

tional plants as well as from different renewable sources, such as solar PV plants, and deliver it to the final users.

GEOSS near-term success project on solar energy data for developing countries

Using the SoDa service[1] as a foundation, NASA and the Ecole des Mines de Paris have collaborated in an effort to provide solar energy data for developing countries. Two databases, the Ecole des Mines des Paris Helioclim database and the Surface Meteorology and Solar Energy (SSE) NASA data set were combined. The SoDa web interface enables automatic access to both data sets, selecting the database with the best temporal and spatial resolution for a certain location.

Daily values of a site's irradiance for a multi-annual time series length can be retrieved via a web service. This project is a successful example of how European and US-based databases can be merged and made available to the global community. This activity is already a part of the NASA Energy Management Applied Science programme, and will be a part of the planned Global Monitoring for Environment and Security (GMES) solar energy radiation core service.

Benefit of earth observation for solar energy users

During the Environmental Information for Solar Energy Industries (ENVISOLAR)[2] project (part of the European Space Agency's Earth Observation Market Development programme), users sought to raise awareness on GEOSS capabilities. The user group included institutional investors, engineering companies active as project developers, assurances, banks and professional operators of solar power plants, private investors, utilities, and load management software operators.

SAG Solarstrom AG builds and operates different sized PV installations and provides full financial investments to its customers. Benedikt Ortmann, chief financial officer, says: "Looking at our huge investment, we have to be sure that we minimize the risk. Constant solar radiation is the basis for that." SAG Solarstrom's Uwe Ilgeman states that he cannot set satellite-derived data aside when building and operating systems. "Especially with regard to future markets like Spain, we need solid information for investment decisions," he says. "The resolution of ground-based data is too coarse — for example in Spain there are only 30 sites available at the moment. Here, satellite-derived data could help a lot."

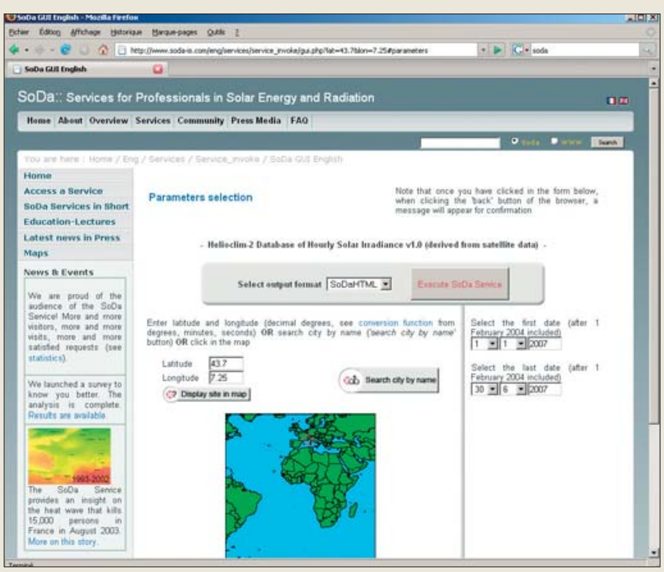
Contracting company Edisun Power AG, the largest contractor of PV plants in Switzerland, orders site evaluations based on earth observation data. Site evaluations for PV systems are of high importance for the investor, as location is one of the most important factors in determining the profit or loss of a PV plant. Before satellite-based irradiance values were available, reliable yield estimations for many regions remained wishful thinking. Edisun Power AG director Robert Kröni confirms: "Comparison with existing PV installations, the best source for site evaluation, is only available for regions where the contractor already has a sufficient number of PV installations. When a new market opens this source is not available, as PV operators do not usually publish their production values. We are now expanding into countries like Germany, Italy and Spain where we have no operation experience. To assure the flow back of investment we must be sure that we build the PV systems at locations with enough solar radiation".

"In developing countries all over the world we have removed some of the uncertainty about the size and intensity of the solar and wind resource," says Klaus Toepfer, former executive director for Solar and Wind Energy Resource Assessment (SWERA)[3] at the United Nations Environment Programme (UNEP). "These countries need greatly expanded energy services to help in the fight against poverty and to power sustainable development. SWERA offers them the technical and policy assistance to capture the potential that renewable energy can offer," he says. "As energy planners seek cleaner energy solutions using renewable energy technologies, the availability of reliable, accurate and accessible solar and wind energy information is critical and can significantly accelerate the deployment of these technologies. In the case of renewable energy, knowledge is literally power".

Peter Toggweiler of Enecolo AG tells of its problems with plant monitoring: "As an engineering consultant, Enecolo AG is mandated to monitor more than 30 PV plants with a total installed power of about 2.5 MW. The PV plants are distributed all over Switzerland and the southern part of Germany, and differ widely in installed power, module types, inverters and monitoring procedure. Most PV systems are provided with a device that allows connection to the inverter. But for each type of inverter, another software and data logger is needed and a different type of data is provided.

"For most PV systems we receive the monthly energy yield via fax or e-mail. All these data are then manually collected and analysed. This procedure is very time consuming and ineffective. As we only receive monthly data, it can be 31 days before we recognize a malfunction. Failures that don't lead to a complete outage but only to a minor reduction of the energy yield are often not detected at all, or only after several months. With a satellite-based service, plant monitoring will be facilitated and more efficient: hourly data of the energy yield of the PV plant is automatically collected on the server and delivered to the operators of the PV system through the Internet. Thus, no time-intensive manual collection of the data is necessary. The data is updated every day, so it is possible to detect malfunctions within one day instead of within one month".

SoDa interface



The SoDa web interface enables automatic access to both the Ecole des Mines des Paris Helioclim database and the Surface Meteorology and Solar Energy NASA data set

Source: www.soda-is.com

Dr Henner Gladen of Solar Millennium AG, a German, global-oriented technology and service company, says: "Solar radiation time series delivered by DLR were used in the planning of eight projects, with a total peak power of 360 MW. This corresponds to an estimated investment of about EUR1,400 million. Solar Millennium AG is planning further large solar thermal power plants worldwide. The field of large solar thermal power plants is an evolving market with projected worldwide investment to the order of some EUR10 billion over the next ten years. To improve economical analysis we want to make further use of satellite based solar irradiance data. It allows us to receive reliable maps showing the distribution of solar energy in regions of interest, for use in further projects."

Mathieu Sarran from German company Lahmeyer International, which provides technologies for energy infrastructure development, says: "Our consulting activities on rural electricity provision by means of solar energy require accurate data on solar radiation. In Africa, such data are inexistent in under-developed regions. Accordingly, Lahmeyer International installs its own measuring stations. The availability of radiation data that can be accessed through the SoDa service is a real advantage for our company.

"The first benefit is that they are available at any site: there are more data than we can install stations. The second benefit is that archives are available instantaneously while our measuring stations need to work two full years before delivering a consistent and reliable time series. Advantages include fast access to information, reliability of information, large geographical coverage and the dramatic decrease of costs for study and planning. By exploiting these data, projects can be realized more quickly, more reliably, more completely and more competitively."

The future of solar energy resources

Earth observation satellites have proven to be a valuable tool for the optimum use of solar energy resources. Satellites and ground measurements are excellent partners for providing dedicated services, with satellites allowing services on a large regional scale. Both industrialized and developing countries are covered by the same satellite technology and can profit from each other.

Various user statements both from the industrial and public sectors show the benefits of solar energy resources already exist. Nevertheless, realizing the full potential of the GEOSS system requires further collaboration between users and information providers to enable global data access and improved data accuracy. In particular, new approaches in data policy and long-term maintenance of databases, archives and access infrastructure are needed in the GEOSS framework.

Winds of change from space

Pierre-Philippe Mathieu, European Space Agency, ESA/ESRIN;
Charlotte Hasager, RISOE National Laboratory DTU

Wind energy is entering a golden age, with the fastest growth across the whole renewable energy industry. Recent regulations and policy targets related to climate change are driving a booming demand for wind power. The currently installed wind power capacity in Europe generates about 6 per cent of electricity consumption and is predicted to grow to 25 per cent by 2030, in particular via offshore production.

How can Earth Observation (EO) satellites orbiting several hundreds of kilometres above the Earth help in the building and operating of wind farms? The answer lies in the unique ability of EO satellites to deliver global and repetitive measurements of the state of the atmosphere (eg meteorological conditions), ocean (eg coastal wind and wave conditions) and land (eg topography, vegetation cover, terrain roughness). With EO this is even possible in the most remote areas, where no survey data exist, or else are impossible to obtain.

Such global data set can help energy managers and investors to perform technical and financial feasibility studies of prospective sites by quantifying factors determining the revenue (eg wind resources available over the plant life-time) as well as the cost (eg environmental impact, access to turbines for maintenance and connection to the grid network for distribution).

In spite of their potential utility, the operational use of EO data within the wind industry remains rather limited because of significant cultural and awareness barriers, but also due to the need to turn raw data into useable information. Recently, new Virtual Globes technologies, such as Google Earth and Virtual Earth, have significantly contributed to raise awareness about the potential of EO.

Value chain of Earth observation data

Raw data is converted into useful information through pre-processing (retrieval of geophysical data) and integration with other data sources. It is then delivered into user-friendly geographic information systems and software used within the renewable energy industry

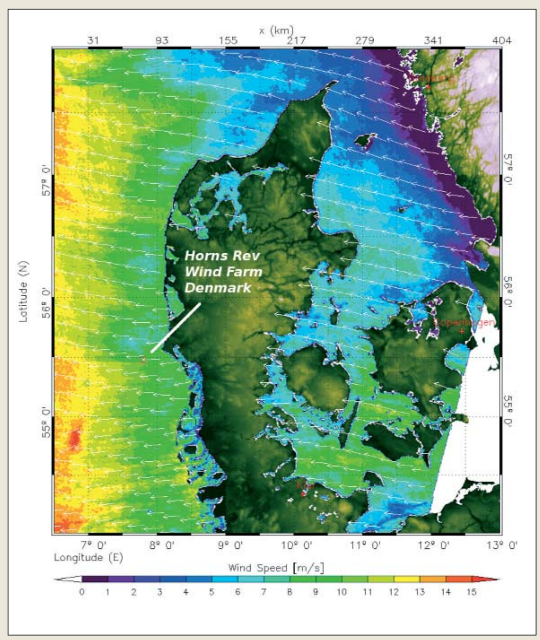
Source: RISOE and ESA

However, more efforts are still needed to make the most of the data. In this context, several demonstration projects have been started in the framework of the Earth Observation Market Development programme (www.esa.int/eomd) of the European Space Agency (ESA). Their aim is to foster the use of EO within business practices of the renewable energy industry by building partnerships between small value-adding companies (specialized in EO data processing) and large downstream companies requiring geo-information, such as Tractebel, BMT, Shell, Vestas, and Airtricity.

Improved wind modelling

Accurate modelling of the wind flow is critical to quantify wind resources at hub height. It also helps to improve the accuracy of short-term forecast, leading to more effi-

Coastal wind measured from space



High-resolution wind field (mainly originating from South West) around the Horns Rev wind farm, off the coast of Denmark. Data derived from the ASAR instrument onboard the ENVISAT satellite on the 14 November 2005

Source: BOOST Technologies and ESA

cient and economic operation of the power system when integrating substantial amounts of wind power.

Satellites can help to improve the accuracy of models by providing data on weather conditions and boundary conditions, both onshore (eg orography, surface roughness) and offshore (eg sea surface temperature), necessary to constrain models. The geospatial nature of EO data is particularly suited to initialize, validate and force models as they capture the heterogeneities of factors influencing the wind flow. For example, satellites can measure the variations in sea surface temperature, which are responsible for a systematic deviation of the vertical wind speed profile from the standard Monin-Obukhov theory (typically found for near neutral and stable conditions).

Synoptic mapping of ocean wind resources

The traditional way to assess the potential energy yield of a prospective wind farm is by using data from a meteorological mast, which is very expensive in terms of installation and maintenance. For example, it can cost around 750, 000EUR for one offshore mast running for one year. Although this approach is accurate, it can only provide point-measurement data for a short period of time (typically one year), while the wind field is generally highly variable in space and time. Using local data can therefore be an issue to assess effectively the 'bankability' of prospective wind farms.

In contrast, satellite measurements of ocean winds provide a more comprehensive and spatially resolved view of wind climatology data and its associated probability distribution. Satellites are capable of taking measurements within a few m/s for the wind speed and approximately 20 deg for the wind direction.[1] An assessment of the variability of coastal wind resources can be readily achieved from space by combining global data from Scatterometers at O(25km) resolution and regional data from Synthetic Aperture Radar (SAR) at O(100m) resolution. Radar data from SAR can also be used to study the shadow effect of mountains and the wake created by large turbines, which may reach more than 20 km downstream of offshore wind farms.[2]

Optimizing design for maintenance operations

Assessing the operability and availability of offshore wind turbines, including the effects of support logistics and the numbers and capabilities of maintenance vessels, is a key part of studying the feasibility of wind farm projects. An important question arising at the earlier stages of development is whether it is more cost effective to spend money on incremental improvements on turbine reliability, or to buy more maintenance vessels.

EO can help address this question by quantifying the site-specific met-ocean conditions through long-term data sets of wind and wave conditions.[3] Such statistical information can be used in a variety of applications, including the determination of the type of vessels needed for maintenance, the quantification of fatigue load of an offshore wind turbine, and the optimal design and assessment of 'downtime' for turbines.[4]

Assessing environmental conditions

Wind farms can raise environmental problems such as the level of noise, visual effect, impact on bird populations and marine biological activity. In order to assess the potential environmental impact of planned wind farms, an acoustic wave and current meter instrument can be deployed at the site to measure the sediment load. However, operating in-situ sensors in harsh marine conditions is challenging and can lead to massive biofouling due to the presence of whelks and eggs covering the sensor after recovery.

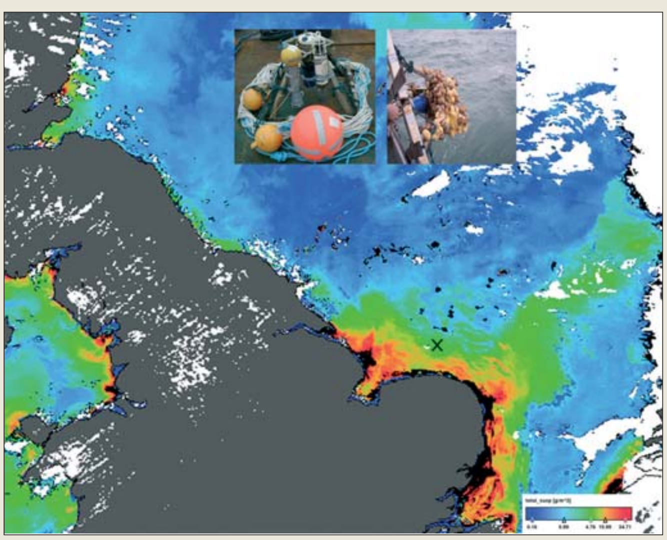
In contrast, monitoring from space suffers from no such problem and can deliver a synoptic map of sediment matter. This combines well with the in-situ data and complements them by providing additional information on the spatial distribution of sediments.

The outlook for Earth observation wind data

EO satellites orbiting hundreds of kilometres above the Earth can help the industry to better harness the power of wind. EO data provide wind investors and engineers with wide-area observation that is unavailable any other way. This data enables them to conduct a first check of multiple prospective sites (even those inaccessible or remote) without leaving their office, and at a much cheaper cost than travelling to the site.

EO is however, only one part of the solution and needs to be integrated with other ancillary data into wider knowledge solutions to open new business opportunities. Realizing the full potential of EO in this context requires further close collaboration between users and providers of the technology.

Sediment load measured from space and coastal observatories



Map of total suspended matter derived from the optical instrument MERIS on board ENVISAT for the 29 April 2005. The colour legend displays increasing sediment concentration going from blue to green to red. The optical instrument cannot see through clouds, which are represented in white. The location of the planned Sheringham Shoal offshore wind farm is marked with a cross. The acoustic wave and current meter sensor used to measure sediment load via acoustic backscatter intensities is also represented before and after recovery. In the upper right image the unit is covered by whelks and whelks' eggs

Source: GRAS, SCIRA Offshore Energy Ltd and Gardline Environmental Ltd

State of the climate — using Earth observations to monitor the global climate

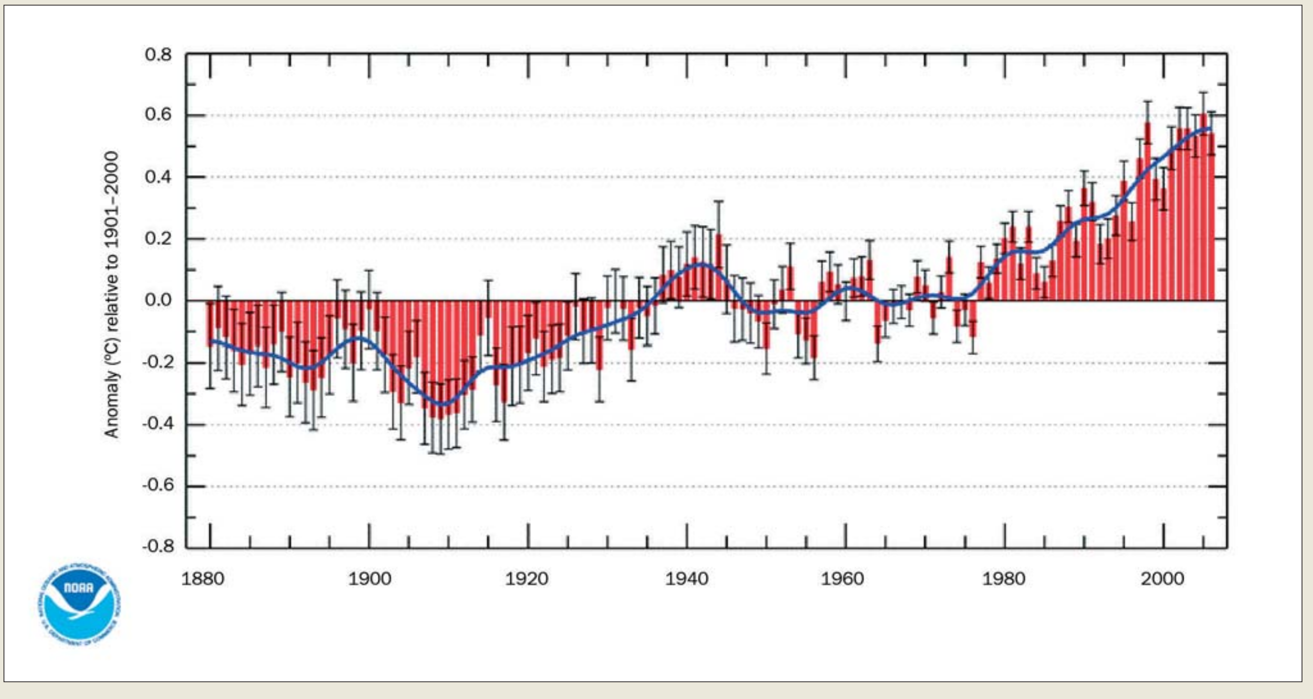
Jay Lawrimore, NOAA National Climatic Data Center

Observed changes in the Earth's climate have been well documented in numerous national and international studies. Eleven of the past twelve years (1995—2006) were among the 12 warmest years in the instrumental record. Also, in comparison with paleoclimatic data, the average Northern Hemisphere temperatures during the second half of the 20th century were likely higher than any other 50-year period in at least the past 1,300 years.[1]

Global temperatures continued to warm at the start of the 21st century. The strong El Niño of 1997—1998 helped push the global temperature to a record high, and only seven years later, in 2005, the global average annual temperature exceeded that record even without the warming influence of a strong El Niño episode.[2] Other observed changes of the past century include an increase in heavy and extreme precipitation events in many parts of the world, rising sea levels, reductions in Arctic sea ice, melting permafrost, and an increasing incidence of drought. Projections indicate that these and other trends are likely to continue well into the future, and in some cases, changes are projected to occur at faster rates in the 21st century.[3]

Climate change may actually provide benefits to some areas of the world in the near term. For example, higher crop yields in mid and high latitudes, reduced cold season energy demand, and more navigable northern sea routes. However, negative impacts are expected to outweigh positive ones, particularly as the rise in temperature reaches the higher end of projections.

January–December global mean temperature over land and ocean



The global surface temperature has risen at a rate greater than 0.6 °C/Century since 1900 and the rate of increase has been almost three times higher since the mid-1970s

Source: NCDC/NESDIS/NOAA

Photo: NOAA/NESDIS/NCDC

Observations are collected from the upper atmosphere to below the ocean's surface using a wide array of in situ observing systems, satellites, and radar. By integrating and synthesizing today's observations with historical records from both instrumental and proxy sources, scientists are able to monitor changes in the Earth's climate in response to man-made and natural influences

Future impacts are expected to include diminishing crop productivity in lower latitudes even for small temperature increases; a likely increase in the extent of drought-affected areas; reduced water availability in regions supplied by melt water from major mountain ranges, and increases in malnutrition as well as vector-borne and cardio-respiratory diseases.[4]

The magnitude and timing of these and other impacts will depend in large part on the future rate of warming, as well as other changes such as the frequency and intensity of extreme weather, climate, and sea level events. Given the many uncertainties regarding the pace of future climate change and the areas and sectors throughout the world that will be most heavily impacted, the need to monitor the Earth's climate on an ongoing basis remains one of the highest priorities of the international community.

Monitoring the Earth's climate

An understanding of changes in the Earth's climate is based on decades and centuries of observations. Included among these are century-long instrumental measurements of surface temperature and precipitation, and records of daily data which are useful in understanding changes in the frequency and severity of extremes such as heavy precipitation events, drought and heat waves. When combined with proxy (paleoclimate) data such as ice cores, tree rings, coral data and sedimentary records, it has been possible to extend the study of climate variability and change back thousands and even hundreds of thousands of years into the past.

Instrumental measurements of the upper atmosphere began in the middle of the 20th century, and satellite measurements, available in the 1960s, provided even greater advances in the scientific understanding of the Earth's atmosphere and surface. By enhancing coverage in areas of the world where in situ measurements were unavailable, satellites have given scientists clearer insights into the global effects of climate changes.

New capabilities have continued to emerge within the past one to two decades, as the next generation of satellite instruments provided even greater capabilities to monitor essential climate variables such as sea level, ocean colour and wind speed.

The improvements to weather and climate observing systems which took place during the past several decades have produced tremendous advances in the ability to monitor the Earth's climate, and it is envisioned that the Global Earth Observation System of Systems (GEOSS) will provide for even greater advances in the future. But only through the integration and synthesis of vast quantities of data (current and historical, instrumental and proxy sources, in situ and remotely sensed) can the observations be used to effectively convey the changing state of the climate system. This integration and synthesis enables assessments of how the climate system is responding to man-made as well as natural influences.

To fully capitalize on converting the array of Earth observations into information that provides decision makers with a reliable source of information on the state of the climate, a collective approach that relies on cooperation and collaboration among nations is essential. While the capabilities of a single country to monitor and analyse current and evolving climate conditions with sufficient historical perspective may be limited, by working together as a collective body to share data and technical expertise, the capability to monitor, analyse and report on the state of the Earth's climate can be greatly enhanced.

State of the climate programme

The National Oceanic and Atmospheric Administration (NOAA) and the World Meteorological Organization (WMO), along with numerous national and international partners, established an annual *State of the Climate* report. The report leverages existing monitoring, analysis and reporting on atmosphere, ocean and land surface conditions from the global to local scale. By combining historical data with current observations, the *State of the Climate* report places today's climate in a historical context. It also provides perspectives on the extent to which the climate system varies and changes, as well as the effect that climate is having on societies and the environment.

More than 150 scientists from over 30 countries are now part of an annual process to turn raw observations collected from the global array of observing systems into usable information. Within the context of centuries of past climate data, the information enhances the ability of decision makers to understand the state of the Earth's climate and its variation and change during the past year. Many observing and analysis systems are unique to particular countries or regions, but through this effort, the information from each system can be openly shared. The report has proven crucial to transitioning data to operational use and filling critical gaps in current knowledge about the state of the global climate system.

The *State of the Climate* report seeks to include as many GCOS Essential Climate Variables (ECVs) as possible.[5] Because the report focuses on the Earth system as a whole, spatial and temporal gaps in data coverage are more easily identified as well as deficiencies in operational systems that provide access to those data. Solutions for filling those gaps are developed through coordination among scientists from participating countries, which in turn supports monitoring and analysis of ECVs that was previously impossible. This exemplifies how experts from numerous and diverse countries can work together on an ongoing basis to provide information which is essential to environmental decision making.

The combination of data collection, analysis and reporting on climate conditions through the *State of the Climate* report is closely aligned with the scope and principles of GEOSS. With a focus on integrating observing system data to useful and accessible information, the *State of the Climate* report serves as a hallmark achievement of GEOSS efforts to use integrated global Earth observations to monitor and enhance the understanding of climate variability and change. It serves as an avenue for providing information that decision makers can use to better understand the changing environmental factors that affect human health and well being. It also positions them to anticipate and manage future risks associated with climate variation and change.

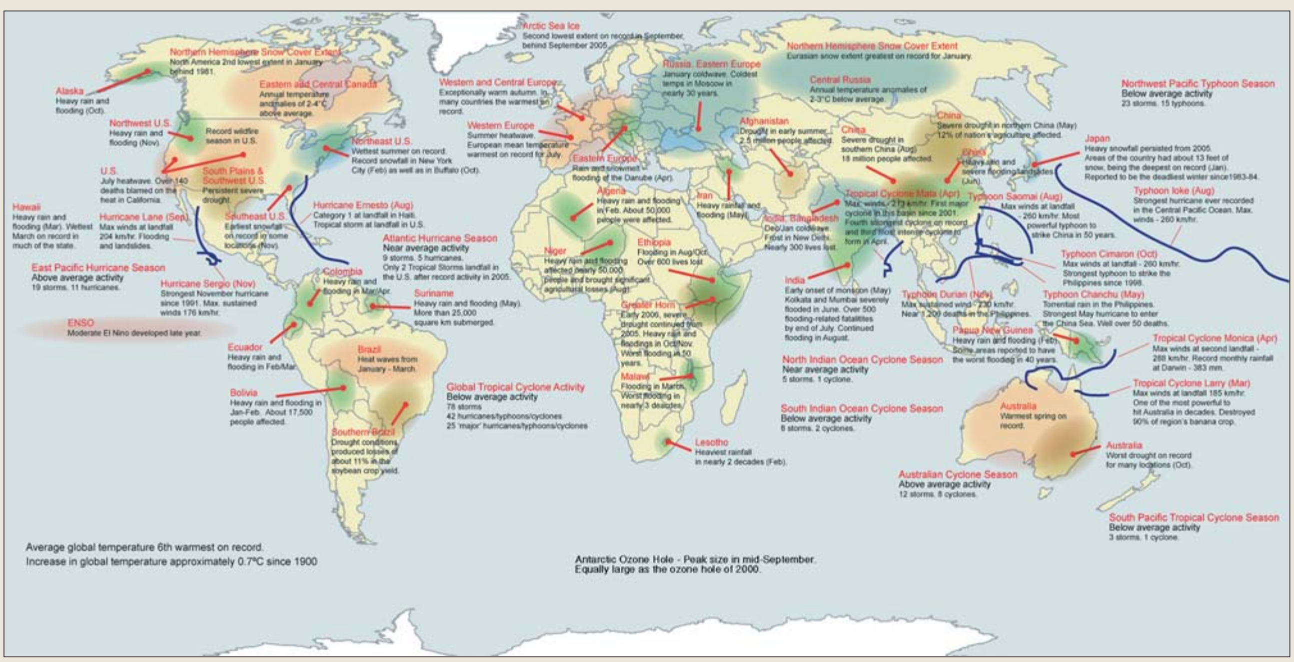
Scientists from institutions in 21 GEO member countries participated in *State of the Climate* reporting in 2007, with scientists from an additional dozen countries that are not yet GEO members also making key contributions.[6]

Monitoring the state of the climate in the future

The *State of the Climate* report is distributed through publication in the bulletin of the American Meteorological Society each year. The report is also translated into other languages and distributed to WMO member nations. Included in the 2006 report was a summary of more than 20 ECVs, from beneath the ocean surface to the upper atmosphere, and in every region of the world. A diverse set of topics included but was not limited to: surface and upper air temperature, precipitation, atmospheric trace gases, ocean salinity, circulation and carbon content, snow cover, sea ice, sea level, and stratospheric ozone.

The focus for the future will be on bringing together new contributing partners from other GEO member countries and further enhancing capabilities associated with the collection, processing and analysis of data from newly deployed observing systems. Potential linkages with additional GEO participating organizations will also be explored, with efforts focused on enhancing the capacity to observe, analyse and report on many more ECVs in future reports. This will provide leaders with an even greater resource for monitoring the Earth's climate.

Significant climate anomalies and events in 2006



The 2006 *State of the Climate* report included more than 130 pages of text summaries along with more than 100 graphs and depictions of significant weather and climate conditions combined with historical perspective provided by decades to centuries of climate observations

Source: State of the Climate working group

GOSAT in practice

Takashi Hamazaki, GOSAT Project Manager, Japan Aerospace Exploration Agency

The IPCC Fourth Assessment Reports[1] reaffirmed that the understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Reports, leading to very high confidence that the global average net effect of human activities since 1750 has been one of warming (causes). The prevention of global warming has become a universal concern, and human beings, who in the past have been capable of taking action only after the occurrence of disasters, are now in the position to take an absolutely remarkable step by standing up for their future.

Greenhouse gases are currently observed at 264 stations (as of 3 September 2007) around the world, and the data is distributed on the Internet by the World Data Centre for Greenhouse Gases (WDCGG). All of these observation points are densely distributed in the developed nations, while they are sparsely located among the rest of the world. This current condition results in estimating an average measure of global warming, but not in details by regions or seasons. Especially with regard to oceans, it is all but impossible to know where and how much carbon dioxide (CO_2) is absorbed and emitted.

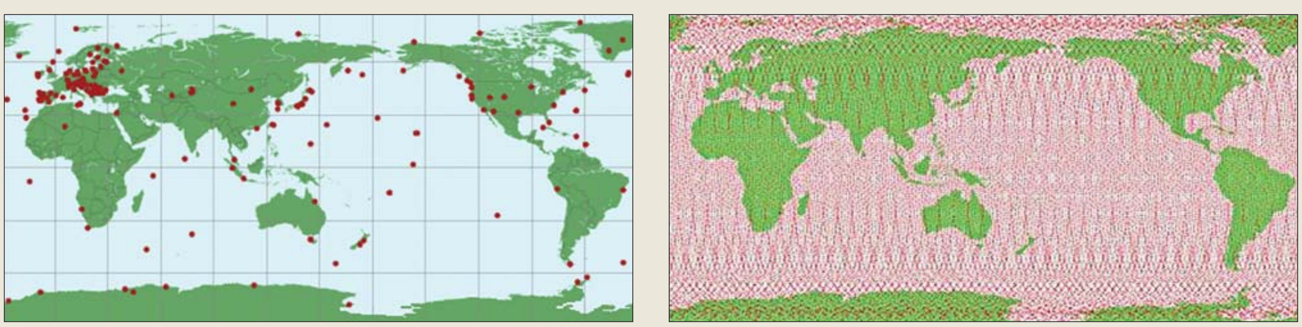
Thanks to a large number of institutes working on global-warming issues, many local phenomena have been observed and reported. For example, in the Amazon rainforest, scientists have found that methane is released from rotten tree roots after the river floods during summer, and in Siberia, it has been observed that melting permafrost is producing methane. However, there exist no comprehensive worldwide global warming data in two-dimensional view like a world map.

The Greenhouse Gases Observing Satellite (GOSAT) will be the first observatory that will steadily and globally monitor greenhouse gases at 56,000 observation points. The satellite will monitor the entire globe in three days, orbiting 14 times a day at an altitude of 666 km. With ground-based observation, a different observation instrument is used for each location, but GOSAT requires only a single instrument. This capability of acquiring global data every three days is one of the major features of GOSAT.

GOSAT has three major mission objectives. The first is to monitor the density of greenhouse gases precisely and frequently worldwide. Greenhouse gases are the major cause of global warming. CO_2 represents 60 per cent of greenhouse-gas effects; methane makes up another 20 per cent. GOSAT will measure the distribution and density of these two main greenhouse gases in detail.

The second mission objective is to study the absorption and emission levels of greenhouse gases per continent or large country over a certain period of time. The Kyoto Protocol, which came into effect on February 2005, requires that developed nations reduce greenhouse gas emissions between 2008 and 2012. The target for Japan is six per cent below 1990 levels; for the European Union it is eight per cent; however

GHG observing points



- 264 stations scattered around the world
- The data from stations are distributed from WDCGG of WMO
- The number of stations is limited, and stations exists unevenly in the world

- 56,000 points, every 3 days
- Global and frequent observation with single instrument onboard

Source: World Meteorological Organization (WMO)/World Data Center for Greenhouse Gases (WDCGG) in reality, there are no standardized means to measure greenhouse gas emissions, and the amount of emissions reported is based on self-declaration. The amount is calculated based on assumptions about such as the volume of the countries' oil consumption, car — driving distances and industrial gas emissions. Therefore if GOSAT observation makes it possible to estimate greenhouse gas emission per continent or large country, GOSAT observation data would be utilized as a means of verification.

The last mission objective is to develop and establish advanced technologies essential for precise greenhouse gas observations. GOSAT is a joint project by the Japan Aerospace Exploration Agency (JAXA), which is responsible for the satellite and sensors development; Japan's Ministry of the Environment (MOE), and the National Institute for Environmental Studies (NIES). MOE and NIES are in charge of data utilization.

Utilizing the JAXA acquired data

NIES is responsible for analyzing the global distribution of CO_2 and methane concentration, and the regional volume of absorption and emissions. It may take some time before preparing the data for distribution; however, free-of-charge GOSAT global observation data will be distributed for scientific use within a year of the launch.

GOSAT is scheduled to be launched in 2008 by the H-IIA launch vehicle. During the first three months all functions of the satellite will be tested. Then in the following three months, data will be collected intensively and compared with ground observation data. After the verification of its accuracy, GOSAT will finally start its assigned mission to acquire data.

Besides GOSAT, there is another greenhouse gas observation satellite in plan, the Orbiting Carbon Observatory (OCO), from NASA/JPL in the United States. It is scheduled to be launched in 2008, to simply monitor CO_2.

Having similar objectives, OCO and GOSAT share similar technological issues, and as such, some cooperative projects are being planed. For example, OCO and GOSAT instrument data will be exchanged and calibrated for their accuracy prior to launch, to assign common observation standards. JAXA and NASA are also considering possibilities for comparing post-launch data and conduct calibration experiments together as well as discussing shared data utilization. A similar type of cooperation is also in development with Europe, where JAXA is planning to provide European scientists with GOSAT data via the European Space Agency (ESA).

International cooperation is essential, especially for Earth observation satellites. When monitoring the Earth from space, not just Japan but the entire planet is automatically covered. In that sense, JAXA would ask worldwide organizations to make great use of GOSAT data, and requests feedback from users to help improve observation performance.

Photo: JAXA

Top left: Thermal and Near Infrared Sensor for Carbon Observation — Fourier Transform Spectrometer (TANSO-FTS) Engineering Model. Bottom left: Thermal and Near Infrared Sensor for Carbon Observation — Cloud and Aerosol imager (TANSO-CAI) Engineering Model. Right: Structure and thermal model

Earth observation contributions to assessing Australian terrestrial ecosystems, carbon stocks and greenhouse gas emissions

Gary Richards, Australian Greenhouse Office;
Alex Held & Peter Caccetta, Commonwealth Scientific and Industrial Research Organisation

Australia is a heavy user of earth observation data. Uses include ocean and coastal monitoring, climate and weather assessment and modelling, water resources monitoring, and terrestrial mapping and monitoring. Several ground facilities have been established over the last 30 years across the continent to receive satellite-data. Australia has also maintained strong involvement in international programmes that aim to provide improved access to data, especially by countries that do not operate space-based observing systems. Such international programes include the Committee on Earth Observing Satellites (CEOS), the World Meteorological Organization (WMO), the Integrated Global Observing Strategy (IGOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS) and many more. Australia is also a founding member of the inter-governmental Group on Earth Observation (GEO) partnership, and shares its vision to implement a Global Earth Observation System of Systems (GEOSS).

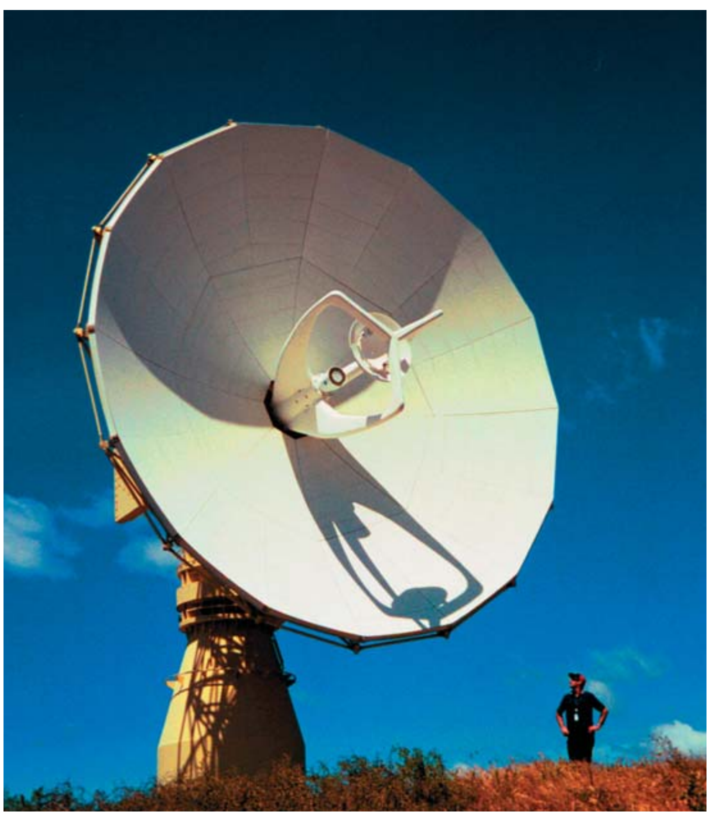


Photo: CSIRO

Tasmanian Earth Resource Satellite Station (TERSS) near Hobart

Australian experts take part in key GEO terrestrial applications tasks to improve, through more efficient Earth observation, sustainable management and protection of global natural and managed ecosystems. The scope of these tasks includes understanding, monitoring and conserving biodiversity, reducing loss of life and property from natural and human-induced disasters; and adapting to climate variability and change. These same goals are being accomplished in Australia in cooperation with international programmes, through development of modern, earth observation, natural resources assessment programmes and information dissemination systems. These national monitoring programmes now help underpin evidence-based environmental policy implementation.

One of the largest users of earth observation data in Australia is the National Carbon Accounting System (NCAS), which includes land-cover mapping and monitoring in support of national reporting of greenhouse gas emissions and carbon stocks to the United Nations Framework Convention on Climate Change (UNFCCC). For this, Australia has developed a comprehensive, model-based assessment of dynamic patterns of sources and sinks, informed by remotely sensed information. The Intergovernmental Panel on Climate Change (IPCC) guidelines[2] propose a comprehensive approach to emissions reporting, including both natural and anthropogenic emissions, but only considering managed lands. Consistent with the intent of the UNFCCC to monitor anthropogenic emissions, emissions from unmanaged lands are considered to be predominately natural, and are not reported. Unmanaged lands are subject to potentially large-scale natural disturbances, such as wildfires, which can lead to large emissions and changes in carbon stocks.

Reporting of both all emissions and identification of anthropogenic-only emissions can be achieved simulta-

Simultaneous reporting

Simultaneous reporting on all and anthropogenic-only emissions can be done by applying models of atmospheric fluxes

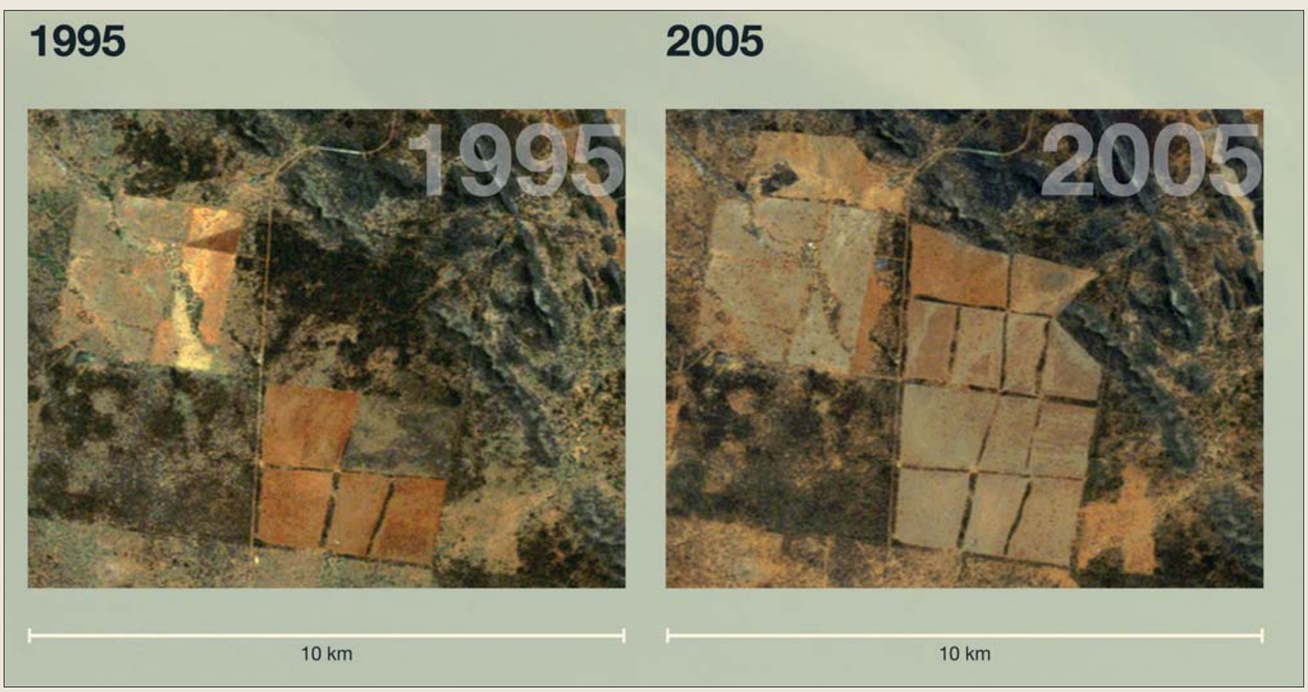
Source: Australian Greenhouse Office

neously through the application of models of atmospheric fluxes, driven in part by earth observation data. This is the approach adopted for Australia. The NCAS approach provides increased understanding of the seasonal and spatially dynamic variations in atmospheric exchanges of all greenhouse gases, rather than only providing terrestrial carbon stock assessment. Australia's NCAS uses a spatially explicit hybrid-model approach (at 25 metres grid scale) of a carbon-to-nitrogen ratio, and a mass balance ecosystem model. This results in estimates of all emissions from all lands (managed and unmanaged), yet still allows for simple extraction of reportable anthropogenic parts, as currently required by the UNFCCC. This, we think, provides an ideal approach, strongly reliant on high-quality earth observation data and robust, repeatable and auditable modelling and data processing methods. The ability to adapt and continuously improve estimates of national carbon stocks and emissions is an integral component of the NCA framework.

NCAS was set up by the Australian Government in 1998, to monitor all greenhouse gas emissions at all scales, with coverage of all gases (CO_2 and non-CO_2), all lands and activities. This very methodical approach is bottom-up, spatially and temporally explicit, and inclusive of all lands and causes of emissions and removals, including climate variability. The 'Land Cover Change Project' remote sensing programme in NCAS, underpins Australia's continental mapping and monitoring of the extent and change in perennial woody vegetation. It is based on Landsat satellite imagery, assembled as a publicly available time-series of 15 national mosaicked coverages (at 25-metre resolution).[3] The database includes some 5,000 original Landsat scenes (185km x 185km), which have been analysed to specific land-cover products, and then used to calculate annual greenhouse gas emissions. Each time-slice of a national coverage includes derived products to provide the information needed for estimating greenhouse gas emissions for various accounting frameworks:

1. Forest extent and change
2. Planted forest type
3. Sparse (non-forest) woody vegetation.

Land cover change



The NCAS Land Cover Change Project remote sensing programme underpins Australia's continental mapping and monitoring of the extent and change in perennial vegetation. It is based on Landsat satellite imagery, assembled as a publicly available time-series

Source: Australian Greenhouse Office

Further Australian initiatives to reduce global carbon emissions in the region will help in tropical forest mapping, change detection and regional information dissemination. These have a particular focus in the Asia-Pacific region, of which Australia is a part. The Global Initiative on Forests and Climate (GIFC) was initiated in early 2007, as an Australian contribution to the global UNFCCC-coordinated Reduction of Emissions from Deforestation and Degradation (REDD) process. Deforestation is not well addressed within existing international frameworks for climate-change mitigation measures, yet it has been recognized by the IPCC that emissions from deforestation in developing countries represent about 20 per cent of annual global greenhouse gas emissions, or about 7.2 billion tonnes of carbon dioxide per year (IPCC 2007). This is second only to emissions from burning fossil fuels to produce electricity, and is more than all the world's emissions from transport. Reducing deforestation, together with planting new forests and investing in sustainable forest management across the developed and developing world, is considered among the best ways to reduce global net greenhouse gas emissions. This also addresses the UN Millennium Developing Goals of enhancing benefits for biodiversity, repairing landscapes and improving livelihoods across the globe.

Under the $200 million GIFC initiative, Australia will help partner countries in the region gain improved access to policy-relevant and transparent earth observation satellite data to assess the state of their forests and to manage forest-use activities in a sustainable manner. This regional initiative will draw heavily on the knowledge gained and systems developed in implementing Australia's NCAS, including access to the methods and models produced by the NCAS, and using where feasible local satellite acquisition facilities and regional data distribution networks such as 'Sentinel Asia' and GEONETCast, this later developed under GEO, to make the information available across the Asia — Pacific region. To help in regional forest monitoring, Australia has earmarked $25 million to set up additional infrastructure for access to satellite data of all forms, collected over the Asia-Pacific region.

Australia has also proposed to expand NCAS to a Global Carbon Monitoring System (GCMS). Like GEOSS, GCMS is to be comprised of a network of systems, supported by conventional and next-generation Earth observation satellite technologies operated by different countries, and integrated with agreed carbon accounting approaches. The goals here are to determine with precision global extent and changes in forest cover, and estimate changes in carbon stocks and emissions of greenhouse gases due to changes in forest cover, including deforestation and degradation.

It follows therefore, that from an Australian perspective, many of the GEO-initiated international coordination tasks and the development of GEOSS, leading to improved data interoperability standards and long-term continuity of publicly-funded satellite data, are vital to continuing public-good environmental programmes such as NCAS and GIFC. GEO tasks related to quality assurance, improvement of methods of global land cover mapping, coordination of ecosystem observation and monitoring networks, space-based CO_2 monitoring, and long-term satellite data continuity and redundancy (in the form of 'virtual constellations') are also important to these programmes. These will ensure future access to high-quality satellite data for long-term regional and global ecosystem mapping across developing and developed countries.

Photo: CSIRO

Lowland rainforest in the Asia-Pacific region. Reducing deforestation, together with planting new forests and investing in sustainable forest management across the developed and developing world, is among the best ways to reduce global greenhouse gas emissions

Tropical forest remnants, agricultural fields and tree plantations in the Asia-Pacific region

Australia is helping regional forest monitoring and verification by investing in setting up additional infrastructure for access to satellite data of all forms, collected over the Asia-Pacific region

Source: CSIRO

Climate monitoring and prediction in Korea

Man-Ki Lee, Administrator, Korea Meteorological Administration

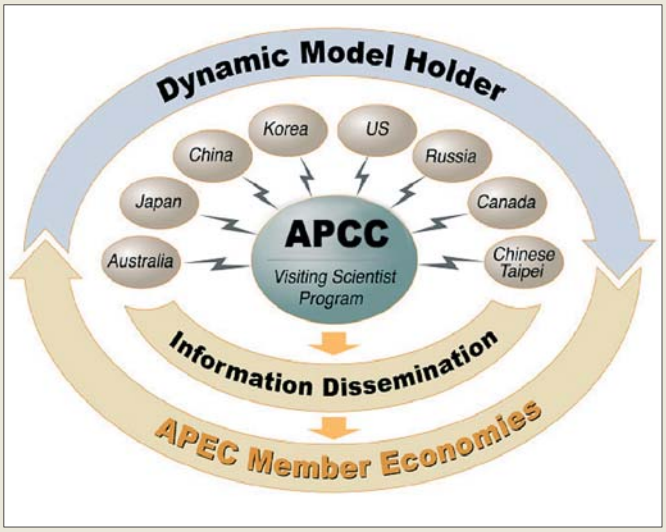
Recently, many parts of the world have experienced serious natural disasters associated with unusual climate, resulting in a significant impact on their economy and social life. Korea has also suffered from natural disasters such as severe yellow dust storms in spring, torrential rain during a rainy season, typhoons in summer, and heavy snowfall in winter. During the past ten years (1995-2004), total property damage caused by natural disasters in Korea reached USD18 billion and the number of victims was around 1,300. In particular, the total amount of damage in 2002 and 2006 reached USD6 billion and USD2 billion respectively. Reports suggest that the occurrence of extreme weather and climate events (drought, flooding, cold surge and heat wave) may become more frequent in association with global warming.

In order to improve understanding of the realities of the global environment, and to cope with global and regional climate change, the Korea Meteorological Administration (KMA) has operated a climate change monitoring system since 1992, based on the World Meteorological Organization Global Atmosphere Watch (WMO-GAW) programme. Under the system, a Korea Global Atmosphere Watch Observatory (KGAWO) was set up in Anmyeon-do in 1996, located on the western coast of the Korean peninsula, and formally registered in May 1998 as WMO-GAW Station number 47132. Elements monitored at KGAWO in Anmyeon-do are greenhouse gases, reactive gases, precipitation chemistries, airborne particulates, atmospheric radiation, aerosols, ozone and ultraviolet radiation based on regulation of the WMO-GAW programme. Data measured at KGAWO is being used nationally and abroad as well. It has been used for analysis of background atmosphere change over the Korean peninsula and for producing high-quality data to meet WMO standards through the exchange of data with World Data Center (WDC) and technical cooperation.

In addition to the Anmyeon-do KGAWO, KMA operates two ozone, four ultraviolet radiation and three acid rain measurement observatories over the peninsula; one ozone station in Seoul (GAW/GO3OS station No. 252 by Dobson spectrophotometer) in cooperation with Yeonsei University and the other ozone station in Pohang (GAW/GO3OS station No. 332 by Brewer spectrophotometer). In an effort to expand its GAW network, KMA appointed Kwangju Science and Technology Institute's Advanced Environmental Monitoring Research Center as a new cooperative observatory in December 2006. In order to densely monitor global and local environmental change, KMA is going to establish the second KGAWO in Gosan, Jeju island, which is recognized as one of the appropriate places over the Korean peninsula for monitoring the characteristics of the East Asia atmosphere. The second Gosan KGAWO will implement measurements of greenhouse gas, atmospheric radiation and precipitation chemistry, and it will be used as an international cooperation special campaign site for Asia Characterization Experiment-Asia (ACE-Asia) and Atmospheric Brown Cloud (ABC).

There has been growing recognition that the improvement in climate monitoring and prediction techniques could be one of the means to cope with and minimize those natural disasters and negative social and economic impacts. In this regard, KMA embarked on a eight-year long-term project from 1999 to set up

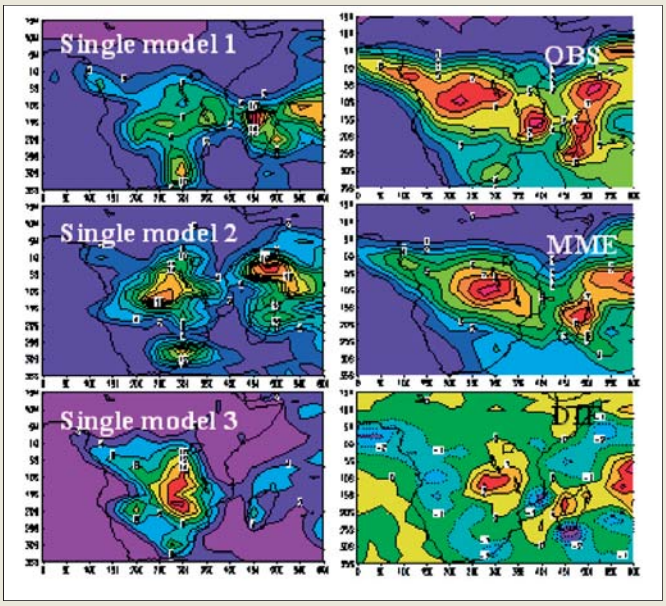
APCC multi-model ensemble system



APCC has processed and disseminated operational climate prediction information and products based on the MME technique to all member economies

Source: APEC Climate Center

Single model vs. multi-model ensemble



MME techniques, which has been proved to be a leading-edge technology in compensating for the systematic errors of each single model. Here, single model results are compared with multi-model ensemble predictions

Source: Won-Tae Yun, Florida State University (FSU) Multi Model Superensemble Prediction system, The Second Regional Climate Modeling Workshop for the Greater Horn of Africa, DMC Nairobi, Kenya, February 2004

an El Niño and La Niña/climate monitoring system and a long-range forecast system. Through this project, the El Niño prediction and a dynamic long-range forecast system has been operating since 1999. Since then, several improvement projects have been carried out such as a global sea surface temperature forecast model and a long-range forecast model development. Currently, the systems operationally carry out monitoring and prediction of global climate, including El Niño and La Niña, and predicted information and products are being provided to the WMO and used for WMO press releases for the El Niño/La Niña Update.

Based on statistical methods, KMA started to issue a monthly long-range forecast in 1973, a cold and warm seasonal three-month long-range forecast from 1984, and four seasonal forecasts from 1991. The dynamic long-range forecast system has been operating since September 1999 using a global long-range forecast model, Global Data Assimilation and Prediction System (GDAPS T106L21), which was developed through aforementioned projects. Currently KMA produces three types of dynamic long-range forecasts: one-month, three-month, and six-month forecast. The one-month forecasts are issued three times a month, consisting of temperature, precipitation and air pressure patterns for the next 30 days. The three-month forecasts, which are produced on a monthly basis, consist of temperature and precipitation trends including special seasonal events such as Asian dust, Typhoon and Changma (rainy season over Korea) for the next three months. The six-month forecast is issued twice a year (May and November). Those results and activities are presented and discussed at the Joint Meeting on Seasonal Prediction of the East Asian Monsoon, in which the East Asian countries participate.

The effort to improve climate prediction techniques was also realized in the establishment of the APEC Climate Center (APCC), which was set up in Busan, the Republic of Korea in November 2005, with a view to enhancing the capacity of monitoring and predicting unusual weather and climate changes in the Asia-Pacific region. The basic principle in the operation of APCC is to share optimized and high-cost climate information and products with the participating organizations from APEC member economies. The APCC tries to realize the APEC vision of regional prosperity through the enhancement of economic opportunities, the reduction of economic loss, and the protection of life and property by responding effectively to natural disasters and mitigating economic losses in the case of extreme climate events. The APCC contributes to the enhancement the socio-economic well-being of APEC member economies by utilizing up-to-date scientific knowledge and applying innovative climate prediction techniques. APCC, which was also registered as a modelling and data processing centre for the Global Earth Observation System of Systems (GEOSS), has processed and disseminated operational climate prediction information and products based on the multi-model ensemble (MME) technique to all member economies APCC carries out sensitivity studies of various individual models and the APCC-MME system to surface boundary forcing. In this connection, a statistical downscaling using MME products is developed and implemented for the estimation of rainfall over the Korean peninsula and other regions. Examinations of predictability of specific phenomena, such as the El Niño-Southern Oscillation (ENSO), Pacific/North American pattern (PNA), tropical cyclone activity, intra-seasonal variations of monsoon prediction, Asian dust, and extreme climate events are also being carried out.

With the above experiences in the area of climate monitoring and prediction, KMA has recently served as one of nine WMO Global Producing Centres (GPCs) for long-range forecasts (LRF) since November 2006.[1] Recently, KMA began to distribute long-range forecast data to other GPCs and WMO member countries through the website.[2] The further development of advanced prediction schemes for long-range forecasts is now a current task of KMA. KMA is operationally using the MME techniques, which has been proved to be a leading-edge technology to make up for the systematic errors of each single model. A comparison of single model results and multi-model ensemble prediction indicates that MME results are superior to the individual models. With recognition of this experience, KMA will also work as a collector of global LRF data provided by other GPCs. Such prediction data will be standardized and disseminated to other GPCs and Regional Climate Centers (RCCs).

The provision and sharing of technical information and techniques about MME is important for users to pursue LRF MME predictions. In this connection, KMA

WMO Lead Centre for LRF MME prediction homepage

KMA will work as a collector of global LRF data provided by other GPCs. Such prediction data will be standardized and disseminated to other GPCs and Regional Climate Centers (RCCs)

Source: www.wmolc.org

operates a technical cooperation programme, the Expert Program for Climate Predictions, to which long-range weather forecasters from developing countries in the Asia-Pacific region are invited every year. It is implemented with full financial support from the Korea International Cooperation Agency (KOICA). To assist developing countries in their development of numerical weather prediction skills and capacity building, a GEO cooperation programme such as the GEO Capacity Building Training Workshop for Numerical Weather Prediction has also been organized by KMA. The first training workshop was held at the KMA headquarters in Seoul, in April 2007. The fifteen participants from fourteen GEO member states in Asia, Europe and Africa attended at the training programme with the full financial support of KMA. During this workshop, both theoretical lectures and some exercises in NWP were provided, with special classes by invited lecturers from the GEO Secretariat and Environment Canada. Such training events will continue to be organized, with a hope that KMA will partner in the endeavors of National Meteorological and Hydrological Services in developing countries to cope with unusual climate and meteorological disasters.

GEO Capacity Building Training Workshop for Numerical Weather Prediction

Photo: KMA

In April 2007 fifteen participants from fourteen GEO member states in Asia, Europe and Africa attended GEO Capacity Building Training Workshop for Numerical Weather Prediction with the full financial support of KMA

African Climate Atlas: making IPCC AR4 data available

Richard Washington, GEO-WCRP-CLIVAR-VACS

We live in the information age where, for the first time in the planet's history, there are vast data sets which quantify a huge variety of the Earth system. Climate is no exception, although the development of climate models, perhaps one of the great scientific triumphs of the twentieth century, allows us to go further than the present in that we now have quantitative views of the long-term future too. In this respect, scientific advances in climate modelling are a quite special achievement. There is a clear need to make the most of the opportunity that such insights provide.

Through the efforts of the World Climate Research Programme Climate Variability and Predictability project (WCRP-CLIVAR), and especially the world's major climate modelling centres, we have a database created from a common set of scenarios of future greenhouse gas emissions, which sets out plausible future climates.

Photo: Richard Washington

Several regions in Africa are projected to experience dramatic changes in climate, with recent research pointing to changes in aridity

Achieving this has been a monumental task with few parallels in science. The latest version of this extraordinary effort is often called the Intergovernmental Panel on Climate Change (IPCC) AR4 dataset. From a planning perspective this dataset offers an enormous opportunity, particularly to those areas most vulnerable to climate change. The African continent is among them.

Delivery and accessibility of information is often one of the key bottlenecks which acts to constrain its use. In the case of the vast IPCC AR4 climate datasets there is very real need to store such information efficiently (in terms of computer disk space) as well as unambiguously in terms of which part of the world the data relates to, which moment in time and, of course, the many variables that make up the climate system. Scientists normally resort to data formats as a way of storing the data. Such formats solve both these problems simultaneously, but the price to be paid is that it is often only the climate scientists who can deal with the data and the formats in which the data are confined. And therein lies a big bottleneck.

In an effort to extend the use of climate information, particularly in Africa where the need is high, but resources for dealing with such data sets is typically low, the Group on Earth Observation (GEO) and WCRP have joined forces to create a component of the African Climate Atlas which makes the IPCC AR4 dataset easily available. Instead of wrestling through complicated data formats and through multi-level arrays of global datasets, the vision here is for users to be able to select the spatial domain, time slice and variable which they really want in a simple point-and-click environment. We expect that such data will be more readily used in this environment and may therefore be of more benefit to those responsible for planning sectors exposed to climate now and in the future.

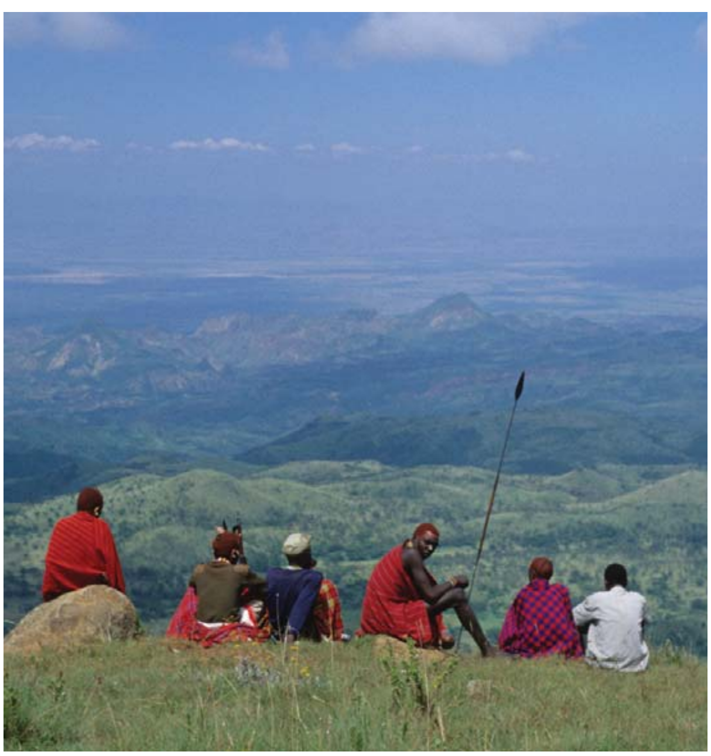
The African Climate Atlas

The African Climate Atlas (the Atlas) is a joint initiative between WCRP, CLIVAR and Variability in the African Climate System (VACS), with four current components that are focused on observed climate and observed climate anomalies. The Atlas allows any user to make online plots of a range of climate variables (e.g. temperature, humidity, rainfall) over numerous parts of the world including global, Africa and regions within Africa. So far, the Atlas accesses observed data sets which have been put onto a regular global grid. Mineral aerosol or dust is a unique feature of the African climate system in that North Africa produces more than half the world's dust. A single basin in Chad, the Bodele Depression, is also the world's premier dust emission source. Part three of the Atlas is an interactive component that allows users to plot satellite estimates of dust loadings. The well-known high quality ERA-40 reanalysis dataset, which could be described as a mixture of model and observed data, is also available as Part four. We are adding a fifth component in the form of frequently asked questions on African climate. The GEO-WCRP component is the sixth, and will focus on the climate change information from the IPCC AR4 effort. The Atlas may be viewed at: http://www.geog.ox.ac.uk/~clivar/ClimateAtlas/ and has been used by government ministries, non-governmental organizations, universities and farmers — to mention a few — over the past few years. It was the original aim of the Atlas to bring climate information to such users in a simple way and thereby to promote the use of African climate information. The Atlas is free to use and is based at the University of Oxford in the UK.

The African Climate Atlas and climate change

The climate change component of the African Climate Atlas is an interactive web page which provides a user-friendly and simple web-based way of plotting images and making available subsets of data from the IPCC AR4 climate change model dataset. Without a tool like this, one would need fast computer links to download very large datasets from the IPCC AR4 data centres. One would also need software and fast computers capable of reading the data formats (such as netcdf and grib) as well as programs to process the data and show

Photo: Megan Gawith



Data such as the IPCC AR4 dataset offer an enormous opportunity from a planning perspective, particularly to those areas most vulnerable to climate change, such as Africa

the differences in the future climate from the current climate. In many cases one would need software to plot the data on a map. The skills and machinery required to complete these tasks is really quite specialized. Instead, the Atlas offers a simple point-and-click way of achieving all these steps. If, in addition to a map, the actual data for a particular region is required, then this is also made available in a simple format suitable for spreadsheets. Users may, for example, wish to undertake further downscaling of their own with these data or use the data as input for other impact models.

In short, the data is made easily accessible and useable to the layperson, for the time slices they might need and over regions that they can define. The Atlas offers a choice of climate models and emission scenarios too.

Africa and climate change

Climate change is a vital part of the African development agenda (recently embraced by the African Union and, before that, highlighted at the Gleneagles G8 summit of 2005). Climate models are the only means we have for generating future climate scenarios, and the datasets that result from the joint experiments, such as IPCC AR4, provide the underpinning science for climate change adaptation.

It turns out that several regions in Africa are projected to experience dramatic changes in climate. Recent research published in leading scientific journals has drawn attention to changes in aridity. In the case of southern Africa, dune systems that have been stable for several thousand years are likely to become mobile again towards the end of the twenty-first century, with desperate consequences for the livelihoods of people who currently live in the Kalahari. Similarly, North Africa is projected to undergo significant decreases in future rainfall. Streamflow of the perennial rivers in the continent is likewise predicted to drop by some 25 per cent. In a continent where so many people have to fetch their own water, this statistic is striking. In contrast, the East African Short Rains, particularly in northern Kenya, are shown to increase by around 40 per cent towards the end of the century in some of the greenhouse gas emission scenarios. For other parts of Africa, such as the Sahel, the history of twentieth-century climate change has already been long and hard. The Sahel has recorded the planet's largest extended drought, with rainfall from the mid-1960s to near present being below the long-term average. What kind of future can the Sahel expect in the twenty-first century? Is the observed long-term rainfall downturn a permanent feature?

Adaptation to climate anomalies needs to start immediately, as the climate of the planet is already changing due to increasing greenhouse gas concentrations. Such adaptation needs to be underpinned by the best available science. The tool presented here is one small step to improving the availability of climate science to the practitioners on the ground, the non-governmental organizations, the local national hydrological and meteorological services officers and the government ministries across the continent.

Global water quality monitoring

Steven R. Greb, Wisconsin Department of Natural Resources;
Antti Herlevi, World Meteorological Organization; Paul DiGiacomo, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service

Monitoring of water quality is critical to the future health of the human population as well as the health of the ecosystem.[1] Monitoring of inland and coastal areas is a particular concern with the majority of the world's population living in these riparian and coastal areas. In addition, half of the earth's available freshwater is currently appropriated. Concurrent with increased demand on freshwater, the supply of 'clean' water continues to dwindle as a result of contamination from pollutants in municipal and industrial discharges and non-point source runoff. This contamination affects coastal receiving waters, inland water bodies and groundwater. Further, increased sedimentation can adversely affect fisheries, shellfish, plant life and coral reefs. Large influxes of nutrients can potentially lead to harmful algal blooms, decreased dissolved oxygen and hypoxia in coastal areas. Another major water quality issue is water-borne pathogens. Every year, over two billion people suffer from water-borne illnesses, and water-related diseases account for five million deaths. More than one-fifth of the world's people do not have access to safe drinking water and one-half of the population does not have adequate sanitation.

Monitoring plays a critical role in determining the current status of water quality conditions and helps anticipate and hopefully avoid future water catastrophes. Given the great number of global issues directly or indirectly linked to water resources, or more specifically here, water quality, this priority area has been identified by the Group on Earth Observation (GEO) as one of the key societal benefit areas, and it seeks advances in earth observation capabilities.

Water quality monitoring and assessment is generally grouped into two approaches, either remotely sensed (satellite, airborne or ground-based) or in situ (collected by field staff). These multiple approaches, sometimes in concert, can address water quality on local, regional or global scales. Many water quality monitoring programmes are deficient. For example, many countries lack the technical, institutional, financial resources and infrastructure, and sometimes the political stability, to conduct proper water quality assessments on a long-term basis. Today, the United Nations Environment Programme (UNEP) archives freshwater quality data from national and international cooperators around the world in its Global Environmental Monitoring System (GEMS).

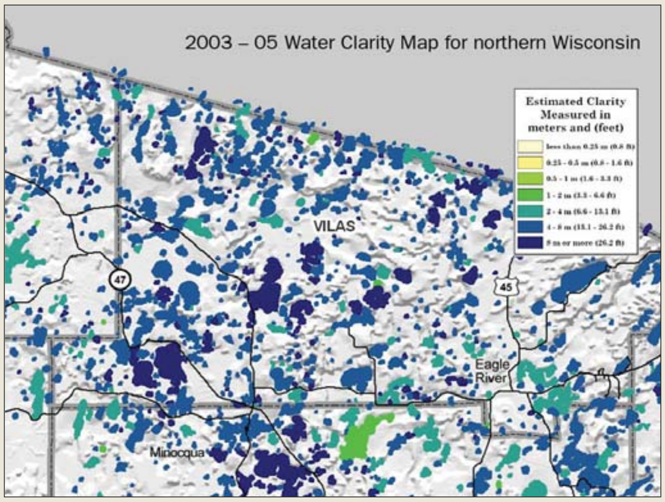
Remote sensing technology is an emerging capability that can greatly bolster traditional in situ methods, but the field is relatively new, especially in addressing optically complex waters. Satellite remote sensing potentially offers a promising alternative for scientists and managers to use for assessment of a large number of water bodies in an economical and timely fashion. Today, global-scale aquatic satellite remote-sensing systems are generally limited to oceanic products, e.g. daily and also composite eight-day and monthly composite chlorophyll images generated from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) to address a variety of biogeochemical and ecosystem issues. With respect to coastal products, increasing interest in the monitoring of coastal areas has led to new and ongoing regional efforts such as the ChloroGIN Africa, Antares (South America) and European Space Agency (ESA) GMES Services Element (GSE), MarCoast (Baltic Sea) initiatives and networks. Objectives of these and other similar efforts include mapping of turbidity, chlorophyll, primary productivity and forecasting of harmful algal blooms (e.g., NOAA HAB Bulletin). Monitoring of inland water quality using remote sensing is virtually non-existent on a global operational level.

There are some unique challenges to the application of remote sensing to water quality in inland and coastal regions. These waters are a complex mixture of constituents, the composition of which varies across water bodies, regions and globally. Unlike open-ocean surface waters, which are generally clear and typically contain only low concentrations of phytoplankton, inland and coastal waters contain a myriad of both dissolved and particulate matter. In addition, they can exhibit significantly heterogeneous patterns of water quality. These patterns and associated processes and phenomena are frequently dynamic, short-lived and small-scale, and may be missed by satellites with inadequate spatial and/or temporal observing capabilities. Small water bodies such as lakes are irregularly distributed across the terrestrial landscape, often representing only a few pixels in a satellite image, and confounded by a number of 'edge' pixels.

In addition, remote sensing generally only represents surface conditions, and it can be difficult to relate what the satellite can actually 'see' (e.g. ocean colour) versus those properties primarily of interest to a manager or decision-maker (e.g. bacteria).

Remote sensing has attempted to quantify a number of water quality parameters, with varying degrees of success and utilization. These include biological,

Water clarity



A map of water clarity generated from a Landsat image. The area is in the northern lakes region of Wisconsin, USA

Source: Steven Greb, WDNR

biogeochemical and ecological parameters such as chlorophyll concentrations, turbidity/suspended solids, clarity, macrophyte surveys, and slick and spill detection, and underlying geophysical parameters such as surface temperature, winds, currents and waves, bathymetry and flood area. The broad suite of ocean colour parameters (e.g. chlorophyll), as well as temperature, currently represent primary areas of user interest and also research and development activities.

GEO workshop brings experts together

The first GEO Inland and Nearshore Coastal Water Quality Remote Sensing Workshop was held in Geneva, Switzerland on 27-29 March 2007. This seminal gathering of 55 experts from 26 countries was hosted by the GEO Secretariat as a part of GEO's activities on water resources. The goal was to bring together remote sensing data providers and expert users to improve their ability and capacity to remotely assess and monitor inland and nearshore coastal water quality. This was viewed as a forum for a diverse group, from data providers to end users, to collaboratively chart a course for the future of this emerging science.

The final report covered six major issues and aspects addressed in the workshop. For each major issue, the report identified gaps and issues, and gave recommendations to data providers and GEO members and participating organizations on short-term priorities for improving remote sensing capacity and utilization for water quality assessment and monitoring. In addition, it formulated short and long-term strategies to identify, enable and implement enhanced capabilities. The following briefly summarizes the six major issues.

Satellite sensors — Underlying efforts to generate products and information for managers and decision-makers of nearshore coastal and inland waters are the data streams generated by a suite or virtual constellation of international satellite sensors, providing different types of information at different spatial and temporal resolutions. Users require timely and accurate data at regular intervals over sustained periods for their particular region that adequately resolve the processes, phenomena and characteristics of interest for regional and local water quality monitoring and management. A key concern among users is ensuring the continuity of the data both from satellite systems and in situ networks. There is also a compelling need for new and improved observations that can help address water quality needs in these regions, recognizing that tradeoffs will be necessary in order to accommodate the diverse and challenging user requirements.

Calibration and validation requirements — Calibration and validation (cal/val) are key components required for satellite remote sensing of properties that contribute to or impact water quality. Satellite remote sensing of ocean colour in particular entails very stringent requirements on the sensor's radiometric calibration in the visible spectral region due to the significantly low (<10%) contribution from the ocean (versus atmosphere). A robust collaborative validation system for the international aquatic science community is crucial. The validation programme serves functions for product quality assurance, algorithm performance validation, and the development and refinement of algorithms (especially for optically complex waters). This also ensures that satellite-derived products meet scientific requirements for both research and applications.

Data acquisition and distribution — The impact of satellite sensors (research or operational) for inland or coastal water studies is dependent on the ability of users to access appropriate quality data in a straightforward, timely fashion. Routine water quality management issues (e.g. beach closures) frequently require the most rapid access to data to enable an accurate decision to be made in a timely manner. Key issues to address include the necessary processing level of the data, its quality, how quickly it is needed, and in what format and by what means. Others issues include establishing initial access and resolving limitations on use or redistribution.

Data processing and product development — A number of fundamental issues are related to the use of optical remote sensing data in coastal and inland waters. These must be addressed to enable applications to make use of the full potential of these datasets. In many cases these issues are common to optical remote sensing over any water body (including the open ocean), but are often amplified in the coastal and inland waters by their specific morphological and dynamic characteristics. These issues include the need for standardized, community-based open-source radiative transfer (atmospheric and water) models, the need for standardized algorithmic methods to be well documented and user-adaptable, and the need for interoperable data formats, taking into consideration not only the preferences/ideals of the remote sensing specialist but also those of potential end users.

Developing countries — Developing countries play an important role as key shareholders of large tracks of coastline, large estuarine areas and vital inland ecosystems. There is, therefore, a need to address issues and needs for monitoring and management of inland and near-coastal water quality, which are particular to developing nations, in order to better articulate their role and participation in this field and in the GEO process in general.

What can vs. what should be delivered — Inland water quality remote sensing is generally viewed as a local or regional concern. Consequently, the inland water remote sensing community has never been able to organize itself compared to the ocean remote sensing community. Therefore it does not enjoy some of the technological advances and resources — for instance it has a lack of suitable sensors for complex inland waters. Because coordination is lacking and no standard approaches exist, the use of results by managers is limited. Coastal remote sensing has made gains recently with some national programmes and increasingly international programmes such as in the European Union (e.g. MarCoast). Satellite sensors such as MERIS, MODIS and SeaWiFS are more suitable (but not necessarily ideal) for coastal remote sensing than for inland water remote sensing.

Selected workshop recommendations

The following recommendations are made to the GEO member nations and participating (or related) organizations, including the Committee on Earth Observation Satellites (CEOS).

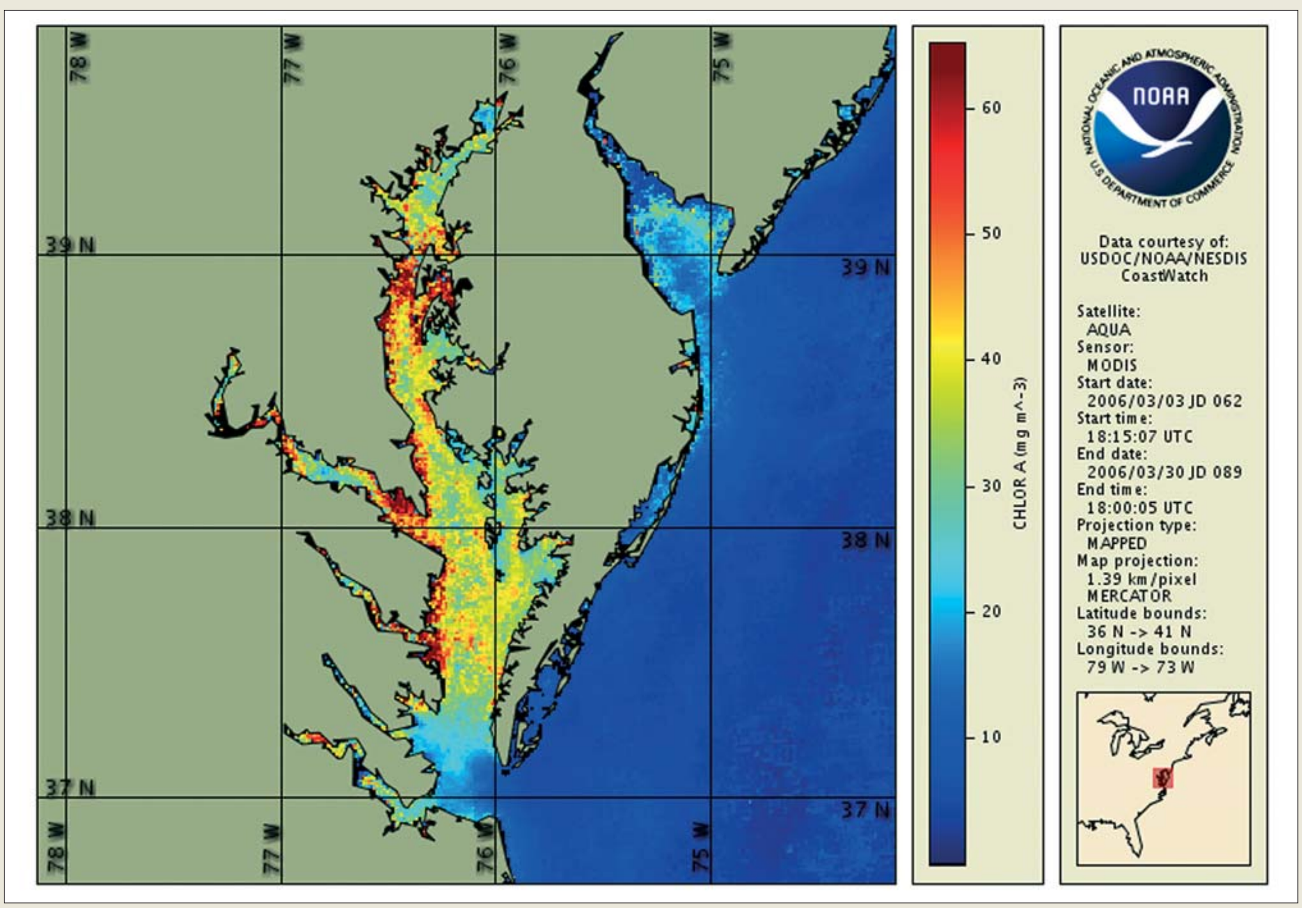
New high resolution local aquatic imaging missions(s) are required in low Earth orbit, with a goal of 10m or better ground resolution and a constellation of imagers and/or pointing capabilities utilized to provide more frequent looks (weekly or better) than currently available through existing sensors such as Landsat or ASTER. Potential partnership opportunities exist with the terrestrial observing community.

A constellation of regional geostationary ocean color imagers is needed to provide regional high frequency temporal revisits (goal of one hour or better for revisiting dynamic events), moderate (~ 100-300 m) spatial resolution and good offshore coverage of coastal regions globally. Potential partnership opportunities could exist with the atmospheric/regional air pollution communities.

Hyperspectral sensors are desired for the mission types identified above, but minimally twenty (or greater) narrow (~5-10 nm) spectral bands providing broad spectral coverage, extending from the ultraviolet (UV) (0.35 m) through the near-infrared (NIR) (1.1 m), with shortwave infrared (SWIR) bands desired to support improved atmospheric corrections (thermal bands also generally desirable). A high signal-to-noise ratio is needed to support aquatic (versus land) applications.

The water quality community should become active in future mission concept studies and scoping studies, with guidance and advice to be provided by the water quality

Phytoplankton biomass



Chlorophyll-a monthly composite image of Chesapeake Bay (USA) from NASA's MODIS (Aqua) sensor

Source: NOAA CoastWatch Program

remote sensing working group (or community of practice), to be formed as a result of this workshop.

The water quality community should send letters to various agencies to encourage continued support for cal/val activities and in situ monitoring. There is a need to promote and organize international field measurement campaigns (also as capacity building segments) in developing countries and support developing countries for instrumentation needed for in situ cal/val operations and Earth observation data acquisition.

In cooperation with other organizations, e.g. the International Ocean Colour Coordinating Group (IOCCG), international partnerships should be built within GEO member countries for cal/val activities and to discuss issues like instrument calibration and data processing, accuracy, sharing, protocols etc.

Raw data should be released within minutes of reception and processed products within one to two hours. Near-real time (NRT) metadata should provide information on accuracy (or errors), and faster access to ancillary data is needed to improve accuracy of NRT data.

Use of GEONETCast and ESA DDS should be encouraged, to improve data distribution particularly for developing countries. Server-side options could be implemented, such as spectral or spatial sub-setting on demand to reduce data transmission size.

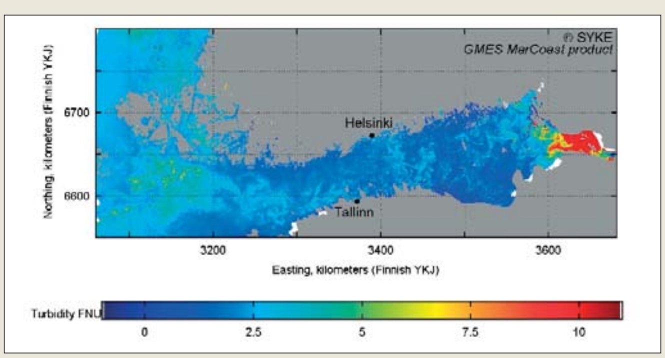
Data should be provided in agreed formats, and data networks should be more interoperable. Open formats should be required and open source software encouraged for multiple platforms. A consensus building exercise led by the space agencies is needed to standardize data and metadata formats that are compatible with end user requirements.

An international activity/entity is needed to ensure that coastal and inland water algorithmic requirements (e.g. SWIR wavelength atmospheric correction, adjacency effects, optical parameter assignment in semi-analytical models) are taken into consideration for present and future missions. A working group (possibly through IOCCG) should explore methods for regional algorithms implementation.

Harmonization of quality control and accessibility of in situ data (atmospheric and in-water) for algorithm parameterization purposes should be improved, and extended to include inland waters.

Needs for water quality products should be defined in relation to developing countries, with points of contact established in GEO member countries in relation to the water quality theme (e.g. start from UNEP GEMS focal points).

GMES MarCoast Product



GMES MarCoast product showing distribution of turbidity in the Gulf of Finland, Baltic Sea

Source: © SYKE

Initiatives should be launched in the capacity building and educational area in developing countries, such as specialized graduate programmes, the development of e-learning and distance learning using freeware and open source domain software tools. Awareness and interest in water quality at secondary school level must be initiated, and support given for ICT initiatives to promote Earth observation — derived water quality maps in e.g. Google Earth or similar web-based global services.

Awareness of inland and coastal remote sensing capabilities should be increased through a number of coordinated programmatic activities including: creating a global remote sensing of inland and coastal waters community of practice (CP) or joining a related CP (e.g., the Coastal Zone Community of Practice), or forming a new organization similar to the ocean colour coordinating group. An ultimate goal could be to establish a global freshwater and coastal 'water watch' programme.

Demonstration projects should be established in each hemisphere of the world, involving water quality management staff that want or need to embrace what remote sensing technology can offer.

Value-added products should be provided, which utilize time series statistics to establish baselines, seasonality, trends and extreme events. Ultimately, watershed remote sensing and data assimilation should be fully integrated with receiving river, estuarine, coastal and ocean data and models. Long-term datasets of water characteristics should be analysed to provide an informational clearinghouse for disputes of water diversions and fate, and what quality was evident.

Conclusion

Having and maintaining suitable water quality is critical to sustaining life on our planet. Monitoring of water quality using remote sensing, in conjunction with strategic in situ sampling, can play a crucial role in determining the current status of water quality conditions and helps anticipate, mitigate and even avoid future water catastrophes. The GEO workshop discussed here helped identify issues, gaps, solutions and recommendations to expand our capability to utilize this technology. Key recommendations focused on continuity of existing satellites, development of new and improved sensor/platform technology, algorithm development and cal/val activities, improvements in data accessibility, education and capacity building through new demonstration project initiatives, and the formation of a scientific group dedicated to inland and coastal water quality remote sensing.

Acknowledgements

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The observational aspects of water cycle knowledge and applications

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The availability of adequate and safe water is critical to the economic development of human societies. Surface waters are also of great importance for both human and ecosystem health. The global water cycle provides a conceptual framework that links observations and scientific understanding to those elements of society which need to plan water supplies for these purposes. The global water cycle consists of reservoirs (e.g., oceans, atmosphere, land) and fluxes of moisture moving from one reservoir to another — redistributing water and replenishing reservoirs. Reservoirs in the global water cycle are under a number of pressures, most notably the growth of the world's population,[1] the modification of water systems for expanded development, the growth of megacities, climate change and land use.

Observations play a central role in the understanding, monitoring and prediction of variability and change in the global water cycle. Observations and related value-added products, such as predictions, are needed for developing water management strategies. This article describes the recent history of the coordination of global-scale water cycle observations in support of better understanding and decision making by water managers.

Historical developments in an integrated approach to water cycle observations

GEWEX — Many water cycle issues are coordinated within the scientific framework of the Global Energy and Water Cycle Experiment (GEWEX). GEWEX was initiated in 1988 under the World Climate Research Programme (WCRP), in part to utilize the growing capabilities of Earth observing systems in an effort to understand the climate system. To a large extent the GEWEX mission could be defined functionally as the development and application of planetary Earth science, observations and models to climate and hydrology. GEWEX has contributed to the development of more than 40 coordinated projects and activities that involve global and regional datasets and products, climate system analyses, model development, predictability studies, field campaigns, process studies and applications.[2]

Global observing systems — In order to plan Earth observation systems in a more coordinated fashion, several observational programmes were launched. In the 1990s, the Global Observing System programmes were established to address the needs of different communities to coordinate observational systems. These included the Global Climate Observing System (GCOS), the Global Terrestrial Observing System (GTOS) and the Global Ocean Observing System (GOOS), all of which deal with elements of the global water cycle. The GCOS plan deals with many of the issues that concern the water cycle community.[3]

IGOS-P — In 1998, the Committee on Earth Observation Satellites (CEOS) joined with global environmental programmes to form the Integrated Global Observing Strategy Partnership (IGOS-P). IGOS-P launched a number of themes and established the necessary working groups to oversee their implementation. In 2004, the Integrated Global Water Cycle Observations (IGWCO) theme was approved. IGWCO has developed a number of strategic initiatives including the observation of priority water cycle variables, the integration of datasets of different types, and the use of information in meeting the demands of users. IGWCO strategies act to improve coverage, utility and integration of critical water cycle observations. Specific IGWCO activities include:

- Precipitation: in collaboration with GEWEX and the International Precipitation Working Group (IPWG), IGWCO has begun to evaluate integrated high-resolution precipitation products
- Soil moisture: soil moisture activities support the GCOS Implementation Plan and the launch of the Soil Moisture and Ocean Salinity Mission (SMOS) by the European Space Agency (ESA)
- Water quality: IGWCO is assessing the potential of remote sensing to detect areas with poor water quality
- Streamflow: streamflow activities are supporting the development of an integrated surface water runoff product building on enhanced in situ observations and altimetry measurements
- Groundwater: plans for an assessment of the adequacy of groundwater observations are under development.

Other IGWCO activities of a more integrative nature involve collaboration with the Coordinated Enhanced Observing Period (CEOP)[4] strengthening links with GTN-H (Global Terrestrial Networks — Hydrology) and capacity building efforts taking place in Latin America and Asia.

GEO — In 2004, the Group on Earth Observations (GEO) was initiated to lead in the development of the

Water cycle information needs by societal benefit area

Societal benefit area	Water cycle information needs
Reduction of natural hazards (floods, drought, impacts)	Floods: precipitation, runoff Drought: soil moisture, precipitation Impacts: groundwater, streamflow
Human health (disease vectors, drinking water)	Disease vectors: surface water area, precipitation. Drinking water: water quality, groundwater, streamflow
Energy management (hydro, alternate, fossil fuel)	Hydro: streamflow, precipitation. Alternate: clouds, surface water storage Fossil fuel: streamflow, surface water store
Climate (trends, prediction)	Trends: clouds, precipitation, streamflow Prediction: precipitation, soil, moisture, sea surface temperature
Water management (resource inventory, hydrologic prediction, water supply)	Resource inventory: surface water store, groundwater. Hydrologic prediction: precipitation, streamflow. Water supply: streamflow, groundwater
Weather forecasting (initialization, severe weather, long-term forecasts)	Initialization: clouds, precipitation, soil moisture Severe Weather: precipitation Long-term forecasts: soil moisture
Ecosystems (ecosystem integrity)	Ecosystem integrity: Water quality, streamflow, surface water store
Agriculture (crop monitoring, irrigation scheduling, livestock)	Crop monitoring: precipitation, soil moisture. Irrigation scheduling: precipitation, soil moisture, surface water storage. Livestock: surface water store, water quality
Biodiversity (habitat)	Habitat: water quality, surface water store

Source: R. Lawford

Space, time and accuracy requirements for water cycle variables

Variable	Spatial res.	Temp. res.	Accuracy
Precipitation	4 – 5 km	3 hrs	0.1 mm/h
Soil moisture	10 – 100 km	1 – 10 days	5%
Streamflow	1 – 10 km (for basins)	1 – 10 days	5%
Lake levels	1 – 10 km	1 wk – 1 mo	5%
Snow cover	1 – 10 km	24 hrs	10%
Clouds	100 m – 10 km	3 hrs	5%
Water vapour	10 – 100 km	3 hrs	5%
Surface fluxes	10 – 100 km	3 hrs	5%
Short wave	10 – 100 km	3 hrs	5 W/m^2

Source: adapted from IGOS-P, 2004

Global Earth Observation System of Systems (GEOSS) over the next decade. This programme, which is described elsewhere in this publication, addresses nine societal benefit areas and has core committees dealing with architecture and data management, science and technology, capacity building and user interfaces.

Review of existing water cycle information systems

To meet the requirements of the GEO societal benefit areas, water cycle observations must provide a basis for stable information systems, long-term statistics and resolving scale issues. They must also be easily accessible, and available as soon after the observation are taken as possible. When combined, localized high resolution in situ data and the coarse global data available from satellites can meet the requirements of a wide range of users. The status of measurements of different water cycle variables differs among variables and applications. A limited set of requirements was compiled from interactions with users.[5] The status of these observations is desrcibed below.

Precipitation — At present, precipitation is observed with a wide variety of systems including precipitation gauges, surface-based rain radars, observations of passive visible, infrared and microwave radiances and active sensing from satellites. Integrated data products such as the Global Precipitation Climatology Project (GPCP) products combine data in different ways to meet the resolution and accuracy requirements of users.[6]

Surface water store and stream discharge — Although streamflow measurements are taken by nearly every country, due to data-exchange policies and the net loss of hydrometric stations over the past two decades,[7] the capability of monitoring water resources has diminished. The Hydrological Applications and Run-Off Network (HARON), a joint GEO/World Meteorological Organization (WMO) project, will accelerate the development of integrated runoff data products that combine in situ and satellite observations. Snow is another example of important surface water reservoir at higher latitudes. Observations of snow cover for climate purposes are made primarily from polar orbiting and geostationary satellites, while passive microwave measurements combined with in situ measurements (e.g. snow pillow, snow rulers) provide a basis for estimates of water equivalent.

Soil moisture — Networks of periodic soil moisture measurements are maintained by some countries, but international coordination and standards are lacking. The beneficial use of remote sensing for soil moisture has been convincingly demonstrated in terrain covered by thin or moderately dense vegetation (e.g. typical crops) using passive microwave emission radiometry. ESA is currently implementing the SMOS mission for the measurement of soil moisture. These space-based data sources combined with data assimilation systems will make it possible to meet the information needs of the hydrometeorological and agricultural communities.

Water quality — The quality of water in lakes, rivers and reservoirs is affected by increasing industrialization, including many areas where environmental standards are neither developed nor enforced. Water quality monitoring programmes exist in many developed countries, usually relying on in situ sampling and laboratory analyses. Efforts are underway to assess the potential of satellites to provide a partial alternative to the monitoring of ambient water quality.

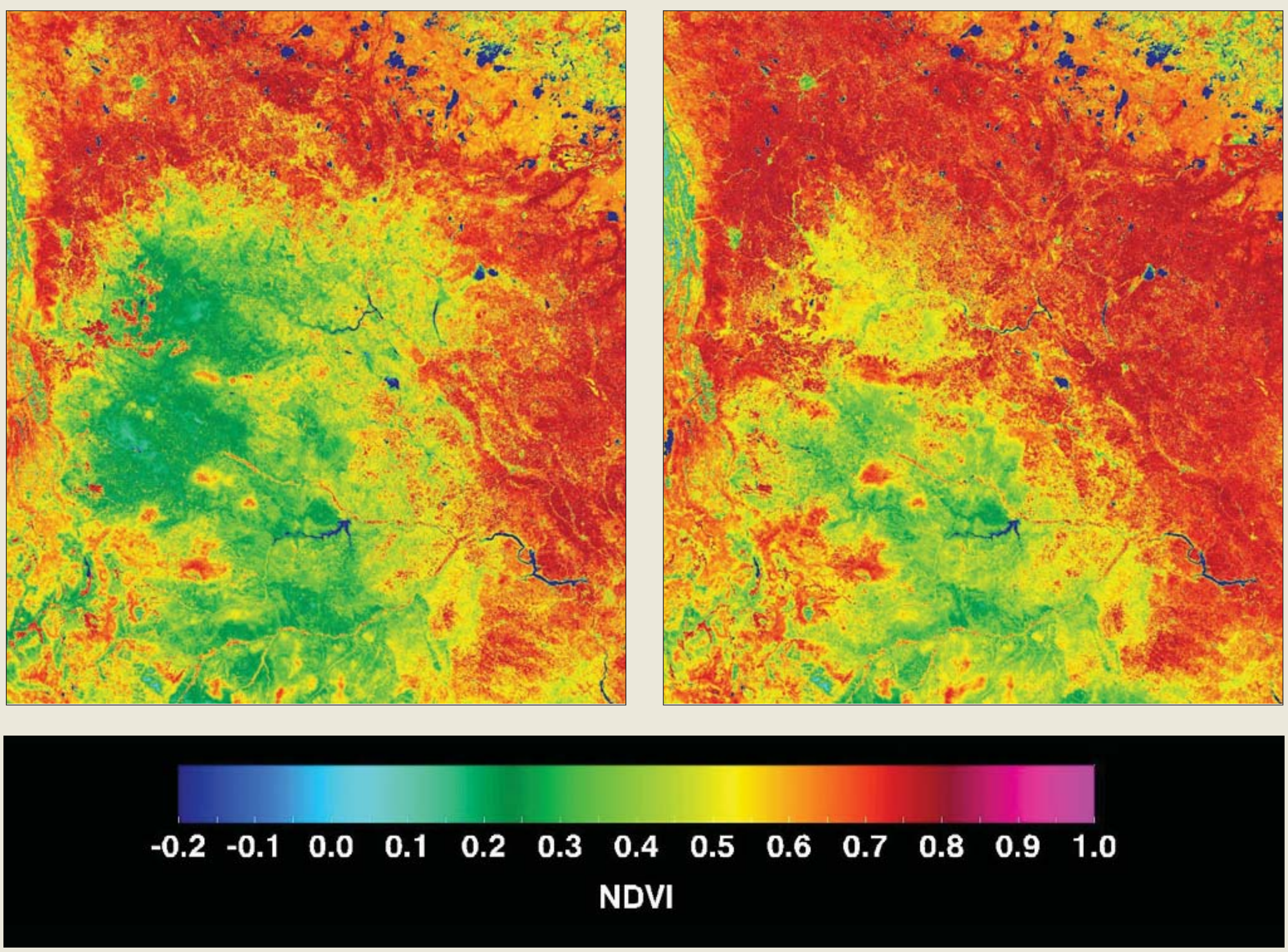
Evaporation — Evaporation is not measured directly, with the exception of surface flux measurements taken at flux towers and by buoys on the ocean. Remote sensing techniques can be used to indirectly estimate evapotranspiration (ET) and carbon uptake by plants from the energy balance equation.[8] As the GEWEX SEAFLUX project has shown,[9] evaporation over the ocean can be derived from in situ and satellite measurements.

Groundwater — While many in situ groundwater measurements exist, groundwater observations and data processing methods have not been standardized internationally. Progress is being made in the estimation of groundwater from time variant space-based measurements of the gravimetric anomalies, such as the National Aeronautics and Space Administration (NASA) Gravity Recovery and Climate Experiment (GRACE) mission.[10]

Summary and conclusions

There are many applications of Earth observations in the water sector that bring large benefits to society. These already aid in a number of societal benefit areas, but improvements to these observational systems would greatly enhance many of the benefits. International programmes such as GEWEX and IGOS-P have played an important role in structuring our approach to water cycle measurements. The GEO initiative has the potential to support the next quantum advance in water cycle observations if it can mobilize the resources needed to fully address the gaps and opportunities present in the water cycle observing system.

Vegetation indices provide information on water stress and drought severity



Left-hand image: July 10-21, 2001 - A dry year; Right-hand image: July 10-21, 2005 - A wet year

Source: Alexander Trishchenko, Canada Centre for Remote Sensing, Government of Canada

Development of a global in situ soil moisture network

Peter J. van Oevelen, International GEWEX Project Office; Thomas J. Jackson, USDA Hydrology and Remote Sensing Lab; Pedro Viterbo, Instituto de Meteorologia; Dara Entekhabi, MIT; Yann Kerr, CNES/CESBIO

Soil moisture observations are critical for understanding the global water and energy cycles. Availability of better spatial estimates of surface soil moisture will help, through assimilation into hydrometeorological models for example, to improve forecasting of precipitation, droughts and floods. It will also contribute to further the development of other hydrological applications that can support water resource decision-makers.

Surface soil moisture is a determinant of the partitioning of surface precipitation into infiltration and runoff. Across many landscapes of the mid and higher latitudes soil moisture and its freeze/thaw state control evapotranspiration providing the link between terrestrial water, energy, and carbon cycles. Based on theory and experiments to date there is a general agreement that improvements in our understanding of the water cycle and our ability to predict short-term events (hydrometeorology) and long-term patterns (seasonal) are dependent on developing an integrated global soil moisture observing system. Improving these global observations is needed on a priority basis.

The Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programmeme (WCRP) along with the Integrated Global Water Cycle Observations (IGWCO) theme of IGOS-P are contributing, amongst others, to the development of a global in-situ soil moisture network. Such a network is intended to support a global soil moisture observing system as part of the Global Earth Observation System of Systems envisaged by GEO. The practical coordination and implementation is done through the International Soil Moisture Working Group with additional financial support from the European Space Agency (ESA) to develop a soil moisture data hosting centre by the Instituto de Meteorologia in Portugal.

Photo: Tom Jackson & Gary Schaeffer

Installation of SCAN station in Arizona

The upcoming launch in 2008 of the Soil Moisture and Ocean Salinity Mission by ESA has given a strong impetus to the establishment of the in situ soil moisture network. The global network will help in validating and calibration of the SMOS data products. Also existing sensors such as ASCAT on METOP or AMSR-E can profit from the established network.

However, the network will not only serve as a satellite validation tool, as the in-situ soil moisture data has value by itself in other applications, such as in irrigation practices. The community perspective on soil moisture observations parallels that described in Leese et al.[1] This included in situ measurements, satellite observations, and modelling that must all be developed and integrated, primarily through a data assimilation framework. Modelling and data assimilation are already integral components of national and international weather and climate forecast programmes.[2]

To reach the goal of an integrated global soil moisture observing system it will be necessary to establish, expand and improve current soil moisture observations both in situ and remotely sensed. For the in situ part this involves global network establishment, enhancement by expansion and standardization, improved coordination of soil moisture data network planning, observing standards, and data exchange.

The establishment of a soil moisture data hosting centre to act as a focal point is crucial in reaching many of the objectives. Key to the growth of these efforts is the recognition by international organizations and agencies that soil moisture is an important climate variable and that committed support is needed. Ultimately we hope to find a sponsoring agency that will commit to this global network of in situ soil moisture measurements and that the space agencies will commit to the development of a quasi-operational soil moisture data product.

Coordination of these efforts is done through the International Soil Moisture Working Group and is based upon the following guidelines:

A coordinated plan for soil moisture networks should be developed at both the national and international levels. A supersite programme with high density measurements is required to provide the comprehensive data sets needed for satellite sensor evaluation and calibration, and to provide a basis for developing soil wetness algorithms for satellite measurements and the evaluation of climate model outputs.

Capabilities to measure soil moisture from space have been demonstrated, but committed missions are needed to perfect these measurements and to determine the utility of soil moisture measurements derived from space at different spatial and temporal scales. Vegetation cover can obscure the radiatiances arising from warm wet soils. Research is needed to find better ways of removing the vegetation effect from the signal that is being used to derive soil moisture.

Finally, the relationship between surface soil wetness and deep soil moisture profiles needs to be quantified or at least understood. The measurements within the in situ network will need to measure soil moisture at several depths to establish a soil moisture profile.

In situ networks will occupy a key position in integrated water cycle understanding and quantitative prediction. Beside their role in validating satellite retrieval algorithms, data from in situ sensors can help address the following fundamental science questions about soil moisture, the key variable state of the land branch of the water cycle:

- What is the soil moisture memory? How does it depend on climate variability, climate persistence and soil hydraulic properties? How do vegetation characteristics affect this memory?
- How does soil moisture at the surface and below the surface respond to precipitation events and restore during drydowns?
- What are the functional relationships between soil moisture and evaporation? How does it depend on vegetation, soil type and structure?
- How is surface soil moisture dynamics linked with that in the subsurface profile?
- Are Land Surface Models (LSMs) accurate enough and unbiased enough to be used in data assimilation?

Photo: Tom Jackson & Gary Schaeffer

The pit in which the soil moisture probes have been installed to measure soil moisture over three different depths

Photo: Tom Jackson & Gary Schaeffer

The measurement of soil moisture using the gravimetric method, which is considered to be the standard measurement method for soil moisture

Enhancing global in situ and satellite soil moisture observations involves different types of problems. Some specific considerations for improved in situ observations include: taking advantage of existing infrastructure; opportunity-based expansion strategy; striving for consistency and standardization; linking long records of points to short records of spatial description; exploiting temporal stability; a single point or even a cluster at a station will not necessarily provide the data needed for satellite product validation of data assimilation; and including but not being limited to five cm measurement depth to link to satellite observations.

During the last few years, tremendous progress has been made in understanding the necessity of a global soil moisture observing system. The contributions of international organizations such as GEWEX, IWGCO and GEO, with the support of Space Agencies and with the efforts of numerous individual scientists, has enabled this progress in the realization of a global in situ soil moisture network as part of a global soil moisture observing system.

The reanalysis of daily weather observations at ECMWF

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European Centre for Medium-Range Weather Forecasts

A powerful new approach to climate analysis has emerged in recent years. It applies the tools and techniques of modern everyday weather forecasting in a process called reanalysis. The products, or reanalyses, have applicability far beyond that of traditional climate information.

The Earth's climate has traditionally been studied by statistical analysis of observations of particular weather elements such as temperature, wind and rainfall. Climatological information is often presented in terms of long-term averages, and sequences of observations are examined for evidence of warming, increased frequency of severe storms, and so on.

The new approach of reanalysis plays an important role for the Intergovernmental Panel on Climate Change (IPCC). Three working groups contributed to the Fourth Assessment Report of the IPCC in 2007, with Working Group I ('The Physical Basis of Climate Change') providing a comprehensive assessment of the physical science of climate change. The results presented were based on the extensive scientific literature that had become available since completion of the IPCC's Third Assessment Report in 2001, and had utilized expanded data sets, new analyses, and more sophisticated climate modelling capabilities. The Final Report of Working Group I comprises almost 100 references to reanalysis data sets.

GEO Task CL-06-01 will 'ensure the development of international mechanisms to coordinate and maintain sustained climate data reprocessing and reanalysis efforts.' The European Centre for Medium-Range Weather Forecasts (ECMWF) contributes to this task by its expertise in reanalysis and provision of reanalysis data sets. A reanalysis workshop was held with GEO support at ECMWF in June 2006 to assess and coordinate activities in atmospheric reanalysis.

New approaches to climate analysis

Global weather forecasting has advanced considerably since the 1970s. Forecasts of increasing accuracy have resulted from refining the numerical model of the atmosphere used to make the forecast, and from refining the procedure used to determine the initial model state from which the forecast starts. Both refinements have been made possible by investment in powerful computer systems, complementing the even larger investment made worldwide in the meteorological observing system.

In daily forecasting the latest ground- and satellite-based observations are combined with a short forecast based on earlier observations to create the initial state for a new forecast. The initial state describes the elements of weather throughout the atmosphere and the geophysical properties of land and ocean surfaces. Weather charts with frontal structures and so forth can be drawn from this information to help display and diagnose current weather in the traditional way.

In a reanalysis, the weather observations collected in past decades are fed into a modern forecasting system that is much more refined than the systems available when most of the observations were made. Atmospheric and surface conditions are reconstructed for each day of the period over which suitable observations exist. Reanalysis differs from the traditional climatological approach in that it processes a wide variety of observations simultaneously, using the physical laws embodied in the forecast model and knowledge of the typical errors of forecasts and observations to interpret conflicting or indirect observations and fill gaps in observational coverage.

One of the first reanalyses was started in the mid-1990s by the National Centers for Environmental Prediction (NCEP) in the United States, covering the period from 1948 onwards. This reanalysis has been continued in near real time to the present day. Europe's first reanalysis, ERA-15 (1979—1993), was carried out in parallel with the NCEP reanalysis, until its completion in 1996. Europe continued as a key player in this activity with ERA-40 (1957-2002), carried out (like ERA-15) by ECMWF with support provided primarily by Europe's National Weather Services and the European Commission. ERA-40 provided products of hitherto unprecedented scope and quality. Japan also recently joined the 'reanalysis club' and reanalysed the period 1979—2004. Interaction among reanalysis producers and with groups involved in observational data stewardship has eased the task of acquiring comprehensive past observations in a format that facilitates reanalysis and helps more generally in the preparation of new reanalysis systems.

The capability of reanalysis is illustrated well by one of the most severe storms of the 20th century over Europe, which occurred on 31 January/1 February 1953 causing the greatest surge on record for the North Sea as a whole. Its amplitude reached 2.74m and 2.97m at Southend and King's Lynn in England, and 3.36m in the Netherlands. Almost 100,000 hectares of eastern England were flooded and 307 people died. The Netherlands fared much worse still, as 50 dykes burst and 1,800 people drowned.

Applications of reanalysis

The success of reanalysis as a tool for global climate monitoring can be measured by the number, variety and quality of applications of its products. There are few spheres of life that are not touched by weather and climate. Reanalyses have accordingly found application in sectors such as agriculture, water, air quality, health, ecosystems and biodiversity. Direct applications in the field of weather and climate include studies of predictability from days to seasons ahead, estimation of long-range transport of pollutants, investigation of recent climate change and assessment of the capability of climate-prediction models to simulate such change. As reanalysis systems are further refined, their products will increasingly form the backbone of the quantitative information essential for climate related policy- and decision-making in a changing global environment.

Reanalysis and climate studies

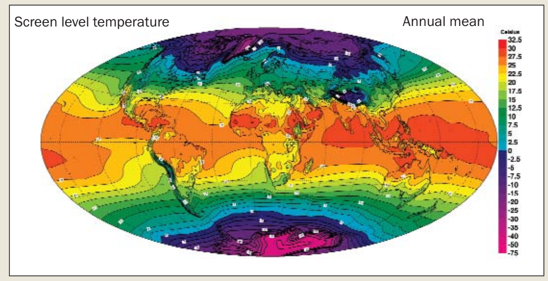
Climate, defined from the long-term statistics of the atmosphere, is demonstrated here with a few examples. A basic climate quantity is the annual mean near-surface (two-metre, or screen-level) temperature. The first image shows this from ERA-40, averaged from 1979 to 2001, the period with the best and most time-consistent product quality for the globe as a whole. The spatial structure over the oceans follows the warm and cold ocean currents near the continents. The warming effect of the Gulf Stream is seen throughout Europe and extreme cold temperatures are found over the high Antarctic plateau.

The graph compares a time-series of monthly means of the ERA-40 reanalyses with the climatological temperature analyses of monthly-mean station data by the Climate Research Unit (CRU) of the University of East Anglia, averaged over the land areas of the Northern Hemisphere. The ERA-40 temperature trend agrees very well with the CRU data from the late 1970s onwards, indicating that the quality of the reanalysis temperatures is good. Earlier, however, the ERA-40 temperatures indicate systematically too warm temperatures, the main reason being that not all observations that went into the monthly-means used in the CRU analysis were readily available as instantaneous values for use in ERA-40. Recovery of such data from national archives and other sources remains an important task, not only for the improvement of future reanalyses but also for direct use of the data in study of climate extremes.

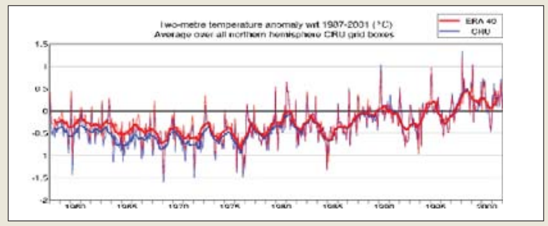
The second global image shows the mean surface wind patterns (mean vector wind and speed). This type of plot picks out where winds blow persistently throughout the year from a prevailing direction, showing the trade winds over the tropical oceans and westerlies around southern latitudes peaking in the 'roaring forties' over the Southern Indian Ocean. Regions where wind direction is more variable on both synoptic and seasonal time scales are de-emphasized, so the storm tracks of the North Atlantic and Pacific Oceans show only weakly. The mean winds and their fluctuations are the driving forces of the ocean circulation, and reanalysis products have important applications in ocean simulation studies and in the development of seasonal forecasting systems.

Annual-mean precipitation, shown in the third image, is not determined directly from observations but is instead a product derived from averaging short-range model forecasts. Its quality is related both to the quality of the dynamical and physical processes of the forecast model and to the quality of the reanalysis of water vapour, temperature and wind used to initiate the forecast. It can be seen that most of the global precipitation is produced in the equatorial convergence zones. The patterns of precipitation are in good agreement with independent precipitation analyses. Mean values are too high over the tropical oceans in ERA-40, but interannual variations are found to be realistic, capturing the major shifts associated with El Niño events, for example.

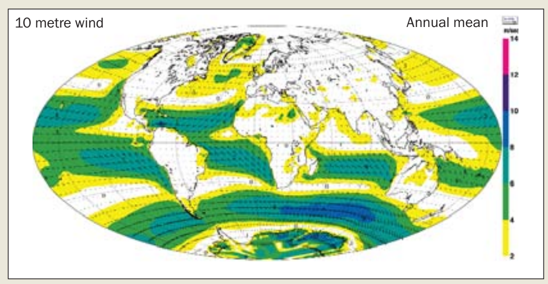
Global climate monitoring



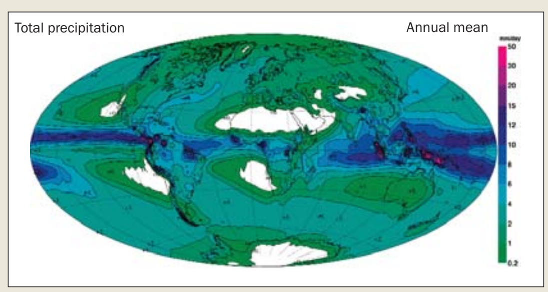
Global mean two-metre temperature 1979—2001



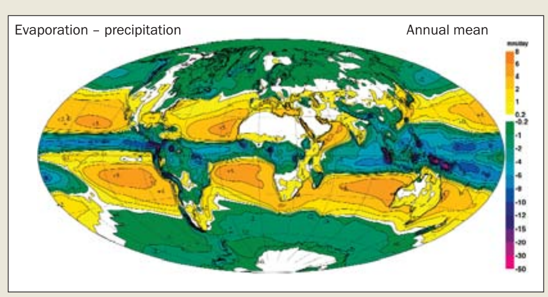
The temperature trends represented by anomalies from the 1987—2001 mean for the ERA-40 reanalysis and for the CRU analysis. Monthly means and 12-months running means are shown



Mean annual near surface wind speed (m/s) and direction 1979—2001



Annual daily mean precipitation (mm/day) 1979—2002



Annual mean evaporation-minus-precipitation (mm/day) 1979—2002

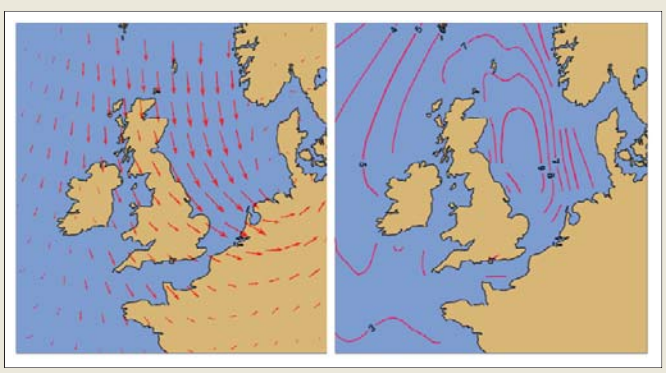
Weather analysis, an optimal combination of observations and model

In a weather analysis each weather element in the free atmosphere is described in three dimensions. Observations are used to adjust optimally the representation of elements within an atmospheric forecast model, at grid points that cover the globe in the horizontal and at a number of levels disributed in the vertical from the surface to the top of the model atmosphere. The density of spacing defines the resolution of the model and of the weather analysis.

		Resolution			*The design year of the system*
		Horizontal	*Vertical*		
			Number of levels	*Top level*	
ERA-15	*1979-1993*	*125km*	*31*	*32km*	*1995*
ERA-40	*1957-2002*	*125km*	*60*	*65km*	*2001*
Operations	*2006-now*	*25km*	*91*	*81km*	*2005*

Better reanalysis products can be produced by improving the model, the observations and/or the weather analysis algorithm that uses the observations to adjust forecast model values. Reanalysis is thus an iterative process. A new reanalysis can extract new and more accurate information from observations relating to the Earth's climate than a previous reanalysis

North Sea flood of 1953



Near-surface wind (maximum speed about 30ms-1) and ocean-wave height (metres) from a reanalysis for 00UTC, 1 February 1953, the night of a devastating North-Sea storm.

The strong winds from the north have a long fetch (the distance over which wind blows without changing direction) to develop more than nine-metres high waves over a large area.

The combination of high tide and the high waves had devastating effect. In order to better understand the effects of the storm, the global reanalysed fields have also been used as boundary conditions for high resolution limited area atmospheric models, which in turn drive detailed storm surge models

When the amount of precipitation is subtracted from the amount of evaporation, areas of net evaporation and net precipitation can be seen. Energy exchanged between the atmosphere and the surface is an important component of what is needed to understand how the Earth's climate system works, how the climate is changing and for what reason. Comprehensive direct global measurements of such quantities do not exist, and a key challenge for future reanalyses is to provide improved estimates in support of studies of climate change, its prediction and its implications.

Web and print versions of an ERA-40 Atlas have been published by ECMWF. The Atlas describes the atmospheric climate for 1979—2001. The climate is presented in maps for the four seasons, the annual average and the inter-annual variability. A selection of time series, showing the quasi-biennial oscillation of stratospheric winds, is presented for the full period 1958—2001. A complementary atlas of the ocean-wave climate has been produced by the Royal Netherlands Meteorological Institute, a partner in the ERA-40 project.

Outlook

An ECMWF 'interim reanalysis' is currently being produced using a more advanced (four-dimensional variational) data assimilation system and higher horizontal resolution than ERA-40. It covers the period from 1989 onwards and addresses several of the deficiencies (such as high tropical oceanic precipitation) identified in products from the later years of ERA-40. Production of ERA-Interim began in 2006 and will reach the present day in 2008, after which it will be updated on a near-real-time basis. ECMWF is also developing plans for a new project, called ERA-75, to cover the period from 1938 to the present using an even more recent version of the reanalysis system, including provision to cope better with the poorer data coverage of the pre-satellite years and poorer quality of early satellite data. The project may start in 2009, subject to establishing the appropriate funding scheme and collaboration partnerships. When the new reanalysis reaches the present day, it may in turn be continued in near real time, and supersede ERA-Interim.

Key to this effort will be coordinated international efforts under the Global Climate Observing System (GCOS), the World Climate Research Program (WCRP) and the wider GEO umbrella to recover and combine historical observational data from a wide variety of sources, to manage these data to modern standards, and to incorporate metadata on the quality of these data, including that derived from any use of the data in earlier reanalyses. Continued collaboration among reanalysis centres to exchange experience and ensure complementary and shared research and development programmes is equally vital to ensure that progress is made in the most effective way, and that the needs of a large and widening user community are met as fully as possible. Open access to the products of reanalysis enables users worldwide to benefit from a specialized and highly advanced central processing of observations that have been gathered throughout the world, and easier future access to more comprehensive and higher-resolution product sets will be essential if reanalysis is to realise its potential as a key component of the Global Earth Observation System of Systems.

The Thorpex Interactive Grand Global Ensemble (TIGGE) concept and current status

Philippe Bougeault, European Centre for Medium-Range Weather Forecasts, UK; Co-Chair, GIFS-TIGGE WG and Zoltan Toth, National Centers for Environmental Prediction, USA; Co-Chair, GIFS-TIGGE WG

Ten operational weather forecasting centres producing daily global ensemble forecasts for one-to-two weeks ahead have agreed to deliver in near-real time a selection of forecast data to the Thorpex Interactive Grand Global Ensemble (TIGGE) data archives at the China Meteorological Agency (CMA), European Centre for Medium-Range Weather Forecasts (ECMWF) and the US National Center for Atmospheric Research (NCAR). This is offered to the scientific community as a new resource for research and education. The objective of TIGGE (GEO task WE-06-03) is to establish closer cooperation between the academic and operational worlds by encouraging greater use of operational products for research, and to explore actively the concept and benefits of multi-model probabilistic weather forecasts, with a particular focus on severe weather prediction.

TIGGE is a key component of Thorpex, which is in turn a major component of the World Weather Research Programme (WWRP) of the World Meteorological Organization (WMO). A key goal of WWRP-Thorpex is to accelerate improvements in the accuracy of one-day to two-week high-impact weather forecasts for the benefit of humanity. TIGGE was initiated in 2005 at a workshop hosted by the ECMWF. The workshop report has been published in the WMO series.[1]

The objectives of TIGGE are:

- To enhance collaboration on ensemble prediction, internationally and between operational centres and universities
- To develop new methods to combine ensembles from different sources and to correct for systematic errors (biases, spread over-/under-estimation)
- To achieve a deeper understanding of the contribution of observation, initial and model uncertainties to forecast error
- To explore the feasibility and the benefit of interactive ensemble systems responding dynamically to changing uncertainty
- To enable evolution towards an operational system, the Global Interactive Forecast System (GIFS).

The highest priority data accumulated in the TIGGE archive are the ensemble forecasts generated routinely (operationally) at major forecast centres around the world. This core data stored in the TIGGE archive is accumulating at a daily rate of approximately 300GB. Additional special datasets will be added in the future for specific research and applications.

The plan is to implement TIGGE in two steps. In the current phase (Phase-1), data are collected in near-real time at a small number of central data archives using existing network and storage capabilities. In Phase-2, envisaged as soon as possible, data archives will be distributed over a larger number of centres, instead of all being held centrally, while maintaining efficient and transparent access to users. This more flexible solution has the potential to eliminate routine transfers of large data volumes, but will require substantial software development, specific funding and coordination with the evolving WMO information system

Partners and linkages

The TIGGE project is developed under the leadership of the GIFS-TIGGE Working Group, under Thorpex. Phase-1 databases are developed by three archive and distribution centres: ECMWF, NCAR and CMA. The operational forecasting centres supplying daily forecasts are the Bureau of Meteorology Research Centre (BMRC, Australia); CMA; Centro de Previsão de Tempo e Estudos Climáticos (CPTEC, Brazil); ECMWF; Japan Meteorological Agency (JMA); Korea Meteorological Administration (KMA); Météo-France; Meteorological Service of Canada; National Centers for Environmental Prediction (NCEP, USA), and the UK Met Office. In addition, the TIGGE website is maintained by ECMWF; the metadata centre is maintained by NCAR, and the verification web by JMA. The WGNE/WWRP joint working group on verification advises the project on verification methodology, and the WMO Expert Team on Ensemble Prediction Systems advises the project on a number of issues, such as metadata formulation.

TIGGE has strong links with the North American Ensemble Forecasting System (NAEFS). Although NAEFS is initially an operational project, TIGGE and NAEFS share many technical aspects, and NAEFS plans to implement results from TIGGE. It is believed that TIGGE and NAEFS will ultimately evolve into a single operational system.

TIGGE is registered as Group on Earth Observations (GEO) Task WE-06-03. It has general relevance to GEO societal benefit areas that will benefit from access to advanced multi-model global weather forecasts and the derived products, especially in areas related to risk management, disaster mitigation, energy and health.

TIGGE users

TIGGE will initially accelerate research at large, and in particular the scientific programmes of WWRP-Thorpex. For instance, the forecast demonstration projects (FDP) of WWRP-Thorpex (e.g. the Beijing 2008 FDP/research demonstration project), the future field campaigns on adaptive observations and the International Polar Year (IPY) projects will be active users of TIGGE. This research will, in turn, lead to targeted applications reducing societal risk to severe weather through better forecasts (for example health, energy, flood warning, fire weather). The hydrological community (e.g. through the Hydrologic Ensemble Prediction Experiment or HEPEX) is expected to be a strong user of TIGGE data. Some by-products of TIGGE have already appeared, for instance, the acceleration in implementing various components of the new WMO information system such as Gridded Binary (GRIB)[2].

TIGGE technical solutions

The data exchange technique is based on the Internet Data Distribution/Local Data Manager from Unidata. The new WMO standard GRIB2 for gridded data was agreed by all partners to support data exchanges between data providers and archiving centres. The database is composed of GRIB2 records. The units, names of the various fields, accumulation periods, etc. are identical for all data providers. The data providers supply data on grids of their own choosing, which are as close as possible to the native grid employed to carry out the predictions. The data are archived on the same grid as received. Data providers must ensure that appropriate software is available to the archiving centres to enable users to interpolate data to latitude/longitude grids and locations of their choosing. They must also ensure that when revisions to their systems are made, revised interpolation software is communicated to the archiving centres immediately. The archiving centres maintain a user-friendly interface based on interpolation software supplied by the data providers. This allows the TIGGE users to retrieve data easily at single points or on regular latitude-longitude grids of their own choosing. Special effort will be made to provide quick access to long series of data at a single point, as this is a frequent request for many applications. Automatic regular requests will also be possible. In Phase-1, each archive centre provides data through its own proprietary user interface. However, the supplied data are of course the same. In Phase-2, the user interface will be unified.

Current status of the TIGGE database

A complete list of data requested from the data providers can be found at the TIGGE Internet site.2 The data from operational global ensemble forecasts are divided into fields in pressure levels and single-level fields. Pressure level fields comprise geopotential, temperature, specific humidity and wind components at 1,000, 925, 850, 700, 500, 300, 250, and 200 hPa. Additional fields at the tropopause level reflect potential vorticity on the 320K potential temperature surface, and potential temperature and wind on the 2PVU potential vorticity level. Other single-level fields are listed in the table.

Currently five providers (ECMWF, NCEP, UK Met Office, JMA and CMA) are delivering data, with initial dates varying from Autumn 2006 to Spring 2007. Pressure level data are available from all five providers, with very few exceptions. Combined streamlines from the five providers can convey a complete picture of the forecast uncertainty. Production of single-level fields has proven to be a tough challenge and availability varies widely between providers. However, the more useful single-level fields (such as the description of basic weather parameters at the surface) are available from all five providers. A detailed list of available data can be found from the data portals.

Five additional data providers (CPTEC, KMA, MSC, BMRC, and Météo-France) have signed to the project and should start providing data before the end of 2007.

Access to TIGGE data for research and education

Data providers supply their products to the TIGGE archive centres under an agreed set of rules, which include redistribution rights. Access is provided for research and education through a simple electronic registration process, with valid e-mail address and acknowledgment of conditions of supply. Under the simple registration process, access is given with a 48-hour delay after the initial time of the forecast. Real-time access is granted in some cases, for example for field experiments and projects of special interest to Thorpex. Registration for real-time access is handled via the Thorpex intellectual property office.

Data access is operated via the TIGGE data portals. Currently these are at NCAR and ECMWF,3 with the CMA portal due to open later in 2007. The data portals can currently be used for registration; search, discover and download of files; selection of data by initialization date/time, data provider, file type and forecast time; checking volume and downloading data. Both portals also provide a selection of parameter subsets. ECMWF offers grid interpolation and a limited amount of spatial subsetting, while NCAR plans to offer these expanded services in the future.

Outlook

It is anticipated that limited-area ensemble prediction systems will also form an important component of GIFS, whose development is dependent upon TIGGE. The priority requirement here is to develop standard formats enhancing the interoperability of the existing systems. A key objective is to facilitate the use of lateral boundary conditions from global systems by various limited-area systems. A panel of experts called TIGGE-LAM has recently been set-up to organize the limited-area-model component of TIGGE.

Single level fields in the TIGGE database

10 meter u-velocity
10 meter v-velocity
Convective available potential energy
Convective inhibition
Field capacity
Land-sea mask
Mean sea level pressure
Orography
Skin temperature
Snow depth water equivalent
Snow fall water equivalent
Soil moisture
Soil temperature
Sunshine duration
Surface air dew point temperature
Surface air maximum temperature
Surface air minimum temperature
Surface air temperature
Surface pressure
Time-integrated outgoing long wave radiation
Time-integrated surface latent heat flux
Time-integrated surface net solar radiation
Time-integrated surface net thermal radiation
Time-integrated surface sensible heat flux
Total cloud cover
Total column water
Total precipitation
Wilting point

Mapping global ecosystems — the GEOSS approach

Roger Sayre, US Geological Survey; Alberto Yanosky, Guyra Paraguay; Douglas Muchoney, Group on Earth Observations/US Geological Survey

The intergovernmental Group on Earth Observations (GEO) is leading a worldwide effort to build a Global Earth Observation System of Systems (GEOSS) to provide comprehensive, coordinated Earth observations from thousands of space-, water-, and ground-based instruments worldwide, transforming the data they collect into vital information for society. GEOSS is programmatically organized into nine societal benefit areas: disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. A number of priority tasks have been developed for each of the societal benefit areas, and these tasks collectively represent the GEOSS work plan. One of these tasks, EC-07-02, in the ecosystems societal benefit area, calls for the development of a robust, practical, standardized classification and map of global terrestrial, freshwater and marine ecosystems. A scope of work has been developed and initiated for this ambitious effort, and standardized ecosystems mapping is completed or underway in South America, the continental United States, China, Africa and Australia. When complete, the global ecosystems map will represent the first attempt to map the planet's ecosystems in a standardized, scientifically rigorous fashion, at management-appropriate scales. Both the initial mapping and subsequent monitoring of global ecosystems require comprehensive earth observation.

Ecosystem services

Provisioning Services	Regulating Services	Cultural Services
Products obtained from ecosystems	*Benefits obtained from regulation of ecosystem processes*	*Nonmaterial benefits obtained from ecosystems*
• Food • Fresh water • Fuelwood • Fibre • Biochemicals • Genetic resources	• Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual and religious • Recreation and ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage

Supporting Services
Services necessary for the production of all other ecosystem services
• Soil formation • Nutrient cycling • Primary production

Millennium Assessment, 2005

The need for a global map of ecosystems

Ecosystem management is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way, and has been adopted as a best practice by the global conservation community (Convention on Biological Diversity, 2000, Decision V/6). Ecosystems are recognized as fundamental components of biodiversity that need to be conserved and, in some cases, restored. In addition to their biodiversity value, many ecosystems should be conserved for the economic value and societal benefits they confer to humans through the provision of ecosystem goods and services (such as food, fuel and fibre). Classification and valuation of ecosystem goods and services is an emerging science. The Millennium Ecosystem Assessment (2005) produced a framework for understanding ecosystem services, which demonstrates the importance of ecosystems for supporting human societies.[1]

Unfortunately, ecosystems are increasingly threatened by fragmentation, alteration, loss, invasive species, fire, climate change, incompatible resource extraction and other threats. Two recent major ecosystem health analyses conclude that many ecosystems are either imperilled or significantly compromised in their ability to provide the goods and services that societies require.[2] These and other reports serve to underscore the importance of ecosystems for healthy societies, and their utility as resource management units. Previously a focus mainly of earth scientists and ecologists, ecosystems are now emerging as a mainstream societal concern.

As the essential life-support systems of the planet, it is clear that ecosystems should be well-managed. A prerequisite to ecosystem management is an understanding of the types, distribution and condition of ecosystems as they occur in landscapes and seascapes. The classification and delineation of ecosystems at relatively fine scales is fundamental to managing ecosystems. However, the world lacks a standardized ecosystem map at a scale appropriate for on-the-ground resource management. While some broader-scale ecosystem classifications exist (sometimes called 'ecoregions'), they are generally too coarse for resource planning and management at the local level. In

Ecological systems of South America

The ecosystems of South America, derived from a biophysical stratification of the continent using landforms, elevation class, bioclimate, lithology and land cover

Source: Sayre, R., J. Bow, C. Josse, L. Sotomayor, and J. Touval, Terrestrial Ecosystems of South America: Washington, D.C., Association of American Geographers, 2007 (accepted for publication)

recognition of this problem and the need for finer scale, standardized ecosystem mapping, GEOSS commissioned a new classification and map of the planet's terrestrial, freshwater, and marine ecosystems. The products from this effort will greatly enhance the ability to manage and conserve global terrestrial, freshwater and marine ecosystems. This effort supports, and in some cases underpins, several other GEOSS tasks from the ecosystems and biodiversity societal benefit areas. The map of global ecosystems resulting from this work will represent the first attempt to classify and map global ecosystems in a standardized and robust fashion at a scale appropriate for most 'on-the-ground' management applications.

Ecosystem distributions

Ecosystems have been defined in many ways, all essentially as dynamic assemblages of interacting native plant and/or animal communities that 1) occur together on the landscape or in the water, and 2) are tied together by similar ecological processes (e.g. fire, hydrology), underlying environmental features (e.g. soils, geology) or environmental gradients (e.g. elevation). Ecosystems have both biological and non-biological components.

These biological and non-biological components collectively constitute the structure of an ecosystem. Ecosystems can be mapped by spatially delineating the extents of their structural components. An ecosystem's distribution on the landscape changes when one or more of its structural elements change.

The GEOSS ecosystem classification and mapping approach is based on this premise that ecosystems can be geospatially represented by mapping and integrating their structural components. The ecosystems of South America were recently mapped in this fashion and represent a proof-of-concept for the approach.[3] For South America, continent-wide geospatial datasets were developed for landforms, elevation class, lithology and bioclimate, and these were combined to produce a map of unique abiotic environments for the continent at a relatively fine spatial resolution (450m). These abiotic ecosystem footprints were then combined with land cover, as a proxy for the vegetation (biota). Ecosystems were thus modelled as unique physical environments and their associated land cover. The ecosystems were subsequently labelled ('crosswalked') with ecosystem names from an existing classification. Six hundred and fifty-nine ecosystems, each with multiple polygonal occurrences, were mapped across the continent. Similar work is nearing completion for the continental United States, and mapping ecosystems under the GEOSS commission has been initiated for China, Africa, Australia, and Indonesia/Pacific.

The GEOSS global ecosystems mapping model

The GEOSS has a conceptual model for mapping the planet's terrestrial ecosystems, with freshwater and marine conceptual models in development and testing. The ecosystem mapping is essentially a top-down, biophysical stratification of the planet into unique physical environments and their associated biota. Data processing efforts are considerable, but are likely to be enabled through a combination of GEOSS mandates and opportunities for fruitful collaborations between stakeholders.

Earth observation and global ecosystem mapping and monitoring

The GEOSS global ecosystem mapping approach is fundamentally an application of earth observation from satellite imaging, combined with other physical environment characterizations derived from field observations. Several key input layers representing ecosystem structure (landform, elevation class, soil moisture etc.) are partly or wholly derived from digital elevation models. Similarly, land cover is mapped from image interpretation, and lithology data are often imagery-supported as well. Climate regions are mapped using spatially-interpolated field observations from weather stations. Earth observation data are thus essential for both mapping global ecosystems, and monitoring their condition.

Understanding the coupled human-environmental Earth system: science without borders

Kevin Noone, International Geosphere-Biosphere Programme (IGBP)

An enduring legacy of the Apollo space programme of the 1960s is the iconic 'Earthrise' image of our planet taken from the perspective of a tiny spacecraft in orbit around the moon. It was the first time that millions of humans had the opportunity to see our home planet as a single entity. They got a glimpse of a connected system that transcended the political, social, economic and even scientific boundaries humans have projected onto it. Continents, oceans, clouds, and the fantastically thin shell that is our atmosphere all appeared together as a beautiful whole. From a scientific perspective, these images helped to stimulate us to rediscover the science of the Earth system.

The Earth system has been connected on a planetary scale since life first appeared on it more than three billion years ago. Ever since, the Earth has existed as a highly coupled, interdependent system of components and processes, all of which operate on a multitude of temporal and spatial scales. Throughout most of our history, humans have only viewed and experienced the Earth system on small scales: through the prism of our villages and settlements, and later our cities and nations. Even though humans have transformed the environment in very important ways throughout history, it has only been in the last century or so that human activities have begun to match (and often exceed) the natural forces that regulate the Earth system. Recent ice core data show that current levels of carbon dioxide and methane are well outside the range of natural variability over the last 800,000 years.

Roughly half of the world's ice-free land surface has been altered by human actions. Humans now fix more nitrogen than nature does. Particles emitted by human activities alter the energy balance of the planet, as well as having adverse effects on human health. These may seem unrelated issues; however, over recent decades we have gained a deeper understanding of the degree to which all of these separate issues are linked. The Earth system is very complex with myriad feedbacks, and has exhibited rapid, global-scale responses to changes in environmental conditions. Humans, rather than simply affecting or being affected by the natural environment, are a central component in the Earth system. Within the Earth system, there are feedbacks and teleconnections that operate on a planetary scale, and in which humans are directly involved.

Bridging the spatial and temporal scales of the different interacting processes in the Earth system and putting together the many different disciplines (from both natural and social sciences) is a huge challenge for the scientific community.

For the global change research community, a further challenge is to present research results in more accessible and informative ways to stakeholders, particularly those concerned with sustainable development. We are frequently expected to answer questions on the effects of global change on regional and even local scales. Stakeholders seek strategies to deal with future environmental change, most often with a place-based perspective. This is particularly important for the developing world, since the capacity to adapt to local or regional changes driven by global factors is often limited.

The need to understand how the natural world works has not diminished, but in fact underpins the answers to questions of sustainable development. We must continue to concentrate on first-class science involving the interactions and feedbacks between biological, chemical and physical processes and human systems. However, scientists, resource managers and policy makers require a common understanding in order for their interactions to be mutually beneficial.

The kinds of questions now being asked of the research community have changed over the last decades, and reflect the increasing appreciation of the interconnectedness of the Earth system. In the past, many scientific questions of societal importance could be successfully addressed by concentrating on either individual, or a small number of the components of the Earth system, even though answering the questions still required international, interdisciplinary collaboration. For instance, finding out what caused the development of the Antarctic ozone hole required international collaboration among atmospheric chemists and meteorologists.

In contrast, the kinds of questions now being asked of the scientific community show the increasing need for a more holistic approach. Questions such as: can global warming, urban-industrial emissions and land cover changes influence the Asian Monsoon circulation? How will changes in precipitation patterns caused by global warming influence water management policies, on regional and local scales? What will be the consequences of large-scale land use and ecosystem changes caused by moving towards biofuel production? What are the impacts of the predicted climate changes on food production and human security? What role does urbanization play in the health effects of air pollution? Do megacities play a role in affecting the energy balance of the planet and in the hydrological cycle? What form of carbon sequestration scheme will have the smallest negative impact on the earth system?

Depiction of the complexity and connectedness of the Earth system

Image: commissioned by IGBP from UK artist Glynn Gorick

The Earth in its entirety is at the centre, since it is the whole system that we need to understand. Increasing detail is seen towards the edges of the image, showing individual processes such as chemical reactions, air-sea exchange, and emissions from individual pollution sources. Evident in the image is the lack of borders between the components of the system, and the pervasive presence and influence of humans

Answering such questions requires new tools, both observational and modelling, that to a much larger extent couple the social and natural science approaches and methodologies.

The research community has responded to these needs by forming the Earth System Science Partnership, a partnership among the four major international programmes on global environmental change research: Diversitas, an international programme of biodiversity science; the International Geosphere-Biosphere Programme (IGBP); the International Human Dimension Programme on Global Environmental Change (IHDP); and the World Climate Research Programme (WCRP).

The ESSP has four projects that concentrate on different crosscutting issues in Earth system science, which transcend international and disciplinary boundaries. These are the Global Carbon Project (GCP), the Global Environmental Change and Food Systems (GECAFS) project, the Global Water System Project (GWSP), and the Global Environmental Change and Human Health (GECHH) project. In addition, capacity building is addressed through the Global Change System for Analysis, Research and Training project, and the Monsoon Asia Integrated Regional Study is a crosscutting initiative that looks at coupled human-environmental systems in a regional context.

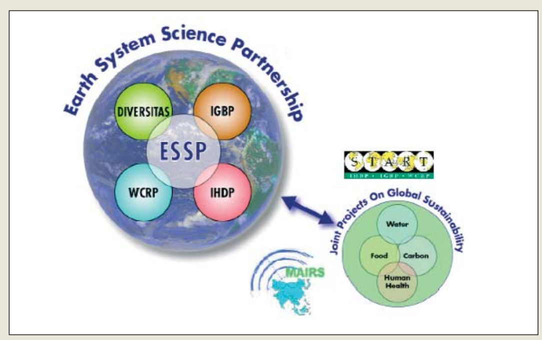
The ESSP and the research going on within it, and within its component programmes, is an excellent example of the research community responding to societal needs and questions.

The role of global observations

If the Apollo images stimulated a rediscovery of the science of the Earth system, modern global observation systems, both remote sensing and in situ, underpin our ability to understand how the Earth system works, and how we affect and are influenced by our environment. The research community in general, and ESSP more specifically, would be unable to pursue Earth system science without such observations. Much of the research being done in ESSP and in the partner programmes helps to understand the processes that determine the behaviour of the coupled human-environmental Earth system. As such, the research community itself is a significant source of observations on the global scale. In addition, there are important in situ monitoring efforts underway for the atmosphere, oceans and terrestrial systems. Satellite observations provide an indispensable source of information and have tremendously expanded our ability to monitor and assess global-scale phenomena.

The ESSP and its partner programmes, such as the Group on Earth Observations (GEO), can foster and enable connections between the observing and research communities. Without these connections, the translation of observations to useful information would be much more difficult and less efficient. Producing information and answers relevant for sound decision-making requires increased and sustained collaboration between the research, in situ monitoring and satellite remote sensing communities. This collaboration is often challenging in terms of human, institutional and financial capacity, but absolutely essential to making progress in the nine critical societal benefit areas outlined by GEO.

The Earth System Science Partnership



The ESSP is a partnership of four international global environmental change programmes Diversitas, IGBP, IHDP, and WCRP. It has joint projects on water, food, carbon and health; an integrated regional study looking at the monsoon Asia region, and a capacity building project

Website addresses for ESSP projects and sponsoring programmes

ESSP	www.ess-p.org
GCP	www.globalcarbonproject.org
GECAFS	www.gecafs.org
GECHH	Website under development
GWSP	www.gwsp.org
START	www.start.org
IHDP	www.ihdp.uni-bonn.de
DIVERSITAS	www.diversitas-international.org
WCRP	www.wmo.ch/web/wcrp
IGBP	www.igbp.net

Global land cover observations

Martin Herold, Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)

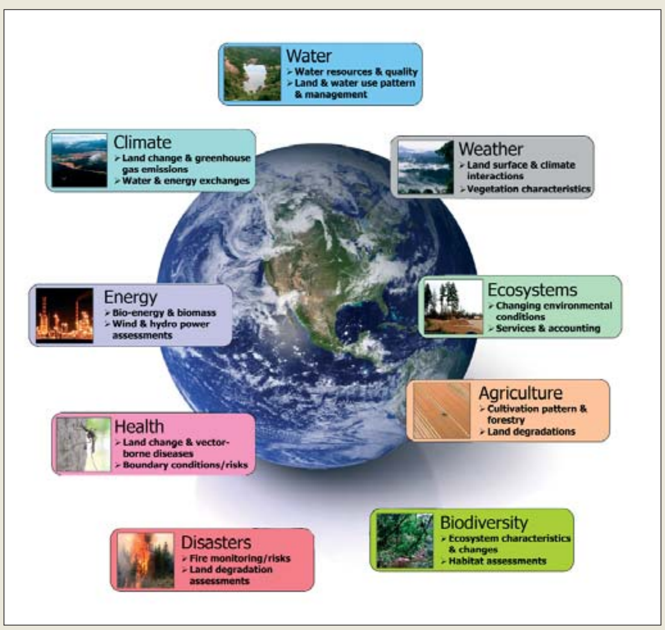
In its ten-year reference document,[1] the Group on Earth Observation (GEO) has highlighted the importance of land cover for all areas of societal benefits. Land cover is one of the most important elements for the description and study of the environment. Reliable land cover observations are of crucial importance to understanding climate change and mitigating its impacts; to sustainable development, natural resources management, conserving biodiversity and understanding ecosystems and biogeochemical cycling.

Land cover change is an issue with far reaching policy implications, internationally, nationally and locally. For example, land cover characteristics can indicate the ongoing processes of deforestation, desertification, urbanization, loss of biodiversity and ecosystem functions, and changing boundary conditions for vector-borne diseases and water and energy management. In situ and satellite-based land observation efforts across disciplines (e.g. geography, ecology, geology, forestry, land policy and planning) use and refer to land cover as the most obvious and detectable indicator of land surface characteristics.

Despite their importance, it is important to recognize that land observations are not operational in comparison to other earth observation domains, such as oceans and atmosphere. The arena of land cover observations is heterogeneous in many ways — in terms of the land surface itself, the approaches to acquire land cover data, and the users of such information. Each land surface worldwide has been mapped and characterized several times and a large number of countries have a monitoring system in place, including forest, agriculture and cartographic information systems and inventories.

With the evolution of satellite-based observations, it has become straightforward to produce land cover maps with a reasonable amount of effort and little difficulty. To build a sustained global land cover observing system, however, requires international agreement and cooperation on the continuity of global observations, the consistency in mapping and monitoring specifications and land cover assessment approaches, and sustained engagement and participation in mapping activities, regional networking and capacity building.

Key land cover observations



GEO SBA's key land cover observation needs the multitude of benefits from continuous and consistent global land cover observations

Source: M. Herold, GOFC-GOLD

A role for GEO

The international land cover community has been working with GEO since 2005 to build the foundations for land cover observations as an integral part of the Global Earth Observation System of Systems (GEOSS). Given the current heterogeneity and lack of coordinated land cover observations globally, GEO has offered a platform for improvement and has been driving observation progress, through:

- Highlighting the societal needs and relevance of land cover observations
- Providing a forum for advocating global land cover and change observations as key issues
- Fostering integrated perspectives for continuity and consistency of land observations, in particular for joint international efforts to provide baseline observations and data suitable to assess global land cover and change
- Helping to evolve and apply international standards for land cover characterization and validation
- Advocating joint participation in ongoing global mapping activities, as well as regional networking and capacity building in developing countries
- Helping to develop international partnerships involving producers, users and the scientific community to better produce and use existing datasets.

A specific task in the GEO 2007-2009 work plan (DA-07-02) is dedicated to 'global land cover'. The overall goal is to provide a suite of global land cover datasets, initially based on improved and validated moderate resolution land cover maps and eventually including land cover change at high resolution.

Examples of national and regional land cover/use mapping and monitoring programmes building upon Landsat-type observations

Region covered	Mapping/monitoring programme	Objective	Data products
Australia	National Carbon Accounting System - Land Cover Change Project (LCCP)	To monitor land cover change for the past 30 years for integrated and comprehensive greenhouse gas emissions reporting for land based emissions and to underpin policies for greenhouse and natural resource management	Land cover change 1972-2000 based on Landsat: maps of forest cover at each time slice; maps of land cover change between each pair of consecutive time slices
Canada	Earth Observation for Sustainable Development of Forests (EOSD)	To produce a land cover map of the forested area of Canada for monitoring of Canada's forests (internal monitoring and reporting, participation in international programmes)	Land-cover map of forested areas from Landsat data for 2000 and eventually for 1990 (base year for Kyoto reporting), updates intended for 2007 and 2012
Different countries worldwide	United Nations Global Land Cover Network (GLCN)	Improve the availability of reliable and standardized information on land cover and its changes at the global level and for a large user community	More than 15 countries fully mapped using Landsat data (i.e. Africover, Asiacover). Translation and harmonization of existing databases. Continuing effort
European Union	Coordination of Information on the Environment (CORINE)	To provide an inventory of the Earth surface features for managing the environment; to compile consistent data of the land cover for Europe in order to determine EU's environment policy, assess the effects of this policy and incorporate the environment dimension into other policies	Land cover/use dataset and land change based on 1990 and 2000 Landsat data. Continuation planned under Global Environment and Security (GMES)
Great Britain	Land Cover Map of Great Britain	To provide a census of the countryside of the UK, in the form of digital maps and databases, plus a range of derived products, for use in a geographical information system (GIS) and statistical packages	Land cover and land use and change for 1990 and 2000 using Landsat data
New Zealand	New Zealand Land Cover Database	To investigate the feasibility of using satellite imagery for forest resource mapping and monitoring within New Zealand	Land cover and land use and change for 1996/97 (based on SPOT) and 2001/02 (based on Landsat)
South Africa	South African National Land Cover Database	To provide strategic, national-coverage land-cover information, on an operationally achievable, repeatable basis for general modelling, natural resource assessment, statistical and data integration purposes	Land-cover database 1994/95 and 2000 based on Landsat data including change assessment
United States	National Land Cover Dataset (NLCD)	To generate a consistent, seamless, and accurate land cover data set for the conterminous United States	Land cover/use maps from 1992 and 2001 Landsat data interpretations and independent per-pixel estimates of imperviousness and tree canopy. Continuation planned

GEO related achievements in 2007

The Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a coordinated international effort to ensure a continuous programme of space-based and in situ forest and other land cover observations, in order to better understand global change, to support international assessments and environmental treaties, and to contribute to natural resources management. The GOFC-GOLD community, with GEO involvement, was able to achieve significant progress in task DA-07-02 in 2007.

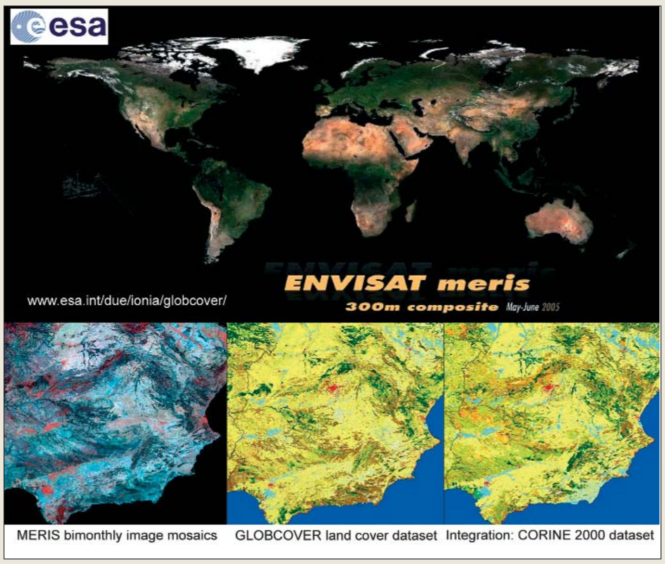
In 2004, the Integrated Global Observing Strategy (IGOS) partnership started to develop an additional theme covering all land requirements outside of those covered by the established themes. The new theme is known as Integrated Global Observations of the Land (IGOL) and defines detailed observation requirements for different areas, including agriculture, forestry, land degradation, ecosystem goods and services, biodiversity and conservation, human health, water resource management, disasters, energy, urbanization and climate change. The IGOL document has been compiled and presented to the IGOS Partnership (IGOS-P) plenary in 2007 as the first comprehensive and integrated observation strategy for the land domain. The process of integrating the IGOL strategies into GEO implementation has been initiated. The land cover requirements of IGOL are widely reflected in the related GEO task DA-07-02 on global land cover.

The new European Space Agency (ESA) funded Globcover product will be based on 2005/06 Envisat Meris data and will provide the highest resolution (300m), consistent global land cover map, fully compliant with international standards for land cover characterization (UN Land Cover Classification System) and validation (CEOS best practices).[2] Additional progress can be reported for national and regional high-resolution land cover mapping programmes, including the Corine/GMES service, US National Land Cover Database, and new products evolving in countries such as Canada and China, as well as those in the UN Global Land Cover Network.

High-resolution land cover change dataset

Work is ongoing toward the development of a high-resolution (Landsat-type) land cover change dataset. NASA and the US Geological Survey have been making progress in acquiring high-resolution imagery for the Mid-decadal Global Land Survey that will provide consistent, preprocessed, global, free-of-charge Landsat data for 2005, extending the existing 1990 and 2000 Geocover Landsat global dataset. The 2005 dataset marks a major contribution in terms of basic data support for any global and regional land mapping activity where user communities require land change information at least every five years. Many national programs already work with such data.

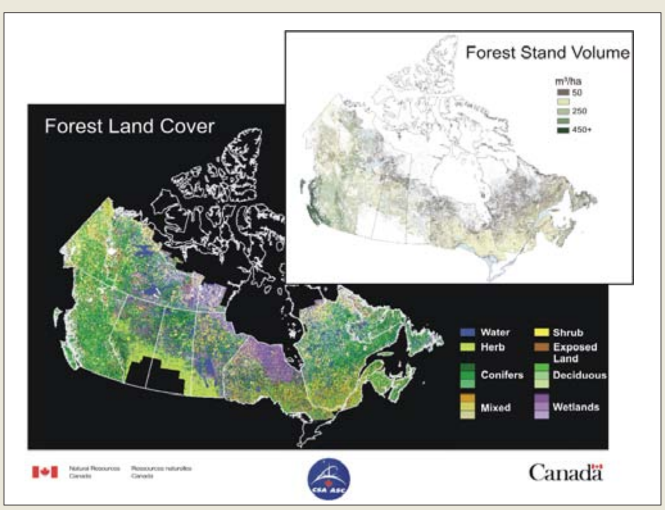
Global mosaic of MERIS satellite data



Global mosaic of MERIS satellite data presented at ESA's Envisat conference in April 2007 (top). The bottom row presents examples of processed MERIS bimonthly mosaics (in an area of Southern Spain) used to create the Globcover 2005 land cover data. Efforts are underway to link the new global data with regional products like the European Corine 2005 dataset

Source: O. Arino, ESA

National land cover and secondary product using Landsat-type satellite data



An example of a Landsat-type national product is the Earth Observation for Sustainable Development (EOSD) land cover map of the forested areas of Canada. The inset map depicts forest volume distribution, derived from integrating land cover with climate and Canada forest inventory data

Source: R. Hall and E. Arsenault, NRCan

Meanwhile, the international community is producing a 'best available' global land cover dataset that could evolve into a 'GEO global land cover product'. Starting with existing, moderate-resolution global land cover datasets, the community harmonizes and validates existing data to derive the best land cover estimate for each location worldwide. Synthesized global maps have been developed for particular user communities. The idea is to further develop this product including regional high-resolution products until a new high-resolution (change) product is produced (the final goal of DA-07-02).

Ongoing commitment and priorities

GEO has helped to bring the relevant community together over guidance and implementation plans for building a land cover observing system as part of a global earth observation system of systems. On the strategic level, the land cover community provided a roadmap built on GEO requirements to formulate global observation strategies and implementation guidelines (i.e. integrating IGOL into GEO).

There is an essential need to ensure the availability of baseline observations. For 2010, the availability of Landsat and Landsat-type data is considered tenuous, and the community is asking GEO to help with ensuring that the decadal global high-resolution satellite mosaic will be produced to reach at least the quality of the 1990, 2000 and 2005 global datasets. There is no lack of observations since many countries maintain Landsat-type satellite assets, which are used for a variety of land cover and secondary products. It would be an international coordination task to ensure such a global mosaic is jointly produced, but also a major step towards building a system of systems.

Existing national and regional land cover databases, Globcover and efforts to evolve a GEO global land cover map will be the starting point to developing new global high-resolution (change) products. It is important to emphasize that an operational land cover observation and validation system is needed to fully achieve the societal benefits advocated. We expect GEO to mobilize more international actors and countries to sign up for this process and jointly participate in continuous and consistent global land cover observations. As an example, global land cover issues are increasingly addressed as part of the European Commission's activities for Global Monitoring for Environment and Security (GMES).

International cooperation on the continuity of global observations, ensuring consistency in land monitoring approaches, community engagement and country participation in mapping activities, regional networking and capacity building remain essential challenges for building a sustained global land cover observing system. The experiences and progress reported here demonstrate initial GEO successes that should evolve and be further extended to related issues which are currently thoroughly addressed by GEO (e.g. fire observation) or need further GEO engagement (e.g. land use observation).

Rapid biological and ecological assessments using Earth observation data

Douglas M. Muchoney, Group on Earth Observations

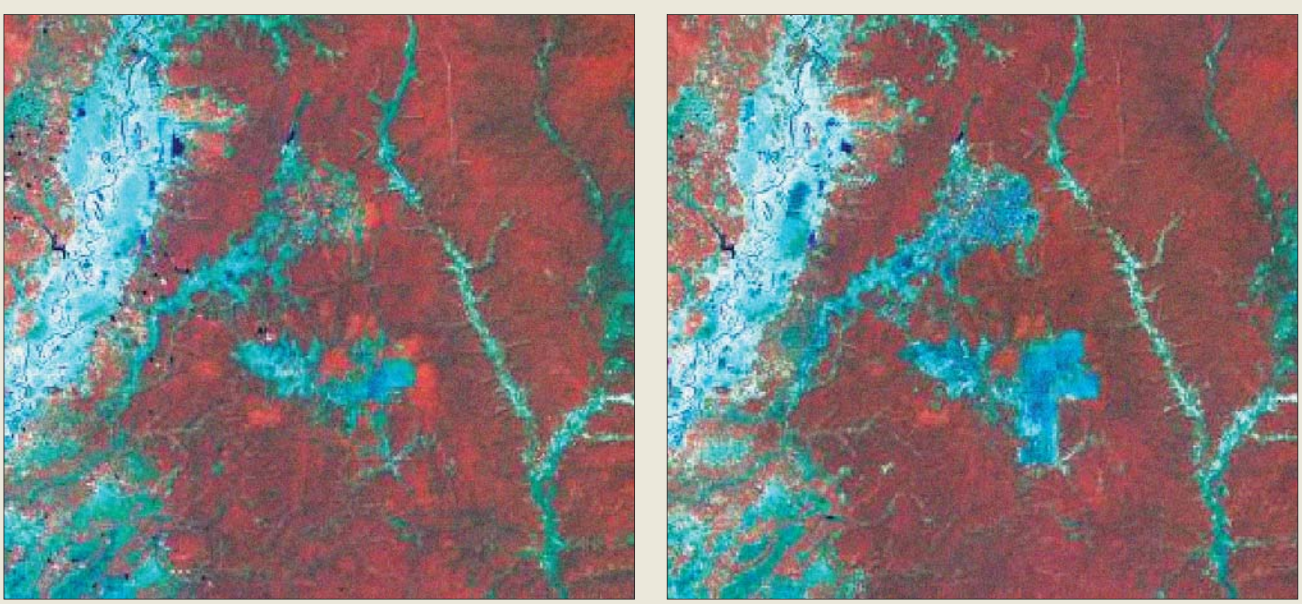
Earth observation data including satellite, aerial and ground data have an extensive history of use to characterize and monitor marine, coastal, freshwater and terrestrial environments. Rapid assessments are undertaken for a whole host of reasons, including protected areas system design and gap analyses, protected areas assessments, threat assessments, management planning, and biological and ecological inventories.

Such assessments are conducted across the entire array of the Earth's ecosystems including marine parks and corals reefs, coastal zones, wetland and forests. Rapid assessments are undertaken when there is a need to quickly obtain information on biological, ecological and environmental status over large areas, and where there are constraints on resources or access issues such as harsh or dangerous terrain.

Rapid assessments take advantage of the synoptic view that satellites provide, in addition to other geospatial data such as soils, geology and terrain data (often satellite-derived as well). They often use aerial data such as photography and videography, and collect field data to understand the relationship between what is observed from space and the air, to actual ground conditions. The field data are also used to 'teach' or 'train' computer pattern recognition algorithms to recognize different types of vegetation. The pattern recognition software can be quite straightforward, involving just a satellite image interpreter that uses colour, tone, pattern and texture to distinguish between different features of the landscape, while others use sophisticated decision tree and neural network algorithms that are designed to function as the human mind does.

In this sense, rapid assessments incorporate many of the aspects of GEO: they require satellite data for synoptic views of the landscape, they use intermediate aerial and high-resolution satellite image data, they integrate remote sensing and other geospatial data, and they employ field data collection to understand the satellite and aerial data. The data that are used include soils, geology, digital terrain, climate and hydrology. There is a

Landsat Thematic Mapper Data 2002 (left) and 2004 (right)



The data enabled the researchers to map the extent and condition of the groundwater swamp forests of the Prey Long region, as well as its alteration over time

Source: Landsat satellite data, courtesy US Geological Survey significant investment in assembling these datasets so that they may be used in tandem to predict vegetation and ecosystems occurrences, and processes. Rapid assessments also require technological capacity and integration of many types of data.

Rapid assessments also require that biologists and ecologists conduct a complete review of the literature on the site's biology and ecology. This enables them to understand what vegetation and ecosystem types have been described and studied. It is also necessary for them to develop a working, mappable classification system that covers all vegetation, ecosystem and land cover classes.

Photo: Douglas Muchoney

The Global Positioning System coordinates and aerial photographs were used to guide the field team to the location of specific patches of forest, and even individual trees

Photo: Eva Galabru

While Landsat data are generally acceptable for mapping forests, in this case they could not be used to locate the sparse palm trees indicative of the wetland forests. These were readily detectable in aerial photographs

An example of a rapid assessment is a recent scientific investigation to map a globally significant occurrence of a freshwater/groundwater inland lowland swamp forest in the Kompong Thom, Kratie, Stung Treng and Preah Vihear Provinces west of the Mekong River in Cambodia. There is scant description of this type of forest, being mentioned previously only by Béjaud in 1932 (translated from the French):

"On sandy humic soils in the places constantly moist, which Cambodians call *Chom* (literally source or spring) develops a shrubby vegetation dominated by the rattans *Phdau Som*, the *Prinh Kantuoy Chke, Chom*.

"In certain ponds that never completely dry, one finds the *Smach Chanluos* of the rear mangrove. They do not reach the large dimensions as when in their real habitat; even sometimes their growth remains shrubby. Cambodians then call them *Smach Tachak*. On other areas occurs a corky plant *Chamrong Pras Ream*."

Expert opinion concurs that Prey Long represents a globally, regionally and locally significant occurrence of this previously unidentified swamp forest. The Prey Long forest, however, is under increasing pressure from logging. Conversion and selective logging have an impact not only on the ecological integrity of the forest and the services that they provide in terms of water and soil conservation; it also impacts the livelihood of the local peoples who make their living from sustainable use of the forest resources, especially from resin tapping. The GEO ten-year plan calls specifically for the continuity of high-resolution imagery for monitoring logging concessions in areas with high biodiversity concentrations, as well as for biodiversity conservation and ecosystem protection.

The objective of this study was to perform a systematic, rapid assessment of the groundwater swamp forests of the Prey Long region, to map their extent and condition and to detect changes in forest cover due to land conversion. Landsat Thematic Mapper data were obtained for 2002 and 2004, and used to detect changes in forest cover. Systematic flight lines were laid out, and the aerial survey collected digital colour photographs of the study area. While Landsat data are generally acceptable for mapping forests, in this case they could not be used to locate the sparse palm trees indicative of the wetland forests. These were readily detectable in the aerial photographs. Global Positioning System coordinates that were collected simultaneously with the aerial photographs were used to guide the field team to the location of specific patches of forest, and even individual trees.

In conclusion, rapid assessments take advantage of current and historic satellite data because of their synoptic cover, and spatial and spectral resolution. Aerial data provide the intermediate resolution between the satellite perspective and the field observation needed to understand the vegetation condition. It is therefore an invaluable tool for biologists and resource managers.

Monitoring land degradation with long-term satellite data in South Africa

Konrad Wessels, Remote Sensing Research Unit, Meraka Institute and Department of Geography, University of Maryland, and Stephen Prince, Department of Geography, University of Maryland

Desertification is defined by the United Nations Convention to Combat Desertification (UNCCD) as 'land degradation in arid, semi-arid and dry sub-humid areas (drylands) resulting from various factors, including climatic variations and human activities.'[1] Degradation includes diverse processes from changes in plant species composition to soil erosion that result in reduced biological or economic productivity of the land. Land degradation affects food security, national economic development and natural resource conservation strategies. Desertification refers specifically to degradation in drylands and it is widely considered to be one of the most destructive environmental processes of our time affecting an estimated 250 million people.

Photo: K Wessels

South Africa's former homelands, now communal areas, show the effects of overgrazing, soil erosion and unplanned rural settlement

One hundred and eighty-four nations are signatories to the United Nations Convention to Combat Desertification (UNCCD), but there is little information on the distribution and severity of desertification beyond local scale studies; reliable and consistent country to continental scale data are entirely lacking. Most global or regional maps of land degradation constitute subjective expert opinions and cannot be used to systematically track degradation through time and space. There is an urgent need for standardized, quantitative and spatially-explicit measures of ecosystem functions to map and monitor land degradation. GEOSS has thus committed to delivering sustained observations of the earth system in order to combat desertification.

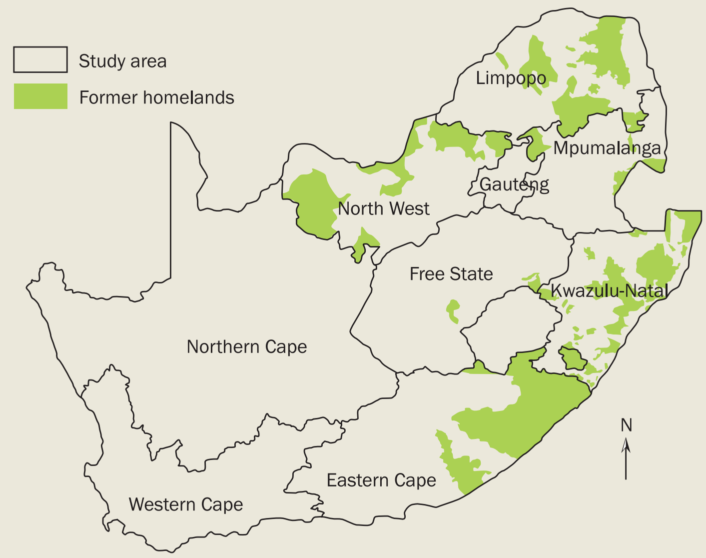
The UN Food and Agriculture Organization's (FAO) Global Land Degradation Assessment in Drylands (GLADA) programme is coordinating an effort to assess land degradation in drylands at the country and global scales. The GEOSS ten-year implementation plan has identified the completion of GLADA as a priority in the context of the agriculture societal benefit area. South Africa (SA) has been chosen by GLADA as one of six pilot countries where land assessment technologies will be developed and evaluated for future implementation in all participating countries. The SA National Department of Agriculture (DoA) is coordinating the current SA LADA process owing to its long record of research on this topic. This chapter summarises some major findings of the research and highlights the importance of long-term Earth observation data as advocated by GEOSS.

Monitoring land degradation with satellite data

Long-term, coarse resolution satellite data have been widely used to monitor vegetation dynamics and detect land degradation.[2] Vegetation production is routinely estimated with the normalized difference vegetation index (NDVI) derived from satellite data. NDVI captures the marked contrast between the strong absorption of solar radiation in the visible and strong reflectance in the near-infrared wavelengths that is characteristic of live, green vegetation. NDVI provides an estimate of the energy used by plants for photosynthesis. Remotely sensed vegetation production may very well be the single most useful indicator of land degradation at regional and decadal scales.[3]

In the early 1990s NDVI data from the Advanced Very High Resolution Radiometer (AVHRR) sensor on the NOAA series of meteorological satellites were analysed and showed that the Sahara desert was not marching southwards into the Sahel, but rather expanded and contracted as a result of interannual variations in rainfall.[4] Recently, a number of studies using 20 years of AVHRR NDVI data have shown that the Sahel, which was once believed to be suffering severe desertification, has in fact become greener during the past ten years as a result of higher rainfall.[5] The occurrence of desertification in the Sahel and elsewhere has become highly controversial, but the debate is being conducted in the absence of objective, consistent data at the appropriate scales. While repetitive, global remote sensing has been applied to mapping and monitoring degradation, interpretation of the results has not always been based on sound ecological principles. A critical aspect of a useful degradation mapping and monitoring system is the ability to distinguish the impacts of human activities from natural variability in climate and spatial variations in soils and land cover types.

Former homelands, provinces and study area in South Africa



Large degraded areas have been found in South Africa's former homelands

Source: K Wessels

Land degradation in the former homelands of South Africa

In South Africa, large degraded areas have been found within the former 'homelands' — self-governing areas created before and during the Apartheid era.[6] Today these homelands, now called communal areas, are characterized by high human and livestock populations, overgrazing, soil erosion and sparse grass cover. Degradation continues to threaten the local resource base upon which rural communal livelihoods depend. The underlying cause of degradation is a combination of unemployment, poverty and an absence or failure of land use regulation. The degradation observed in the communal lands is thus principally a consequence of high population densities caused by the oppressive apartheid system rather than the outcome of traditional communal pasturalism.

These degraded rangelands have been subjectively mapped using single date Landsat images as part of the National Land Cover (NLC) map. The vast majority of the large degraded areas fall within the communal areas. We investigated the long-term vegetation production of these degraded areas with 18 years of 1km² resolution AVHRR NDVI data by comparing them to non-degraded adjacent areas with the same soils and climate. It was found that the non-degraded areas had consistently higher vegetation production as indicated by the seasonal total of NDVI obtained from satellite observations despite a six-fold variation of annual rainfall. This indicates that the degraded areas produce less vegetation per unit of rainfall and suggests that they may have changed to a different ecological state. The results nevertheless indicate that these degraded areas are functionally stable and resilient, but never reach the same vegetation productivity as the neighbouring non-degraded areas.[7] These results are both alarming and encouraging: alarming because the degraded state seems to be permanent; and encouraging because the difference in productivity was approximately 20 per cent, far from a complete loss of production as is sometimes suggested in degraded areas. Whether the difference in total rangeland production translates into economic loss remains to be determined. These results have made a significant contribution to understanding the ecological processes in degraded areas — research that would not have been possible without a long-term, regional satellite data archive.

Distinguishing human-induced degradation from drought

In arid and semi-arid regions vegetation production varies between years caused primarily by inter-annual rainfall variability. Southern Africa suffers periodic droughts, some caused by the El Niño phase of the El Niño-Southern Oscillation (ENSO) cycle. Extreme variability in vegetation production between years makes it exceedingly difficult to distinguish long-term changes caused by human-induced land degradation from the effects of periodic droughts. One approach to monitoring land degradation is to use both long-term AVHRR NDVI data and rainfall surfaces to identify any negative trends in vegetation production per unit rainfall through time (1985—2003).[8]

In the Limpopo Province negative trends were largely associated with the degraded communal lands, although some well-known degraded areas did not show continued negative trends during the study period (1985—2003). A distinction should be made between degradation that occurred within or before the start of the satellite time-series; some homelands were created as early as 1913 so much of the degradation could have occurred before and may not have worsened since. The results of this analysis in northern SA are validated by the National Report on Land Degradation,[9] which shows the perceived rates of change in rangeland condition over a ten-year period (1989—1999), as judged by local experts.

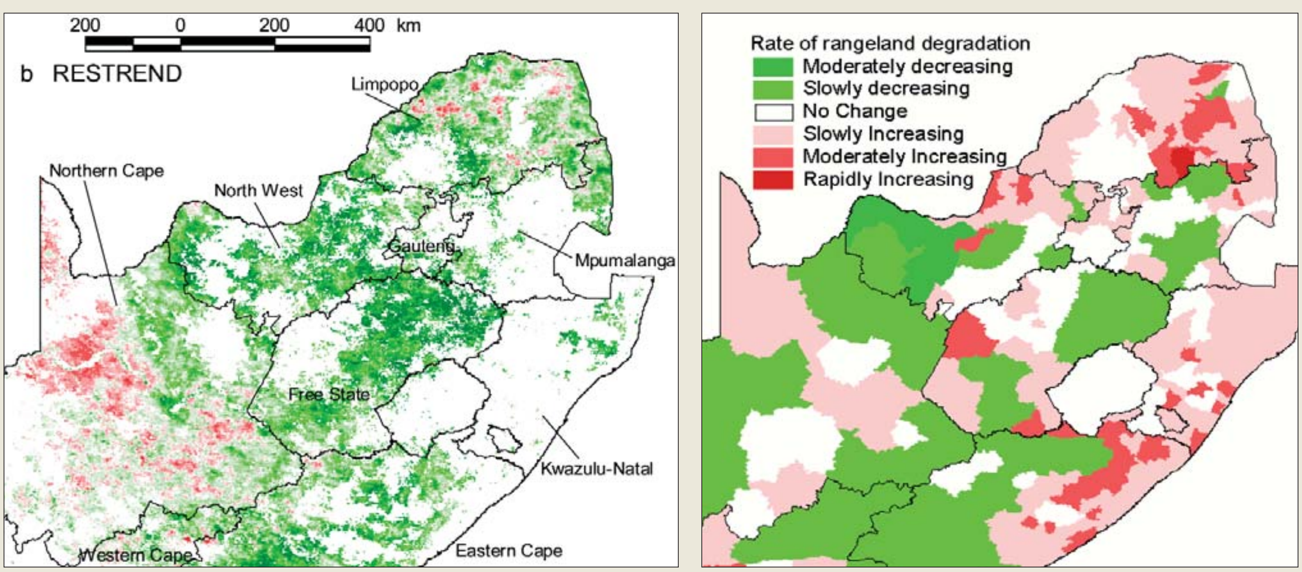
Besides land degradation, other forms of land cover and land use change (e.g. expanding subsistence agriculture or informal settlements) as well as natural processes can also cause a reduction in production per unit of rainfall. The present method should thus be used as a regional indicator to identify potential problem areas that can then be investigated in greater detail, using high-resolution remote sensing data and field data. It is unlikely that any method that depends exclusively on remote sensing from a single sensor will be able to unequivocally map the complex ecological process of degradation. Maps depicting the trends in vegetation production per unit of rainfall, as shown here, require field verification before management and policy decisions can be based on them. The Department of Agriculture is therefore actively involved in the verification process. In contrast to previous maps of land degradation in SA that were mainly based on expert opinions, the remote sensing approach is objective and repeatable, and all indications are that it will furnish a valuable regional monitoring tool.

The long-term, high temporal resolution, satellite data that are being promoted by GEOSS are indispensable, and significant efforts are in progress to improve the quality of the data. The AVHRR instruments were never intended for the uses to which they are now put and the quality of the data, while appropriate for the original application in weather forecasting, are not optimal for remote sensing of vegetation. Newer sensors such as MODIS are now in service, but these are experimental systems, not intended for long-term operational observations. Thus the role of GEOSS in encouraging long-term data collection is very important in the context of mapping and monitoring desertification.

Photo: K Wessels

Degradation continues to threaten the local resource base upon which rural communal livelihoods depend

Trends in vegetation production per unit of rainfall



Left: Temporal trends in vegetation production per unit of rainfall in the summer rainfall region of South Africa (red — negative, green — positive) derived with NOAA AVHRR data from 1985 to 2003. Right: The rate of rangeland degradation as judged by experts (after Hoffman et al. 1999). The two maps agree in many parts of the region. Note the high spatial resolution of the satellite observations

Source: K Wessels

The business of capacity-development

Ehrlich Desa, Joannes Berque, Mika Odido and Stefano Mazzilli, UNESCO/IOC; Geoff Holland, 2WE Associates Consulting, Canada; Antonio Hoguane, School of Marine and Coastal Sciences, Eduardo Mondlane University, Mozambique; Venu Ittekkot, Center for Tropical Marine Ecology, Leibniz Institute, University of Bremen, Germany; Shailesh Nayak, Indian National Center for Ocean Information Services; Ayobami Salami, Space Applications and Environmental Science Laboratory, Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Nigeria; Paco Ocampo Torres, Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Mexico

Understanding the ocean's role in the earth system has increased in importance in recent times as we have come to realize the effect that humankind is having on the planet's climate system. Considering the ocean's size, variability and inaccessibility it is obvious that the task of monitoring and understanding the coastal and open ocean cannot be carried out only by the capable few. All coastal states must be involved in this global activity because even with GEOSS fully functional, local capabilities must still validate products and downscale them for the benefit of local communities.[1] To achieve sustainable benefits, this process must be self-driven — the institute in the developing world must drive the cooperation with its foreign partners.

Lessons from decades of scientific cooperation

Capacity-development (CD) interventions therefore have good reason to be included in all major international programmes. Yet after many decades of such efforts we are not developing capacity fast enough to address the increasing challenges from a rapidly degrading environment. In fact, developing nations are no better off in their capacities to address their own responsibilities and benefits today than five decades ago, because CD has not kept pace with an accelerating environmental degradation.

Climate change will make the world a poorer place and the hardest hit will be Africa and the developing countries,[2] and in response, capacity-development will receive greater attention and resources. Many excellent donor-funded projects in developing regions contribute to capacity-development. However, many others unwittingly have had just the opposite effect.

The differences between working and non-working projects are many, though two important ones need mention. Firstly, local scientists must be involved with externally funded projects from the time of formulation if national priorities are to be met. If this does not happen, local scientists may go to work on 'attractive' externally funded projects, thus neglecting core national priorities. Secondly, donor haste to develop capacity usually targets short-term research projects with apparent tangible achievements, and pay almost no attention to the longer-term programme of developing scientific infrastructure and science education.[3]

Photo: School of Marine and Coastal Sciences, Universidade Eduardo Mondlane

The school teaches degree courses in applied oceanography and marine biology, conducts applied research and implements projects for sustainable use of natural resources

What is the suggested approach?

In principle, capacity-development needs to target national priorities to ensure a greater level of ownership and consequently sustainability of project outcomes. National institutes, with the mandate of addressing national priorities, rather than individual scientists or NGOs, are the best partners to ensure sustainability in defining and planning projects. The capacity-development approaches of many organizations now follow these principles.[4 5 6]

The Intergovernmental Oceanographic Commission of UNESCO (IOC) implements this principle by harnessing the 'self-drive' of institutes. IOC examples from different regions illustrate this approach. Similarly, there are excellent examples of planning and implementing innovative research programmes in developing regions through collaborative research from a research institute in a sponsor's country.

IOC addresses marine science institutes at the level of directors, project leaders and scientists. This constitutes the first phase. Institutes, key players in utilizing earth observations to solve societal problems, are also critical links in developing capacity in a nation, as they link naturally to decision-makers and communities. Strengthening these linkages in the second phase of the CD programme meets the IOC vision of institutes within a region exchanging best practices for safe and sustainable uses of the ocean.

Implementation is through a series of interlinked workshops that aim at advancing skills in leadership for directors, in proposal writing for project leaders, and in team working for scientists. Empowering those who have a vision for their institutes, with tools to improve their own and their institutes' performance and to challenge business-as-usual functioning, is what the workshops set out to achieve.

Besides this, the workshops also transfer the skills to write proposals in a business-like manner, and numerical tools to supplement the lack of expensive infrastructure. These skills will enable institutes to understand, model, visualize local coastal processes and ecosystems, and bid for coastal management consultancies. This is a way for institutes to earn their own capacity-development funds. Collaboration with the social and human sciences is the third phase of the CD programme, where modelling is used as the crucial link between earth observation and societal benefits.

Implementing IOC capacity-development programme

The IOC self-driven capacity-development programme is less than two years old. In this time, thanks to a grant from the Swedish International Development Cooperation Agency (Sida), IOC has engaged with the directors and senior scientists of over 100 institutes in more than 75 countries in the Caribbean, Latin American, East and West African, Indian Ocean, and SE Asian regions. The programme consists of a series of workshops that strengthen institutes by addressing the leadership, proposal writing, and team building skills of directors and their scientists. Coastal modelling using available operational products to create special products for the region also forms an important part of the implementation.

East Africa, where the programme started in Maputo, Mozambique, has achieved the greatest progress amongst the regions. Numerical modelling efforts that use available operational data products are boosting research and consultancy capabilities.[7], [8] Post-graduate education is also progressing well under programmes initiated within and for the region. IOC works as a catalyst in these efforts using its academic contacts and university chairs to promote a network of north-south chairs. These chairs exchange best practices and catalyze long-term education and research programmes required to ensure sustainability of modelling and operational efforts.

Many positive results are already visible in East Africa and have helped the IOC-CD effort to demonstrate special progress there. The three most notable examples being the long-term commitments of Sida to support marine science research through competitive funding; active political support to the general philosophy of self-help;[9] and a history of regional collaboration. The process is showing a similar trend in Latin America and West Africa.

Many such role models exist. Examples in education, research, and use and promotion of operational products follow.

Self-drive in education

In 2006, the Eduardo Mondlane University established a School of Marine and Coastal Sciences at Quelimane, Mozambique. The effort was in response to the University Strategic Plan that envisages curricula development, establishing new courses in emerging areas of major economic and social importance, and expanding the University throughout the country. Furthermore, the establishment of the school is an appropriate response to the long-term trend of increased emphasis on oceans, coasts and associated resources.

The school's main mission is professional teaching of degree courses in applied oceanography and marine biology, conduct of applied research, and implementation of projects for sustainable use of natural resources. Courses in marine chemistry and marine geology will be added shortly. The UNESCO chair in marine sciences and oceanography formed a British Council Academic Link with the University of Bangor in 1997 which contributed directly to the establishment of the school. The school opened with 40 students and seven lecturers in February 2006, and now has 80 students and 11 full time lectures on its rolls.

Partnering the self-drive in research

Research from the Centre for Tropical Marine Ecology (ZMT), Leibniz Institute, University of Bremen, Germany, addresses ecological and socio-economic issues related exclusively to tropical coastal ecosystems, their resources and their vulnerability to natural and human perturbations. Research institutions and universities in the tropics are the ZMT's long-term partners in projects that develop capacity and infrastructure building.

Long-term projects are on going in South and Central America, Africa and Southeast Asia. These projects typically develop after joint surveys of research and capacity building needs through conferences and workshops, as well as through direct information exchange among partners. Issues identified in this way often become the basis for long-term (five to ten year) projects funded by agencies in both countries.

These long-term projects are used as a platform for developing the capacity of young students and researchers, both on- and off the field. The research-based training programmes are supported through international Masters and PhD courses offered jointly by ZMT and the University of Bremen. Further support to the research programmes comes through summer schools and training workshops in cooperation with regional and international organizations. The excellent track record of this long-standing programme has produced young scientists who are now leading national efforts that aim to meet country needs in the long-term.

Developing operational satellite data products for community benefits

The Indian National Centre for Ocean Information Services (INCOIS), in an effort to support the communities of small trawler owners, has been generating Potential Fishing Zone (PFZ) advisories, which use satellite-based sea surface temperature and chlorophyll maps to identify features such as upwelling, eddies, fronts, and meanders. The coincidence of frontal zone positions of chlorophyll and SST gradients indicate coupling of biological and physical processes and potential fish aggregation sites. These identified features are used to generate PFZ maps and PFZ text that give those with access to GPS systems information on latitude, longitude and depth of PFZs.

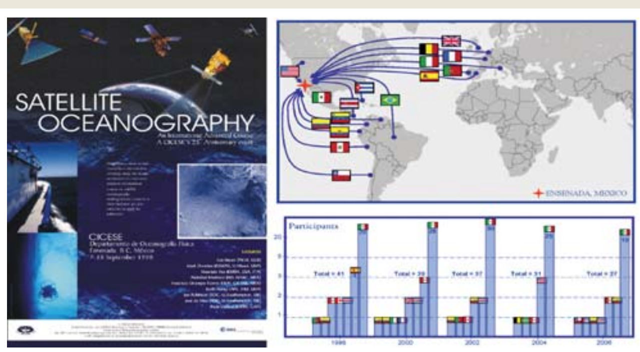
Considering that the majority of users are traditional fishers, information on angle, direction and distance from landing centres/light houses are also provided. PFZ advisories are prepared in many languages and disseminated through a variety of media formats. Results show that PFZ advisories have reduced search times between 30 to 70 per cent, improving the benefit to cost ratio from about 1.3 to over 2.0. Twenty-seven per cent of trawler owners (about 27,000) use the facility. Future plans include integration of currents to increase the validity of the forecast and closer liaison with the Department of Fisheries to monitor the effect of increased catches on fish stocks.

Training in the use of operational satellite products

In September 2003, Nigeria successfully launched NigeriaSat-1. This marked an important step in using satellite remote sensing for coastal management in the country, and of utilizing space-acquired information for management and research. The critical mass of capacity to maximise benefits from NigeriaSat-1 has suffered severe attrition through lowered funding support, resulting in a shift away from this field. Against this background the National Space Research and Development Agency (NASRDA) and the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, signed a memorandum of understanding for capacity building in remote sensing and GIS in 2006.

Many 'train-the-trainer' initiatives have been conducted to catalyze a large home-grown manpower development programme in the country, culminating in the commencement of a series of regular regional capacity building workshops. The first such, held in collaboration with the African Regional Centre for Space Science and Technology Education and supported by UN Office for Outer Space Affairs, was on Capacity Building on Use of Landsat Data Sets for Sustainable Management in Africa. The government's programme to use space-acquired information is supported by a self-driven effort in this regard.

The Satellite Oceanography course



The use of such devices marks an important step in using satellite remote sensing for coastal management, and of utilizing space-acquired information for management and research

Source: CICESE Wave Group

Nurturing a world-class training course

Scientists from the Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (CICESE) recognized that directing the capacity to train students from developing nations in satellite and in situ data analysis and applications leads to wider and better use of Earth observation data sets. As a result they established a successful satellite oceanography course that has run every second year since 1998. Internationally recognized faculty and researchers have participated in this course each time it was offered. The satellite oceanography course has been mainly supported by the European Space Agency (ESA), while some financial aid has also been received from other international and national offices. CICESE will host the sixth edition of a three-week intensive course in satellite oceanography in August 2008.

Through the course, students and young professionals learn to utilize satellite data for applications relevant for ocean monitoring. The course is now highly regarded and its strong foundations, based on lecturers of the highest academic standards, are widely appreciated. One could argue that it provides an example for capacity building strategy that international agencies could follow for other areas in Latin America and the Caribbean. However, it is important to remember that few institutions in the developing world have a sufficient number of experts to delve as deeply as the CICESE satellite oceanography course, which covers practically all ocean observation and sensor types.

The way to sustainability

The capacity-development process promises to be a lengthily one, but done correctly it could be our only chance to achieve true sustainability. Many examples show that in spite of poor resources, determination at the policy-makers level can always drive the agenda. In these cases, capacity-development is self-driven and sustainable. However, the question of poor infrastructure remains. It is in this area that sponsors can make the greatest contributions in collaboration with recipient countries.

It is clear that there are two primary phases that emerge in sustainable capacity-development. The first is in establishing firm foundations in marine sciences and the competencies to address national priorities. Once these are established scientists from the developing world are in a better position to create the products that their governments need. It will be at this time when they can collaborate as peers in regional implementation of global programmes. Only then will GEOSS become a globally shared and globally beneficial Observational System of Systems.

Global agriculture in the 21st century: sustainable production of food, fibre, fuel and more

Ghassem R. Asrar, PhD, Deputy Administrator, Agricultural Research Service, United States Department of Agriculture

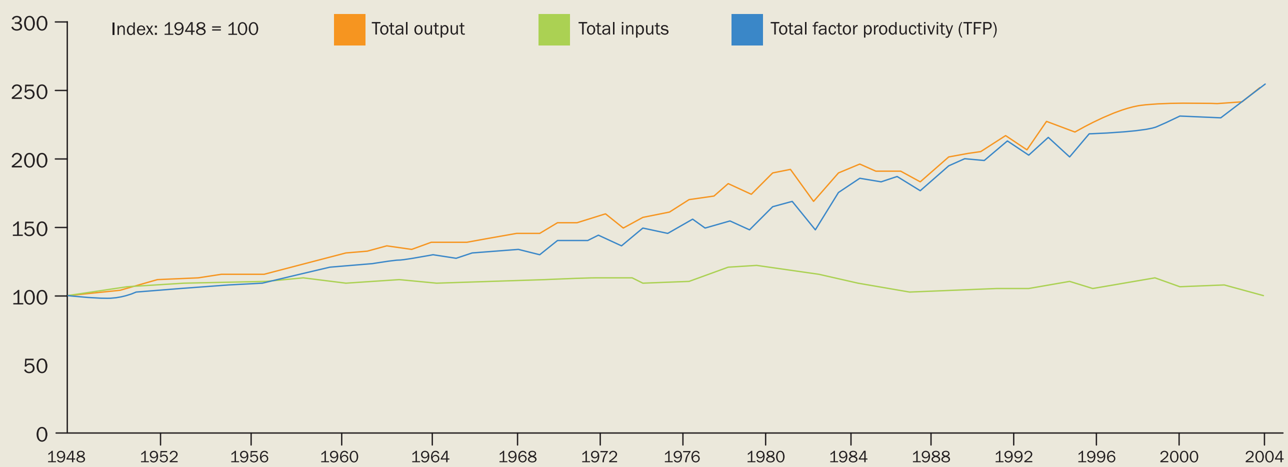
Agriculture is assuming an increasingly important role in today's global economy. In addition to its traditional role as a producer of food, feed, and fibre, agriculture is now expected to provide bio-based energy for a growing population, and to do so sustainably.

In the past, scientific discoveries and technological innovations were instrumental in meeting the world's increasing demands for food, fibre, feed and water. They are now even more vital if agriculture is to also provide bio-based energy while maintaining/enhancing Earth's renewable resources. Throughout the history of modern agriculture, technological innovations have resulted in significant increases in food, feed and fibre production globally, while the total amount of water and energy used to achieve this growth stayed the same or decreased significantly in many parts of the world. Advances in plant breeding, water management, conservation tillage practices and weather prediction contributed to this tremendous achievement. The question now whether we can sustain or enhance this pace of innovation to meet the growing demand for food, fibre, water and renewable energy from agricultural ecosystems for future generations while we maintain the quality and integrity of these ecosystems and the environment.

During the past 300 years, the transition from natural ecosystems into agriculturally used and managed ecosystems has accelerated, especially since the 1950s. More land was converted to cropland in the first few years after 1950 than during the 150-year period of 1700—1850. The world population also grew from 2.5 billion to 6.5 billion during 1950—2005, a factor of 2.6. The world agricultural output grew by a factor of 5, keeping pace with population growth.

Since 1950, agricultural output has been growing at about two per cent per year, with higher rates in devel-

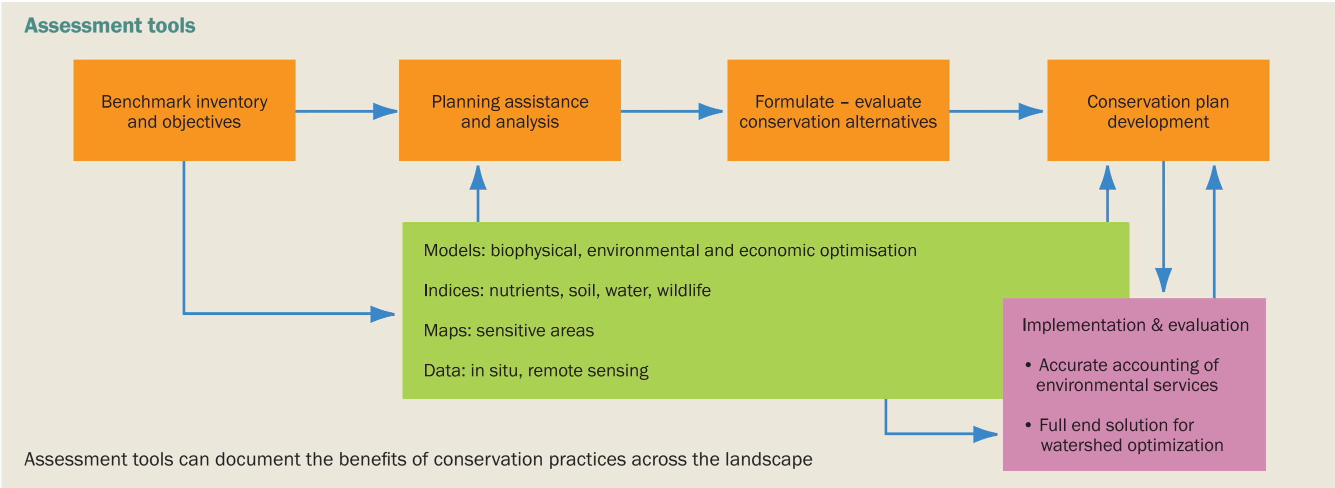
Changes in US agricultural output, inputs and total factor productivity[1] since 1948



[1] Total factor productivity measures total output per total inputs, or the overall efficiency of agricultural production

Technological innovations have resulted in significant increases in food, feed and fibre production globally, while the total amount of water and energy used to achieve this has stayed the same or decreased

Source: Fuglie, Keith O., James M. MacDonald, and Eldon Ball. Productivity Growth in US Agriculture. EB-9, US Dept. of Agriculture, Econ. Res. Serv. September 2007



Source: Ghassem Asrar

oping countries. For example, world cereal production has doubled since 1961, with average yields per hectare increasing around 150 per cent in many high and low-income countries. Despite this great progress, there are about a billion people in the world who suffer from hunger and malnutrition. The projected increase in global population, urbanization and changing lifestyles will continue to exert pressure on natural, agricultural and other managed ecosystems to provide necessary goods and services for the rest of this century.

Challenges facing global agriculture

Agriculture faces many challenges and opportunities in the 21st century, as it has since the beginning of modern agriculture. Today, global agriculture is a complex system that can be described on the basis of biophysical, economic and socio-cultural parameters. All three parameters will have to be considered in responding to 21st century demands. For the rest of this century, agriculture needs to:

- Ensure food security for an increasing global population
- Increase agricultural productivity and its efficiency while sustaining the natural resources base
- Adapt to and/or mitigate the impacts of weather and climate changes
- Accommodate the growing demands for water and energy
- Respond to an evolving global market.

Agriculture is an energy intensive sector of the global economy. Changes in energy types, availability and prices will have a significant impact on food production, processing and distribution. The growing reliance on fossil fuels for farming operations as well as fertilizers and chemicals has increased greenhouse gas emissions, notably CO_2, CH_4 and Nitrogen oxides. This trend is contributing to global and local environmental changes with negative consequences to agriculture itself, thus eroding the natural foundation upon which it depends.

Both global and local policies and decisions continue to influence agricultural development. At the global level major factors such as markets and policies, international trade, and public-sector investments in agricultural research play an important role. At the local and regional level, social and cultural issues, and grassroots solutions to everyday challenges are major factors.

Some factors, such as weather and climate variability and change, are not only important at the local and regional level but also globally. This is especially true with regard to rainfall and water availability. The continued expansion of irrigation and associated water withdrawal for improved agricultural production will continue for the rest of this century. This will further exacerbate the competition between municipal, industrial, agricultural and environmental requirements for fresh water resources. The impacts of these factors on agriculture production vary greatly by region, thus requiring the development of regionally-specific agricultural strategies.

For agriculture to meet these challenges, it requires information and knowledge about ecological, economic, social and cultural aspects of agricultural production, and better-informed citizens and decision makers. These challenges, combined with growing demand for food, feed, fibre and fuel, will result in major shifts in the distribution of natural and managed ecosystems for the rest of this century. They require, in turn, sustained observation and greater scientific and technological innovations to meet the growing demand from agricultural ecosystems.

Opportunities in global agriculture

There are many opportunities to apply science and technology to meet the challenges global agriculture faces. Integrated natural resources management practices such as nutrient, pest and water management together with crop rotations and conservation tillage practices have enabled enhanced production of goods and services from agricultural ecosystems, while preserving their integrity and function.

Advances in biotechnology (i.e. genomics, genetics, and proteomics), nanotechnology, geospatial, and information and telecommunication technologies will continue to enable us to meet these challenges. These include advances in the biotechnologies of genomic, proteomic and new breeding techniques; enhanced agricultural production and efficiency; whole-farm management systems aimed at multifunctional purposes delivering ecosystem services (including food, feed, fibre, biofuels, wildlife habitat, environmental services etc.) while preserving the integrity of these ecosystems; energy conservation and efficiency practices to reduce agricultural dependence on fossil fuel-based technologies, and managing the risks associated with biotic and abiotic factors (e.g. droughts, floods, pests, invasive species etc). However, the impact of these technologies will differ from region to region because of the financial constraints and the rate of the adoption of new technologies by producers and other land managers.

The Global Earth Observing System of Systems (GEOSS) is one promising technology which could help meet the information needs of global agriculture at the local, regional and global level. The GEOSS can monitor and assess the condition of agricultural ecosystems and manage them for optimum use of inputs (water, nutrients, chemicals) and maximum output (yields, environmental services, wild life habitat, biofuels, etc). It can provide advance warning of weather and climate-related events to minimize their impact and manage their risks for avoiding loss of services. It can conduct observations for scientific explorations and technological innovations by researchers around the world, and provide necessary information and knowledge for agricultural managers and policy makers to make timely decisions and/or establish sound agricultural policies. In addition, the GEOSS can provide early warning and assessments for combatting natural disaster affecting agriculture and rural regions, and food aid programmes.

Future prospects

While new technologies can help overcome many of the challenges our food and agricultural system faces, there are fundamental uncertainties associated with the role of agriculture in the 21st century global economy which will impact our quality of life. These uncertainties include, but are not limited to the extent of biofuels and bio-based product development and the factors influencing their use; the ability to manage the risks associated with weather and climate, and mitigate their impact and/or adapt to them; implementation of sustainable development principles to allow multi-use of agro-ecosystems while maintaining their integrity and quality; population migration, capacity building, training and education, and the scientific and technical cooperation and coordination between developed and developing nations.

Agricultural research and innovations together with 21st century technologies are needed to satisfy immediate needs of growing population while maintaining long-term sustainability of agro-ecosystems; to effectively manage the risks associated with environmental changes, mitigate their impacts on agro-ecosystems and/or adapt to them; to satisfy consumer demands by providing safe, affordable and adequate food, feed, fuels and other services from agro-ecosystems, and to promote a balanced approach between 'global' versus 'local' agricultural development to reduce the disparity between developed and developing countries. Ultimately, it will take a concerted effort by scientists, agricultural producers and policy makers everywhere to overcome agriculture's grand challenge for the 21st century — the sustainable production of food, fibre, fuel and more for the entire world.

Food distribution and nutritional needs

* For the transition countries: 1993–95

Agricultural output has grown at about two per cent per year since 1950, but about a billion people in the world still suffer from hunger and malnutrition

Source: FAO

Sustainable agriculture and Earth observation

Glenn R. Bethel, US Department of Agriculture and Gregory L. Stensaas, US Geological Survey

Production of food and fibre, as well as the maintenance and restoration of soil and water resources are vital to human welfare. Increasing population is creating greater demand for resources, generating more waste, and is consequently straining the capacity of the environment to support human activity. High consumption and industrialization, disparity of distribution patterns of wealth and land, conflicting politics, poverty, and inefficient technology interact with population growth to further tax the ability of natural resources, agriculture and forestry practices. Sustainable land use and the prevention of land degradation have become domestic and international priorities. The Group on Earth Observations (GEO) is committed to supporting sustainable agriculture efforts including the economic, environmental, and social sustainability of diverse food, fibre, agriculture, forest, and range systems.

Remote sensing essentially comprises drawing on satellite data and aerial photography to complement field measurements and other data collection sources. It has the potential to provide continual feedback on within-season production progress for remedial actions when factors limiting production such as pests, water, nutrient deficiency, or drought intervene. The same information can support governmental activities, such as managing public lands, monitoring for compliance with land use agreements and resource conservation legislation, as well as detecting signs of bioterrorism.

Photo: Chris Reij and Gary Tappan, SAIC contractor to USGS

Poor production on a farm in Africa due to crop sustainment shortages

This potential cannot be realised until we can consistently deliver credible products with the spatial, spectral, and temporal resolution required to support farm level decisions. National Aeronautics and Space Administration (NASA), the US Geological Survey (USGS), and the US Department of Agriculture (USDA) work with many international organizations and use remotely sensed data to provide objective, global, scientific information to support farm level decision-making.

Farm level information can aid in crop, water, and pest management. Meaningful agricultural monitoring requires the integration of multiple sources of spatial, spectral and temporal remotely sensed data with agro climatic data. These multiple data sources need to be well defined and integrated into the best possible decision support systems to meet the timely and accurate information requirements of farmers, commodity traders, and governments. If a GEO community could be formed to provide analysis based on current factual data for the developers of the decision support models, we could come closer to making accurate models and/or determining what new sensors are needed to optimize the decision support systems and better support societal needs.

Global land observation and agriculture sustainment

Global agricultural monitoring can improve food security, aid in agricultural management, and prevent hunger and starvation. Monitoring the actual changes in the earth's farm land and forests becomes more urgent as land transitions from agricultural and forestry. The analysis of global production is becoming more complex as crops for fuel compete with crops for food, feed, and seed. Shortages of fresh water resources for irrigation and increases in soil salinity and arid climates could further restrict the world's agricultural production.

It is within this context that global coverage of high resolution (30m, Landsat ETM+) satellite imagery for land monitoring and agriculture sustainability becomes so important. Agriculture assessment scientists use such

Landsat 5 MSS and Landsat 7 ETM+ images of agriculture development in Santa Cruz de la Sierra, Bolivia, 1975 - 2003

These two images show an area of tropical dry forest located east of Santa Cruz de la Sierra, Bolivia. They demonstrate information that is vital to the evaluation of sustainable agriculture, vulnerability to climate change, and the social and economic impacts of agriculture and land use change.

The image on the left, Landsat MSS from 1975 shows an undeveloped region. The image on the right, Landsat ETM+, shows the extent of agricultural development by 2003. Since the mid-1980s, the resettlement of people from the Altiplano (the Andean high plains) and a large agricultural development effort (the Tierras Baja project) has lead to this area's deforestation. The rectangular, light coloured areas are fields of soybeans cultivated for export, funded mostly by foreign loans. The dark strips running through the fields are windbreaks, which are designed to protect the fine soil from wind erosion

Source: United Nations Environment Programme and USGS Center for Earth Resources Observation and Science

images, along with other data sources, to develop timely, unbiased global crop production estimates. These images are derived from energy reflected off objects on the earth's surface and picked up and recorded by satellite sensors. Energy reflected off vegetation is distinct from that of other objects, and it is this that renders remote sensing so useful to agriculture. In their photosynthesis process, plants reflect an abnormally high amount of infrared energy. This gives vegetation a unique 'fingerprint' or signature that can be measured by sensors and formed into a picture or image.

In typical false colour images red signifies plant biomass, so that the more red that there is in the image, the more dense and healthy the vegetation. The green or gray areas represent dry or bare fields, which may or may not be planted with yet-emerged summer crops. Cultural features such as roads and towns are also visible and appear dark blue. Landsat allows a more thorough analysis, providing spatial detail and accuracy assessment impossible with lower resolution, meteorological satellites. Satellite imagery is one of many tools used by USDA's foreign agricultural service in its 'convergence of evidence' approach towards global crop monitoring.

Remote sensing and crop disasters

Producers can make all the right crop-related decisions, but a single disaster can nullify their whole investment. Unfortunately, crop related disasters and crop failures are far too common. Such events can have a massive impact on local food supplies and the local economy, the national food security and economies, and global food supplies. To help solve this difficult problem, proper remote sensing monitoring data, satellite, aerial, and in situ, are needed to develop and feed the models and decision support tools.

When performing analysis of agricultural disasters, it is extremely important to have imagery just before and just after the disaster occurs. Unlike assessing damage to structures, assessing damage to field crops is much more of a 'moving target'. Crops are harvested; one day corn is in the field, the next day it is on the way to the market. Meaningful change detection is extremely important in estimating losses and the market impact of disasters.

For example, on 15 July, 2007 a severe storm with hail and wind damage occurred affecting Cass County, North Dakota and its neighbouring counties. The NASA Moderate Resolution Imaging Satellite (MODIS) data subsets gave the initial view of the damage areas.

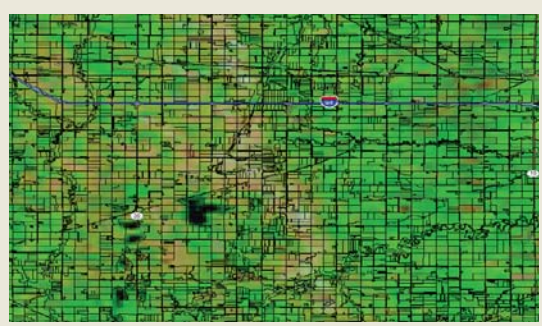
Imagery from NASA's MODIS sensor can provide twice daily coverage at 250m resolution. However, a 250m pixel is limited to gathering crop information for relatively rectangular fields larger than 25 hectares. Using two opportunities per day greatly increases, but does not guarantee, that cloud free imagery of the area of interest will be available every week.

The presence of clouds can be mitigated by creating composites using maximum Normalized Difference Vegetation Index (NDVI) values and cloud screening algorithms to filter out clouds. The SPOT-VEG NDVI product is created every ten days using composite imagery from the vegetation sensor onboard the SPOT-4 satellite.

After creating a time series of NDVI composites, products can be generated that compare the current ten-day composite from an average year, or compared to last year's image, thus establishing whether this year's crop is better or worse than last year. Care needs to be taken not to infer too much from this single data visualization without understanding cloud contamination and other weather factors.

There are many way to use remote sensing dataset to help quantify the environment impacts and support local and international agricultural sustainment programs. The key component is global, usable data, which would

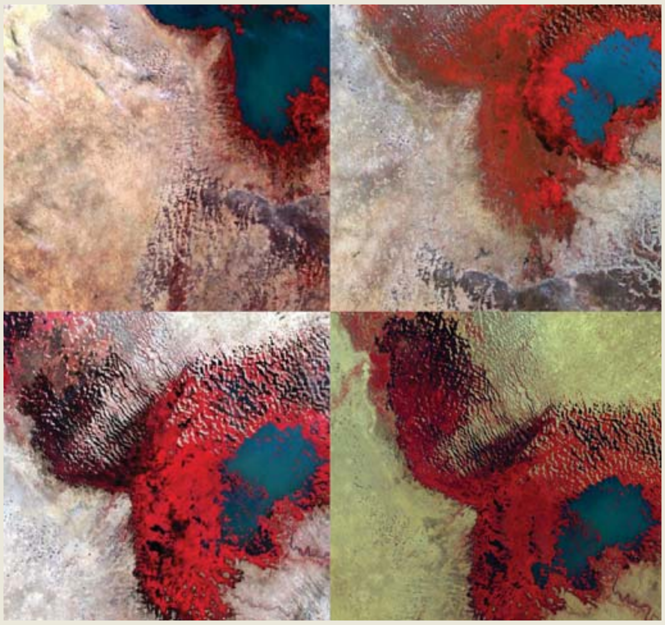
250 meter MODIS image of Cass,County ND



By overlaying additional data, such as, USDA Farm Service Agency Field Boundaries and road information, even a 250 meter MODIS image can be used to aid in the delineation of affected properties

Source: NASA and USDA Farm Service Agency

Lake Chad shrinkage



Landsat image clips - 8 December 1972 Landsat 1 image, 14 December 1987 Landsat 4 image, 18 December 2002 Landsat 7 image, and 8 February 2007 Landsat 7 image

Source: USGS Center for Earth Resources Observation and Science

derive huge support from the development of a standardized Global Earth Observation System of Systems (GEOSS).

Remote sensing water monitoring for sustainable agriculture

Water stored in reservoirs is vital for industry, agriculture and human consumption. Altimeter data is commonly used to monitor reservoir heights. Remote sensing satellite data is also useful for monitoring reservoirs and snow cover during the winter months. It can aid in the prediction of future reservoir levels and is used to visually monitor reservoir levels.

On the edge of the Sahara, the world's largest, driest desert, there lies a large freshwater lake called Lake Chad. It borders four countries in West Africa: Nigeria, Niger, Chad, and Cameroon. Lake Chad was once the sixth largest lake in the world (approximately 26,000 square kilometres in early 1960's), but persistent drought since the 1960s shrank it to about one tenth of its former size. Lake Chad was once the second largest wetland in Africa, highly productive, and supporting a diversity of wildlife.

After the extended drought of the 1970s and mid-1980s, the lake shrunk to less than 3,000 square kilometres, and the Chari and Logone rivers, which contribute more than 80 per cent of the total water supply for Lake Chad, were reduced to a trickle. Throughout Landsat was used to monitor the process.

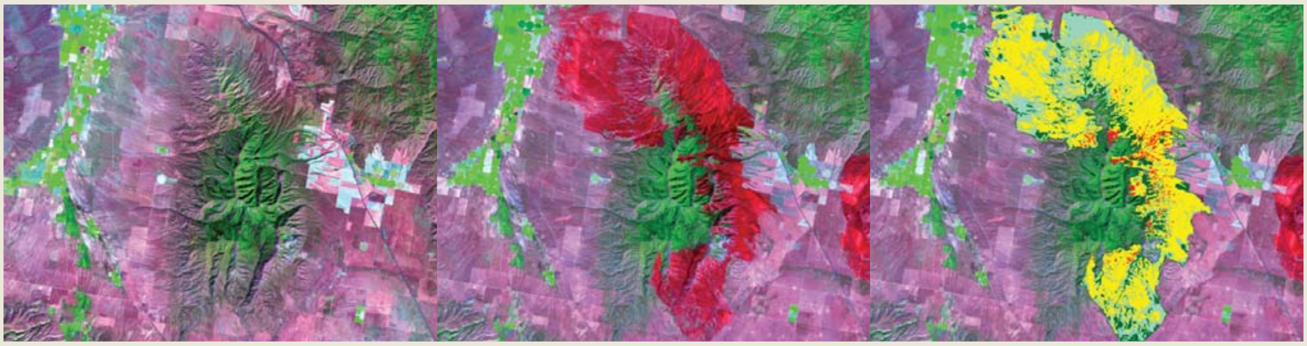
Remote sensing thermal data, such as that obtained from the Landsat satellite, can be used to determine evapotranspiration (ET), measure and monitor agricultural water use and evaluate climate change. An energy-balance model, such as Mapping Evapotranspiration with high Resolution and Internalized Calibration (METRIC), can compute ET directly from Landsat images. METRIC is used to: map ET by land use/land cover type, compute aquifer depletion from irrigation, compute a water balance foreground water models, and compute consumptive water use by irrigated agriculture.

Integrating multiple sources of timely multi-spatial -spectral and -temporal imagery with agrometeorological provides valuable information for monitoring global agricultural conditions. The USDA Foreign Agricultural Service and other US and international agencies draw on imagery, data and capabilities from many other agencies and departments to make forecasts on global agricultural production and yields.

Wildland fires prevention and recovery

Sustained use of Earth observation data as a function of

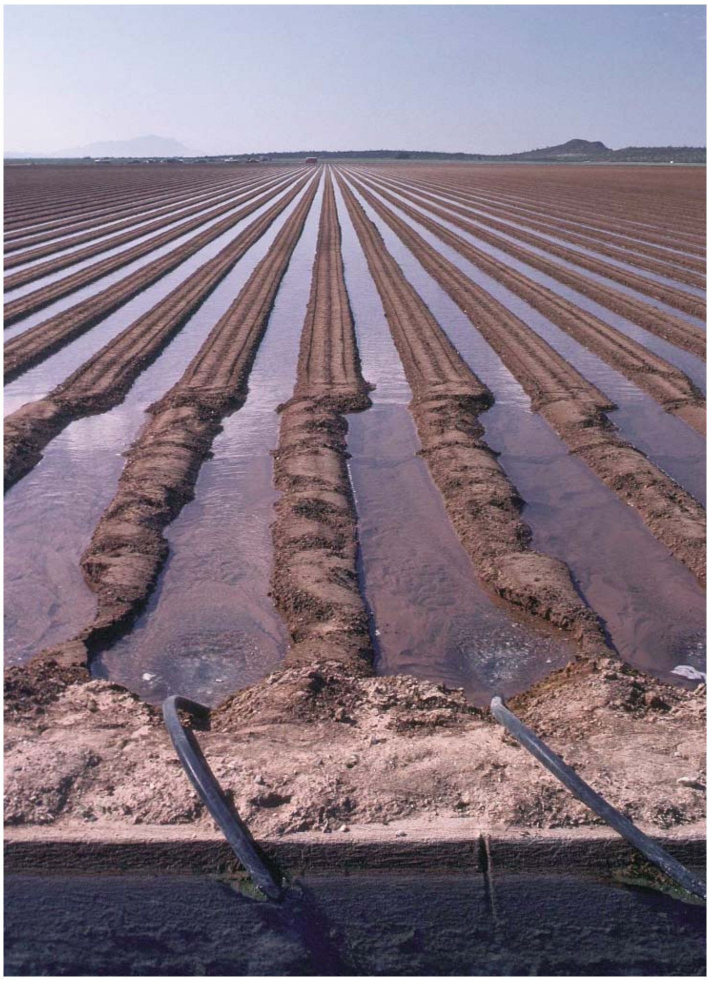
Landsat 5 Thematic Mapper™ in support of BAER classification map



Satellite Imagery, such as the Landsat 5 Thematic Mapper™ scenes shown here, is used to rapidly create a burn index classification which is combined with other geospatial data including soils, hydrology GIS layers, and field inventory data. The final product is a map showing high priority areas for fire risk and erosion control treatments. The images above are for the Black Pine 2 fire located near Malta, Idaho USA in the Sawtooth National Forest. Left: Pre-fire image (13 August 2005); Centre: Post-fire image (18 August 2007); Right: Burn index classification

Source: Jess Clark, USDA Forest Service Remote Sensing Applications Center

Photo: Tim McCabe, USDA/Natural Resources Conservation Service



Laser-leveled irrigated land near Phoenix, Arizona

time can be used to monitor and assess global biomass in support of agriculture. Moreover, accurate knowledge of type and amount of land biomass is essential input for fire hazard information in the framework of disaster prevention and mitigation. Burn Area Emergency Rehabilitation (BAER) teams are formed and dispatched to all wildland forest fires to assess damage and implement a burn area rehabilitation plan.

Such plans consider safeguarding human life and property, protecting municipal watersheds, stabilizing steep slopes, and protecting cultural resources. They mitigate soil erosion, mudslides and the movement of hazardous tree skeletons. The goal is to have a burn area rehabilitation plan created within five days of wildland fire containment. The first task on land denuded by fire is the stabilization of the soils and slopes. After stabilization, workers move to long-term rehabilitation, which includes reseeding native grasses, replanting trees, and preventing noxious-weed growth.

GEO and GEOSS support for agriculture sustainment

There is strong need for an operational, earth observation-based agricultural monitoring system. A system that can provide the inforamtion needed as input to analytical tools and models for agriculture risk assessment including crop failure, crop water stress, bio-mass, forest monitoring, and surface change. GEO must work to help estabish tools and methods via its work plans to obtian better global agriculture assessement methods and models. It must also establish a strong consortium of well understood, consistent, readliy avaialble earth observations datasets via the GEOSS.

There are many partners and programs that could be used as starting points to support such a global need, including: USAID's Famine Early Warning System-Network (FEWS-NET) and Global Monitoring for Food Supply (GMFS). These programs and many other similar ones need to be supported and capitalized on by GEO's future work.

Finally, a strong global land monitoring program via GEOSS will support global sustainable agriculture and all of the GEO societal benefits, including: disasters - natural and man made hazard monitoring and assessment; agriculture - disease, pests, drought monitoring and assessment; biodiversity - invasive species detection and monitoring; ecosystems - monitoring change; energy - infrastructure assessment and monitoring; health - disease carrier monitoring and prevention; water - floods, droughts, water quality monitoring and assessment; and weather - environment impact monitoring and assessment.

Monitoring and Assessment

Moisture assessment using aerial digital camera data from 2004 and 2006 in Ochiltree, Texas

Source: USDA Farm Service Agency National Agriculture Image Program

Applications of remote sensing in fisheries and aquaculture

Trevor Platt, Research Scientist; Shubha Sathyendranath, Executive Director, Partnership for the Observation of the Global Oceans; Venetia Stuart, Project Scientist, International Ocean Colour Coordinating Group, all of Bedford Institute of Oceanography, Nova Scotia, Canada

Collectively, human society is responsible for the well-being of the oceans. Various commercial conflicting interests are concerned that range from fisheries, aquaculture, and mineral extraction to tourism and transportation. Non-commercial issues, such as maintaining a healthy state of biodiversity, are also signifcant.

Internationally, and intergovernmentally, a consensus has been reached that, in meeting the responsibility for stewardship of the oceans, an ecosystem-based approach should be followed. The implication is that management decisions should be made in such a way that the integrity of the ocean ecosystem, its structure and vital function, should not be compromised. Ecosystem-based management is the new paradigm.

But it is far from simple to restate the new principle in operational terms. Here, the primary requirement is for information about the ocean and its ecosystem. First, we need to know the spatial structure. Next, we need to know how the ocean changes in the short term (response to weather), medium term (response to seasonality) and long term (response to climate change). The green plants in the ocean (the phytoplankton) are mostly microscopic and they respond to short-term changes in the environment more rapidly than do the plants on the land. Ideally, we need our information about the ocean to be updated daily if we are to understand the mechanisms underlying ecosystem response to change.

Photo: Meena Kumari, Central Institute for Fisheries Technology, Kochi, India

Local fish market in Nagapattinam, Tamilnadu, India

Earth observation (EO) by remote sensing is the only way in which we could hope to collect the information required on the appropriate timescales at the spatial scale of the ocean. And fortunately, there is a technology available (visible spectral radiometry, often called ocean-colour remote sensing) that enables us to produce maps of the quantitative distribution of plant biomass, indexed as the concentration of chlorophyll, over the broad swath of the ocean. Chlorophyll is a pigment found in all green plants, including the microscopic ones living in the sea: it provides the means by which the ecosystem can interface with its energy source, the sun. When we look at an image of the distribution of chlorophyll in the ocean, we are really looking at a map of connectivity of the marine ecosystem to the source of its sustenance. It is the most fundamental information we could have about the marine ecosystem.

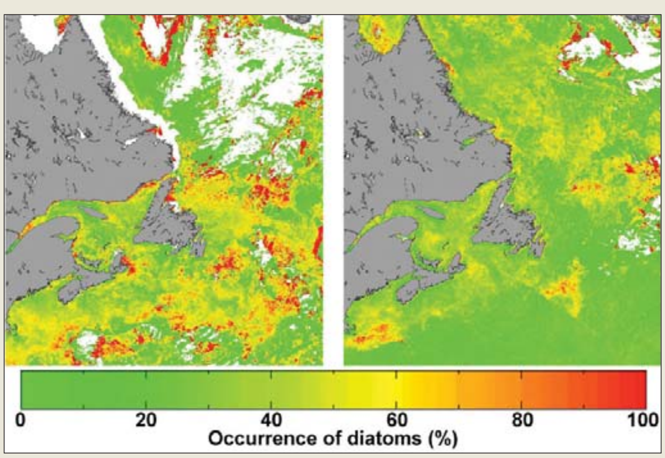
If information is the essential requirement, and if EO is the method to acquire it, what is the best way to apply it? One of the important applications is in the construction of ecological indicators. These are a suite of objective, quantitative indices intended collectively to capture in a few numbers the condition of the ecosystem at a given time and place. The idea is to condense the potentially-bewildering detailed information into an economical set of quantitative indices that should be more simple to assimilate. When the indicators are evaluated in a serial manner, they afford the possibility of detecting, and quantifying, ecosystem changes in response to perturbations such as pollution, over-fishing or climate change. EO has many qualities advantageous in this regard: it can give excellent spatial resolution, high repeat frequency and is very cost-effective. We can expect therefore that EO will be an important contributor to the development of an optimal set of ecological indicators for operational use in the ocean.

Ecosystem seasonality provides a good example. In temperate latitudes, a pronounced peak in chlorophyll concentration in spring is typical. It is such an important event in the ecological year that many species of fish and invertebrates, including those of economic interest to fisheries, time their reproduction to take advantage of it. At a particular location, the timing of this peak in particular years will vary by a few weeks depending on the weather. These fluctuations may have profound effect on the survival of the offspring, to the extent that the success or failure of the year class in a particular year maybe determined by them.

Images of chlorophyll distribution obtained by EO may also be used directly in fishing. It is often found that local concentrations of fish are related to typical oceanographic structures that can be recognized by EO. In India, artisanal fishermen are supplied regularly with analysis of EO imagery as an aid to their work. The intent here is not to overexploit a stock that might already be under heavy fishing pressure. Rather, the purpose is to help the fishermen complete their work with a minimum of searching time and a corresponding saving in fuel.

An important refinement of the interpretation of data from EO of ocean colour is to determine the quality as well as the quantity of plant biomass in the ocean. In the simplest case, all the chlorophyll is treated as a single pool of biomass. But in fact, there is a very large number of species of phytoplankton in the sea, representing several major taxonomic groups. These have different roles in the chemical cycles of the ocean, and also different values as potential food sources for organisms that feed on them. One of the contemporary goals of ocean-colour science is to be able to determine the presence and abundance of these different groups by EO. A major advance in this direction is the algorithm that detects the presence of the important group of phytoplankton known as the diatoms.

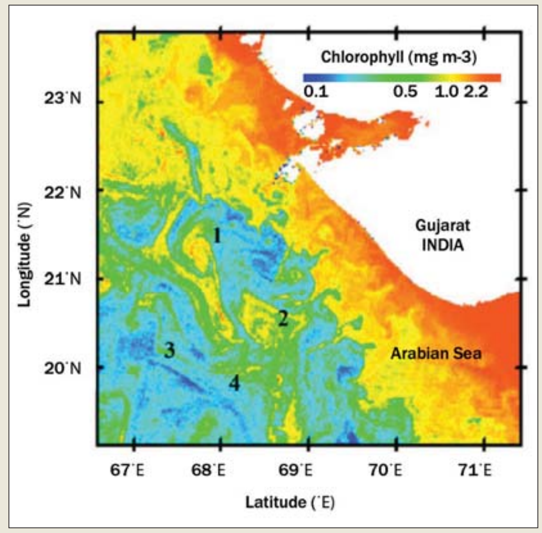
Diatoms



These satellite-derived maps show the probability of the occurrence of diatoms in the Northwest Atlantic Ocean during spring (16-30 April, left) and summer (1-15 July, right) of 1999

Source: Shubha Sathyendranath and Emmanuel Devred, Bedford Institute of Oceanography, Canada

Chlorophyll image of northwestern India



This chlorophyll image of northwestern India on 29 February 2006 was generated from the Indian OCM sensor. Oceanic features such as cyclonic eddies (1 and 2 on the image) and fronts (3 and 4) are known to be productive sites, and are hence relevant for fishery exploration

Source: R.M. Dwivedi, Indian Space Research Organisation, India

A specialized application for identification of phytoplankton using EO is in the aquaculture sector. Here, the occurrence of blooms of certain phytoplankton is antagonistic to the industry. Such outbreaks are referred to as Harmful Algal Blooms (HAB). Some species of phytoplankton are dangerous for culture of salmonids because the cells tend to clog the gills of the fish. Others produce toxins which may accumulate in the tissue of bivalve molluscs that feed on them. Consumption of shellfish containing these toxins may be fatal to people.

Sometimes, phytoplankton that are otherwise not dangerous may become so because, having reached high abundances through vigorous growth under favourable conditions, they may die and decay when conditions become unfavourable, consuming oxygen such that the environment may be rendered disadvantageous for aquacultured species. It is clear that the aquaculture industry can benefit from the information provided by EO to determine the onset, extent and fate of phytoplankton blooms.

The fishery for cultured pearls is also vulnerable to environmental conditions, in this case to the effect of excessive sediment deposition over the oyster beds. Fortunately, the movement of sediments by coastal currents can be monitored by EO, alerting growers to the potential threats following storms or heavy rains.

The ocean ecosystem is not everywhere the same. Rather, it is organized into a suite of more-or-less autonomous subsystems loosely connected to each other. We may call these systems ecological provinces. Informed stewardship of the ocean requires that we understand the organization into provinces and that we can observe its seasonal modification in real time. Here again, EO proves to be a very useful tool.

Coastal sediments

A true-colour image of northwestern Australia, captured by the MODIS ocean colour sensor on 2 July 2003. Commercial oyster farms are located in the clear waters around Broome and the Buccaneer Archipelago. High sediment loads, clearly visible in King Sound, are detrimental to the pearling industry and can be monitored using MODIS data

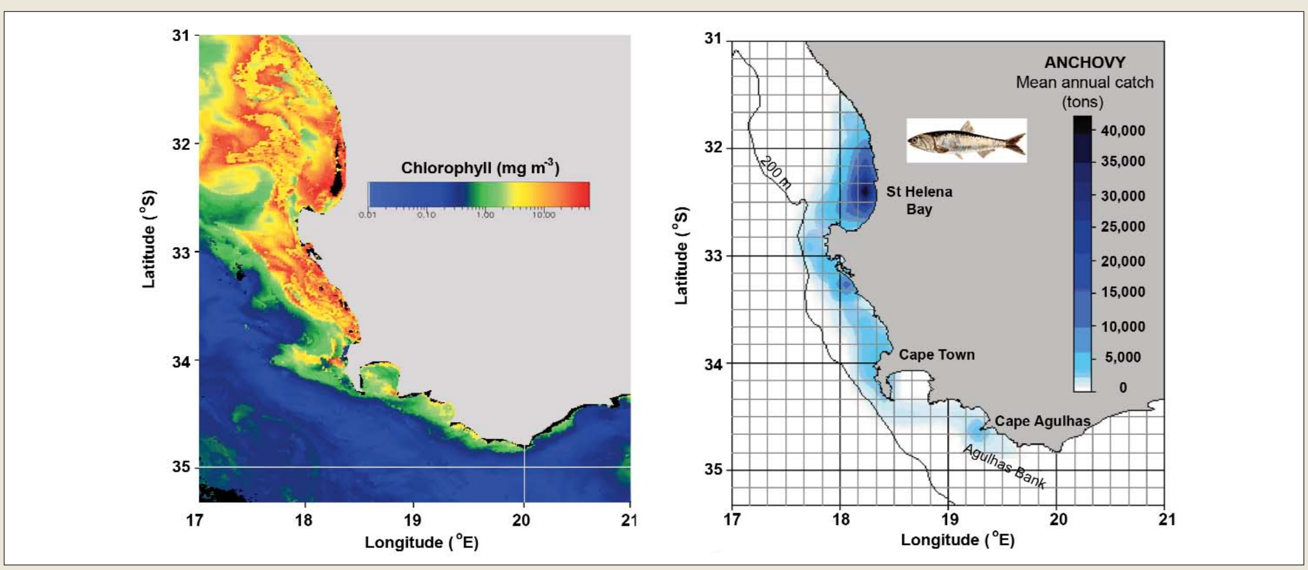
Source: MODIS Science Team, NASA/GSFC and the Remote Sensing and Satellite Research Group, Curtin University, Australia

Generally, we find that the ecological organization is controlled by physical forces, such as currents and wind patterns. In turn, it is frequently found that the spatial extent of fishing stocks is related to the spatial patterns depicted in a partition of the ocean into ecological provinces. An excellent example is found in the Benguela ecosystem off the west coast of South Africa, which is driven by strong south-easterly winds that induce upwelling of cold nutrient-rich water. This strong coastal upwelling leads to high levels of primary productivity, which in turn supports the large commercial fisheries in the area.

From the examples presented, it is clear that there is enormous potential for EO to benefit society through application to fisheries and aquaculture. However, such applications are still in their infancy. To encourage and coordinate, at the international level, the pursuit of excellence in this field, the Canadian Space Agency has agreed to fund the Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery (SAFARI) programme in the context of GEO Task AG 06-02. This programme will host an international coordination workshop; highlight excellent demonstration projects of EO in fisheries; produce a monograph on the state of the art, develop an outreach component to increase awareness of the value of EO in the fisheries and aquaculture sector, and convene an international symposium on this timely topic.

All things considered, there is a promising and exciting future for the application of EO to fisheries and aquaculture, extending the ways that society can benefit from investment in EO capacity.

Benguela upwelling



On the left is an example of a three-day composite chlorophyll image from the Benguela upwelling region off the coast of South Africa captured by the MODIS ocean colour sensor. High chlorophyll concentrations along the coast are indicated in red/yellow, while areas of low chlorophyll are indicated in blue. The image on the right shows the distribution of the mean annual catch of anchovy

Left image: MODIS Science Team, NASA/GSFC. Right image: Kobus Agenbag, Marine and Coastal Management, South Africa

Satellite-based fishery service in India

Shailesh Nayak, T. Srinivaskumar and M. Nagarajakumar;
Indian National Centre for Ocean Information Services

India has a 7,500 kilometre coastline and an exclusive economic zone (EEZ) of about two million square kilometres. About seven million people living along the coast are dependent on fishing for their livelihood. The locating and catching of fish has, however, become increasingly challenging as fish stocks dwindle and move further offshore. This increases the search time, cost and effort involved. A reliable and timely forecast on the potential zones of fish aggregation would benefit the fishing community by reducing search time and the effort involved in locating fishing grounds.

The adaptation of fish to the surrounding marine environment is influenced by various physical, chemical and biological factors, including seawater temperature, salinity and dissolved oxygen. Fish are known to react to changes in their surrounding environment by migrating to areas where more favourable conditions exist. Availability of food is another important factor which effects the occurrence, abundance and migration of fish. The monitoring of these parameters in space and time by in situ measurement is time-consuming and expensive. In fact, a real-time picture of any one of, or a combination of these parameters is almost impossible using in situ methods.

With the advent of ocean remote sensing during the eighties, fishery forecast research derived much needed impetus. The link between satellite-derived sea surface temperature (SST) and chlorophyll with fish aggregation was established. In India, the efforts of oceanographers, remote sensing specialists and fishery scientists resulted in a unique service called the Potential Fishing Zone (PFZ) advisory.

The PFZ forecast is issued three times a week by INCOIS, except during the fishing ban period and on cloudy days. The validity of such forecasts is three days. This is the only short-term marine fishery forecast available in the country for the benefit of small mechanised/motorised sector fishermen (about 100,000 vessels). The PFZ advisory has matured into an operational application of satellite remote sensing, which provides timely and reliable advisories to fishermen. The effort is part of the Common Minimum Programme (CMP), lead by the Government of India.

Generation of PFZ advisories

The ability to forecast catch or seasonal abundance of stocks in different areas requires a understanding of various aspects of the physical, biological and chemical processes of the sea. This includes basic knowledge of currents, upwelling areas, eddies, gyres and thermal fronts over space and time. Remote sensing observations especially on SST and levels of chlorophyll provide a significant part of the information needed to assess potential fishery zones. Satellite technology provides the additional advantage of utilizing synoptic coverage over a short interval of one to two days.

Thermal and chlorophyll features exert a huge influence over the upper ocean biological process. The coincidence of frontal zone positions of chlorophyll and SST gradient represent the coupling of biological and physical processes, and hence, fish aggregation.[1]

SST and chlorophyll over the Indian EEZ have been retrieved from near-synchronous thermal infrared channels of NOAA-AVHRR (10.3 to 11.3 micrometres and 11.5 to 12.5 micrometres) and optical bands in IRS-P4 OCM data, respectively, to identify PFZ along the Indian coastline. The McSST approach suggested by Mcclain[2] is used to compute SST. The chlorophyll retrieval process involves two steps: the atmospheric correction of the visible channels of the ocean colour monitor (OCM) to obtain normalized water radiance, and the application of bio-optical algorithms for the retrieval of water parameters.

The atmospheric correction of OCEANSAT–I OCM imagery was carried out using the approach suggested by Mohan.[3] An empirical algorithm (OC2) was used to retrieve the cholophyll.[4,5] Both the SST and chlorophyll images were corrected geometrically using a set of ground control points located both on the image and on the Naval Hydrographic Office bathymetric map. A composite image showing SST-contours on a colour–coded chlorophyll image was also generated. Features such as upwelling, eddies, fronts and meanders were selected.[1,6] In contrast to demersal resources[7] this technique works best for pelagic and column zones.

The identified features were delineated as PFZ lines and overlaid on the base maps. The entire Indian coastline is divided into 12 sectors in order to generate the PFZ maps: Gujarat, Maharastra; Karnataka and Goa; Kerala; South Tamilnadu; North Tamilnadu; South Andhra Pradesh; North Andhra Pradesh; Orissa and West Bengal; Lakshadweep Islands; Andaman and Nicobar Islands. The PFZ maps contain information about the major landing centres, bathymetry latitude and longitude in addition to the identified fishing zones.

The PFZ maps are translated into PFZ text, which gives information about the latitude, longitude and depth of the shelf at specific locations as well as angle, direction and distance from the landing centres/light houses. These integrated PFZ advisories are prepared in English, Hindi and other local languages (Gujarati, Marathi, Kannada, Malayalam, Tamil, Telugu, Oriya and Bengali). Local measurement units are disseminated three times a week through various modes. The total number of users is about 27,000, which is 27 per cent of boat owners.

This web-based multilingual on-line information delivery system with web-GIS capability enables users to query, analyze, visualize, and download a wide range of ocean data, information and advisories pertaining to any area in the Indian EEZ.

Validation of PFZ advisories

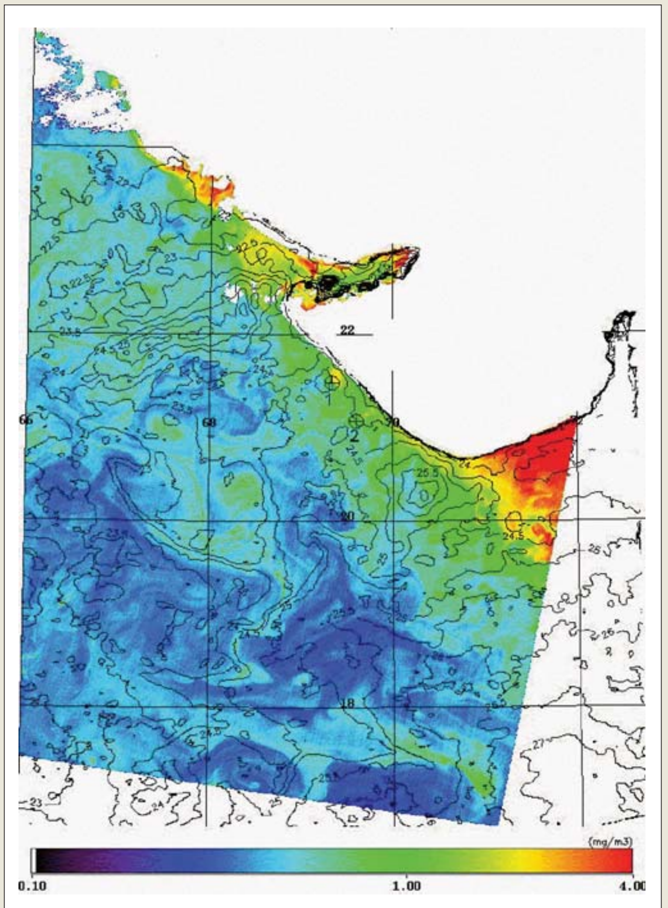
A continuous validation of forecasts was undertaken along the Indian coast. A concurrent and quantitative feedback on the total catch (species-wise) obtained in the notified and non-notified PFZ from the fishing boats operating in the region was attained. The following deductions were made.

PFZ advisories were found to be most beneficial to motorised and small mechanised sector fishermen engaged in pelagic fishing activities such as ring seining and gill netting. The advisories helped to reduce the search time, which in turn resulted in the conservation of valuable fuel oil and human effort.

Forecast reliability was found to be 70 to 80 per cent, with the reduction in search time found to be 30 to 70 per cent. The saving in cost of fuel per vessel was USD1, 5000.[8] The catch-per-unit-effort (CPUE) increased by a minimum of 70 per cent.[9]

The results also demonstrated that commercially important species are more abundant in PFZ areas compared to non-PFZ areas.

Chlorophyll map



Colour-coded chlorophyll map with SST contours overlaid. The coincident fronts indicated by SST and chlorophyll gradients are selected as PFZs

Awareness campaigns

To create awareness and to educate the fishermen on the latest technologies used to make up the advisories, several PFZ awareness and user interaction workshops have been conducted. Sixty-six user interaction workshops and awareness campaigns with the fishing community and state fishery officials were held during 2006-07.

Three short films of fifteen minutes duration have been made on PFZ and telecasted on the Nayi Disha programme, Doordarshan, Delhi (DD-1). The PFZ films have been translated into all coastal languages and have been used during the awareness campaigns. This effort increased the number of active PFZ receiving nodes from 100 to 200, which in turn suggests increased PFZ use.

Socio-economic benefits

There was a great deal of pressure on the well-known fishing grounds and it is this which lead to the decline in CPUE. PFZ methods help to direct fishing to new areas and stimulate better returns. The benefit to cost ratio increased from 1.3 to 2.1 for those who used the PFZ information.[9]

It has been estimated that ten per cent of boat owners, of which there are approximately 10,000, used PFZ advisories in 2002. This is predicted to increase by at least 25 per cent in the next few years. Annual savings equate to about USD130 million (Rs.545 crores) for those adopting ten per cent utilization and USD390 million (Rs.1635 crores) for those adopting 25 per cent utilization.[10] Currently about 27 per cent boat of owners are using the PFZ forecast.

Future plans

Wind monitoring from the QuikSCAT satellite will further help to increase the validity period of PFZs from three to five days,[11] by improving understanding regarding currents. The improved methodology is expected to enhance the success rate by up to 85 per cent, as observed during the experimental phase. In the near future, the PFZ forecast will also harness information on sea state, tide, currents and winds which will help fishermen to reach the PFZ site safely and in the shortest time.

A fish species-specific forecast based on individual species' food habits and environmental conditions is also planned. This would allow fishermen to select the most suitable vessel, gear and fishing technology in advance.

The other major improvement is likely to be in providing location-based services. Experiments are underway to provide forecasts straight to fishing vessels through satellite ratio.

Bridging scaling gaps for the assessment of biodiversity from space

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Various definitions of biodiversity exist, but a common denominator of these is always a certain scale dependency. The United Nations (UN) Convention on Biological Diversity defines biodiversity as: 'the variability among living organisms from all sources, including, "inter alia", terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems'.

Scales in biodiversity are relevant and need to be addressed individually. Biodiversity is often plotted as taxonomic richness of a geographic area, occasionally referenced to a temporal scale. This, along with the uneven distribution of biodiversity on Earth, renders biodiversity measurements using spatially explicit methods particularly complex. Lately, biodiversity is assessed increasingly using air- and space-borne Earth observation instruments. However, ecologists mainly value biodiversity in terms of species richness, as well as using various indices, whereas Earth observation based instruments usually measure the spatial distribution of radiance fields, backscattering and polarization state changes.

Photo: Zbyněk Malenovský, Col du Lautaret, France

Floristic diversity in a sub-alpine meadow

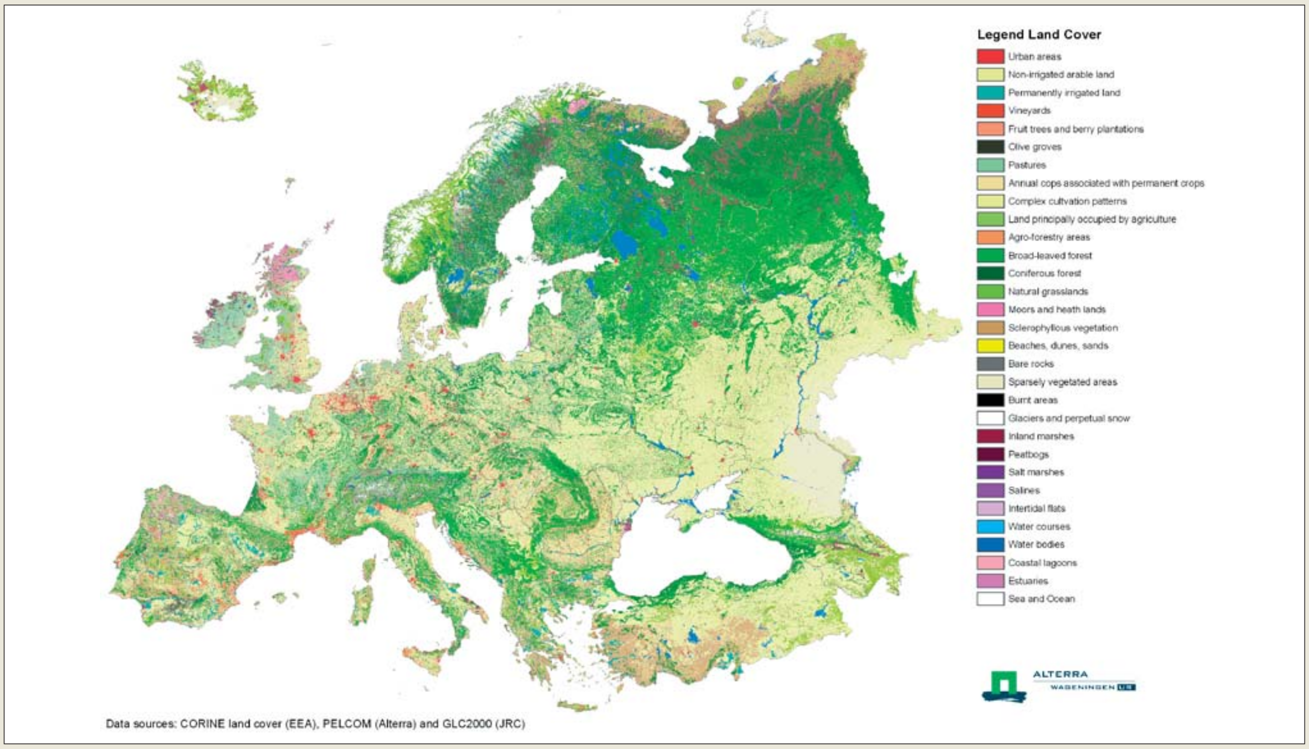
It is the main challenge of Earth observation and ecology to establish semantic interoperability between these two fields, and then develop common sampling schemes and bridge scaling gaps. This would finally allow a spatio-temporal continuous sampling of biodiversity with limited discontinuities. In combination with solid and continuous ground observations, long-term perspectives of various scale biodiversity assessments are emerging. These perspectives recieve strong support from networks including the Global Earth Observation System of Systems (GEOSS) Biodiversity Observation Network, the US National Ecological Observatory Network (NEON) and AlterNet (a network of excellence aiming to build lasting integration of biodiversity research).

There are two particular scaling-based approaches for the assessment of biodiversity at continental and regional scale within this context. A combined disaggregation/aggregation scheme is used to derive dominant species abundances at large spatial resolution (typically 500 to 1,000 m pixel size) for continental scale applications. The other, a regional scale (0.5 — 5 m spatial resolution), is used to assess floristic diversity, canopy biochemistry and structure. Both approaches have been proven to deliver relevant results for the assessment of biodiversity from space, as well as bridging scaling gaps previously unexplored.

Necessity to observe biodiversity changes

The latest trends of the global climate are, unfortunately, weakening the biodiversity-ecosystem bound. Ecosystem biodiversity is strongly related to actual ecosystem services and goods delivered, and affected by natural and human-induced environmental processes. Increasing temperatures are relocating ecosystems on the Earth, and further re-emphasizing the uneven biodiversity spatial distribution. Consequently animal and plant species are

Pan-European land cover map



Source: CORINE, PELCOM and GLC2000

forced to either adapt to these new climatic regimes and run the risk of extinction, or migrate into more suitable environments.

An average temperature change of one degree Celsius can trigger a shift of ecological zones by up to 160 kilometres. The predicted temperature increase of four degrees Celsius over the next century may therefore cause the migration of certain Northern Hemisphere species by up to 500 kilometres (Thuiller, 2007).[1] Such rapid and extreme changes in environmental conditions combined with physical-geographical barriers may overwhelm the ability of species to modify their physiological-seasonal strategies, or follow shifting climate by colonizing new territories; thus lowering their survival rate. Alternatively, extreme events or shifting climate could trigger an invasion of opportunistic species, which may to some extent cause a biodiversity increase.

Apart from ecosystem disruption due to climatic change, biodiversity is also facing direct negative impact from anthropogenic and global human activities motivated by rapid, often economical, benefits. A prominent anthropogenic impact is large-scale wood logging in the tropical rain forest. This results in myriad negative effects, such as soil degradation and biodiversity loss.

It has been observed that land-use change in the year 2100 forced by climate change alone, will be the largest influence on biodiversity decline (Sala et al., 2000).[2] The strongest negative impact from biodiversity loss is currently predicted in Arctic, alpine and boreal ecosystems. Steadily growing long-distance transportation and trade globalization is further fostering the dispersal of exotic invasive species. Due to their progressive life strategies, these invaders manage to occupy the niches of the original conservative species, resulting in biodiversity homogenization and/or loss.

Moreover, such colonization initiates unpredictable ecological interactions between new organisms and the surrounding environment, fosters new ecosystems (Hobbs et al., 2006),[3] and potentially reduces the original variability of natural habitats.

Bridging scaling gaps

Limitations relating to generalization are inherent to experiments carried out under scale-limited laboratory or field conditions. Such small-scale experimental design is unable to reveal the complex spatial and temporal character of larger scale ecosystems and their biodiversity response to accelerated climate change.

Nature's complexity is successively scaling various structures, states and processes over time and space. The chain of scales starts at the ultra-cellular structure of plant membranes, accommodating instantaneous biochemical processes (occurring in fractions of seconds), that are scaled through cellular tissues, leaves, shoot/branches, crown canopies, habitats and ecosystems up to biomes, ending with the global biogeochemical cycles (having response times of several years). The latest state-of-the-art science in Earth observation related remote sensing (RS) enables the bridging of these scales and processes using radiative transfer based models, data assimilation and evidential reasoning (Schaepman, 2007a).[4]

Various air- and space-borne Earth observation instruments are currently in use for regular large-scale and long-term monitoring as well as regional, high spatial and spectral resolution mapping of biodiversity related activities. However, alone, even systematic satellite-based biodiversity monitoring is not able to reveal changes in biodiversity (past data records are partially incomplete, discontinuous, or simply not long enough to monitor relevant changes). On the predictive side, Earth observation is well suited for now-casting applications, but cannot predict the future evolution of ecosystems.

Continental, or even global, scale Earth observation at larger spatial resolution (typically 0.25 to 1 kilometre) using instruments such as MERIS on ENVISAT, MODIS on Aqua/Terra, or NOAA/AVHRR, cannot be directly used for individual and indicator species identification. However, these data are well suited to derive dominant species composition or depict abundances of plant functional types (PFTs).

Spatio-temporal disaggregation schemes, evidential reasoning and data assimilation are often part of such applications. In addition, given that sufficient temporal resolution data are available, products such as vegetative change cover and species-specific phenological indicators may be further derived. These products are well suited to initialize and parameterize ecological models that predict vegetation development or dynamics. However, not many of the existing vegetation models are ready to directly assimilate Earth observation data.

Regional scale biodiversity assessment, which has a typical spatial resolution between 0.5 and 30 metres, has been pioneered by Landsat sensors. In this category, instruments such as Landsat ETM+, CHRIS on PROBA, EO-1 Hyperion, HyMap, and NASA JPL AVIRIS are named most frequently. Semantic interoperability and proper interfacing sampling design, as well as schemes between ecological and Earth observation activities are the most important factors driving the success of this bottom-up scaling-based approach.

Indicator species mapping is only possible if the spatial resolution is at a fraction of the species size, otherwise only dominant species mapping can be performed. Recent imaging spectrometers have contributed to the mapping of quantitative vegetation biochemical and structural parameters (such as, concentrations of leaf biochemistry, assessment of foliar pigments), disturbance occurrence, and invasive species. These applications have the potential to contribute to vegetation modelling. However, many of these models (for example, SMART/SUMO/NTM model suite to predict floristic diversity) have been developed without Earth observation input in mind.

Combined disaggregation/aggregation scheme: towards habitat abundance mapping

Large-scale characterization of ecosystems, landscape diversity and functions is in increasing demand, particularly at finer spatial resolution and temporal scales. While large-scale stratification using climatic data may be sufficient to define broad eco-regions, combining it with landscape spatial information allows a variety of subclasses to be identified at a finer scale. Such landscapes consist of a multitude of habitats and plant communities of coexisting biological species. A method combining disaggregation of remotely sensed data with evidential reasoning can produce probability maps of dominant plant species habitats. Such maps can be re-aggregated to produce fractional abundances of PFTs.

The PFTs represent important input into dynamic vegetation models (Sitch et al., 2003),[5] because they have the capacity to forecast floristic diversity under various scenarios. The PFT maps allow the evaluation of results from scenarios initiated in the past (for example, using a historical pollen distribution database) as well as to assess the potential accuracy of future projections.

A current disaggregation scheme in development is based on a pan-European dataset. The approach relies on identifying all major habitats in Europe defined in accordance with Annex I of the Habitat Directive, which specifies 198 distinct habitats (Mücher et al., 2005).[6] The data set is compiled using current state-of-the-art land cover databases (namely CORINE, PELCOM and GCL2000). Harmonization of the data sets is implemented as far as possible according to the CORINE land cover nomenclature to avoid loss of information.

Additional stratification and evidential reasoning is used by integrating datasets such as biogeographic regions, digital elevation, soil information and other geographic and topographic data to finally arrive at a probabilistic species distribution of a particular habitat. These maps can support better management of protected areas, allowing monitoring of the long-term stability of ecosystems, identification of potential species reintroduction sites and finally, protection of the original ecosystem species against invasive species by predicting their potential colonization areas.

Towards dominant species mapping

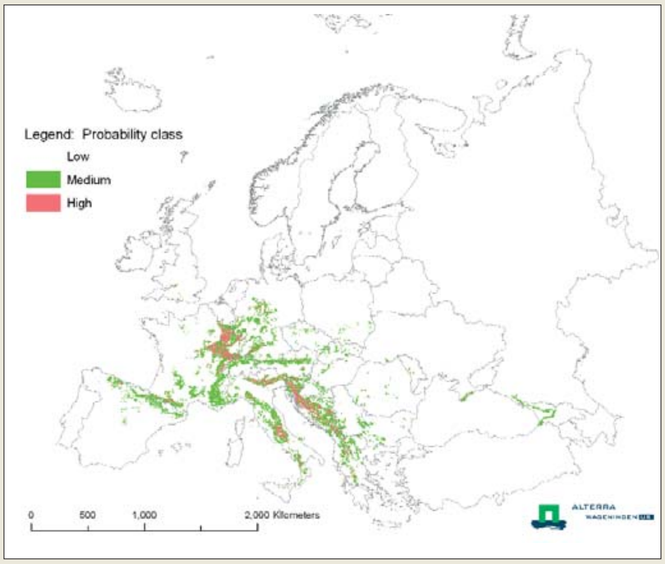
Using a remote sensing-based approach of vegetation sampling in the field may lead to significantly differing results compared to a more traditional vegetation mapping scheme, such as the method of Braun-Blanquet. Remote sensing approaches will always spatially integrate information over the instantaneous field of view (IFOV). This results in spectrally mixed radiometric quantities affected by the most dominant species and the fraction of non-photosynthetic vegetation and soil in vertical projection.

Ecological sampling schemes, however, frequently focus on indicator species sampling, where these indicator species may have no significant spatial abundance in the sampled area. Recent advances in measurement of leaf optical properties combined with advanced radiative transfer (RT) modelling (for example, PROSPECT/SAIL), allow in forward mode, to-scale leaf biochemistry and structural parameters up to higher scales. They also allow an inverted mode to retrieve vegetation biochemical and structural properties from the reflectance signal measured within the sensor IFOV. Spectral libraries of leaf optical properties can be used to spectrally unmix large areas and derive abundances of dominant species, given that all dominant species are represented well in the library.

Further analysis of dominant species abundance results in solid estimates of vegetation net primary productivity (NPP). This is approximated from remotely sensed light use efficiency (proxied by the photochemical reflectance index (PRI), photosynthetically active radiation (PAR), and the fraction of PAR absorbed by photosynthetic tissues. The latter, being basically a function of leaf area index (LAI), is again retrievable from spectrometric data by inversion of RT models.

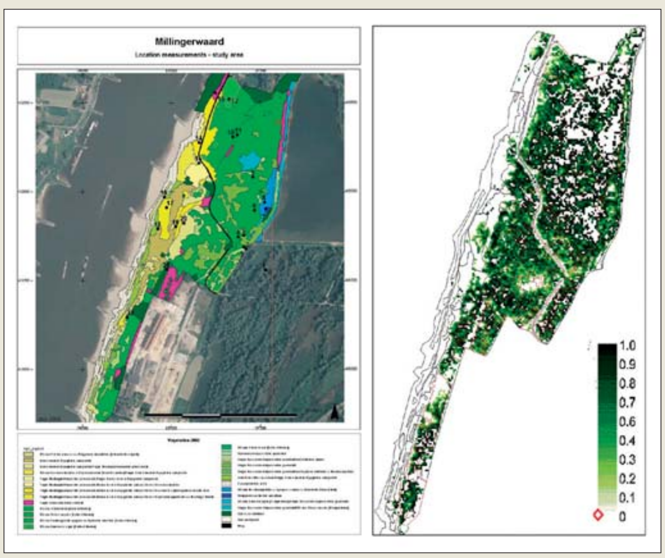
These advanced remote sensing product combinations can serve as an input to dynamic vegetation models, such as the SMART (soil processes), SUMO (vegetation processes and succession), and NTM (potential floristic

Spatial distribution of the habitat 'Calcareous Beech Forest' in various probability classes



Source: Mücher et al., 2005

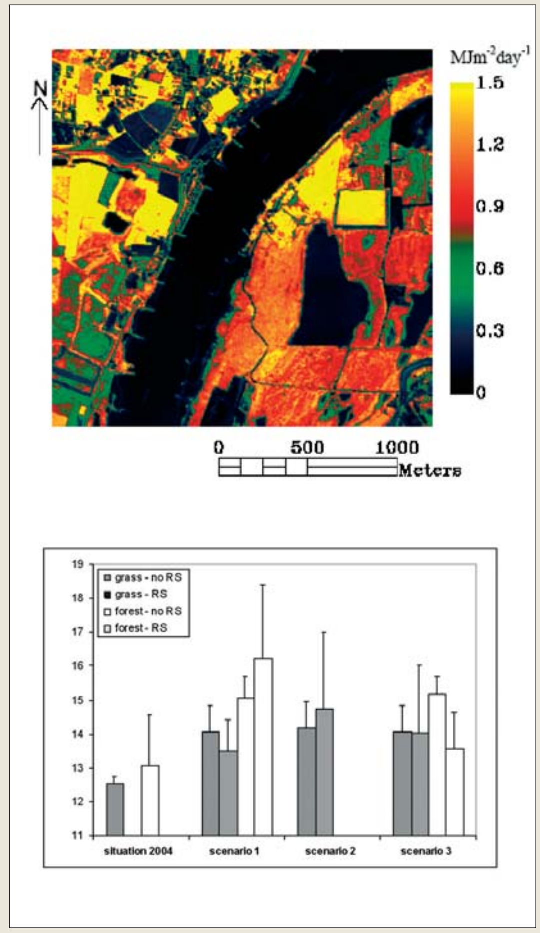
Mapping approaches compared



The results of two methods, classical vegetation sampling as well as the spectral unmixing approach. The unmixed abundance of Rubus sp. corresponds much more to the actual average impression of the test site, rather than the effective floristic diversity, due to sparse spatial distribution of these species

Source: Schaepman, M.E., Wamelink, G.W.W., van Dobben, H., Gloor, M., Schaepman-Strub, G., Kooistra, L., Clevers, J.G.P.W., Schmidt, A., & Berendse, F. [7]

Vegetation mapping data



Net Primary Productivity (NPP) estimates using advanced remote sensing methods (top) and potential floristic diversity as predicted by a combination of dynamic vegetation models (bottom)

Source: Karle Sykora, WUR

diversity) model combination, which supports the assessment of biodiversity at regional scales (Kooistra et al., 2007).[8]

Conclusions

Increasingly, Earth observation data and products are used to assess biodiversity from space. Since large-scale spectral, spatial and temporal high-resolution instruments have become available, significant advances have been made in contributing to the structured monitoring of biodiversity from space. However, due to inherent observational limitations, scaling gaps need to be bridged in all of the above domains.

Disaggregation and reaggregation combined with evidential reasoning at continental scale and radiative transfer based inversion methods at regional scale, are just two examples indicating the increasing applicability of remote sensing in the structural assessment and monitoring of biodiversity. Sound forecasting methods of biodiversity trends in the future will not only rely on the above methods, but also increasingly include temporal information and data assimilation based methods. Infrastructure access such as defined in GEOSS in combination with structured biodiversity observation networks will facilitate the operational monitoring and forecasting with latest technology achievements and scientific methods.

Predicting the impact of climate change on biodiversity — a GEOSS scenario

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Hannu Saarenmaa, Finnish Museum of Natural History;
Jeremy Kerr and Heather Kharouba, Canadian Facility for Ecoinformatics Research;
Éamonn Ó Tuama, Global Biodiversity Information Facility;
Siri Jodha Singh Khalsa, National Snow and Ice Data Center

While some two million plus species have been described, and many millions more remain to be discovered, climate change threatens to commit 15 to 37 per cent of these to extinction by 2050, accelerating a dangerous trend that land use change has already set in motion. An extinction episode of this magnitude would likely severely degrade the quality of vital ecosystem services, such as nutrient cycling, atmospheric regulation, soil formation, water purification, and pollination, upon which the human enterprise relies. Scientists are presented with the formidable challenge of assessing likely impacts of unprecedented interactions between rapid climate and land use changes, predicting how those impacts will unfold into the future, and providing policy options to decision-makers. These issues have been highlighted in stark terms in the newly released Fourth Assessment Report of the Intergovernmental Panel on Climate Change.[1]

In short, global change requires a monumental scientific response, drawing on infrastructure that integrates the enormous volumes of data available from biodiversity research, earth observations, and climate models. Components of this megascience infrastructure already exist, having been established by the IPCC and Global Biodiversity Information Facility (GBIF). Integrating these disparate components will require great effort in terms of metadata development and related service coordination. However, the Global Earth Observation System of Systems (GEOSS) provides the basis for realizing these goals through its interoperability infrastructure.

Here, we describe the results of linking the biodiversity and climate change research infrastructures to enable scientists to conduct new, broad-scale ecological analyses. We describe a generic use scenario and a related modelling workbench for studying the impacts of climate change on biodiversity. A scenario, as described here, provides a basis for predicting biodiversity impacts of climate change into the future by demonstrating recent impacts of anthropogenic changes in the 20th century. Models such as this are built using the infrastructure being developed by GEOSS and provide an essential benchmark against which forecasts for the future might be constructed. This development has been conducted in the framework of the GEOSS Interoperability Process Pilot Project initiative.

Scenario definition

One of the most widely used techniques for large-scale biodiversity data analysis is Ecological Niche Modelling (ENM), which was pioneered by Peterson et al.[2,3] and refined subsequently by many others.[4] ENM is now employed in a range of global change and macroecological applications.[5,6] GBIF has promoted this approach and organised several international workshops on the topic.

A scenario for predicting the impact of climate change on biodiversity involves several steps[7]:

Step one — Identify the species for which sufficient data exist: such data should span at least 30 years. There are many biodiversity datasets that satisfy these stringent criteria and, although they are usually patchily distributed (for example, birds from the United Kingdom, butterflies from Canada, and so on), ENM can be applied to them. However, identifying the existence of the datasets is a challenge. If multiple datasets are cached in a repository somewhere, cluster analysis and data mining can be used to discover the most suitable datasets. If caching or other central repositories do not exist, expert human advice is needed to select the datasets.

Step two — Assemble biodiversity datasets and map their spatial and temporal distributions, after which gaps in data become clear. Such gaps can provide new data sharing opportunities within and among countries, and the need for more and better data can be communicated to policy-makers. Presentation of such spatial trends can also encourage additional data providers to permit access to their data holdings.

Step three — Determine which environmental characteristics are most likely to influence target species' niches. High resolution land cover and climate data are commonly required for this purpose. Although satellite data have not yet been widely or effectively used, GEOSS infrastructure will enhance access to high quality earth observation datasets of relevance to ENM.

Step four — Determine which historical and future scenario climatological data are needed for ENM of the selected group of organisms. This may include measurement of how the species in question has/have responded to recent climate changes, thus strengthening any inferences related to how spatial ENMs will change temporally.[8]

Step five — Determine which modelling algorithms will most accurately and precisely predict shifts in distribution and abundance for the selected group of organisms. Identify the reporting needs in terms of data accuracy and error propagation.

Step six — Download the selected species occurrence data (eg from GBIF) and environmental and climate data (eg from IPCC) to the modelling workbench.

Step seven — Run the models and present the outputs as a series of maps and predicted species' ranges or abundances, as appropriate. Measure uncertainty in model outputs under the range of desired scenarios so a realistic depiction of policy options is available to policy-makers. This approach resembles that of the IPCC in presenting different climate change scenarios depending on variations in emission reduction efforts.

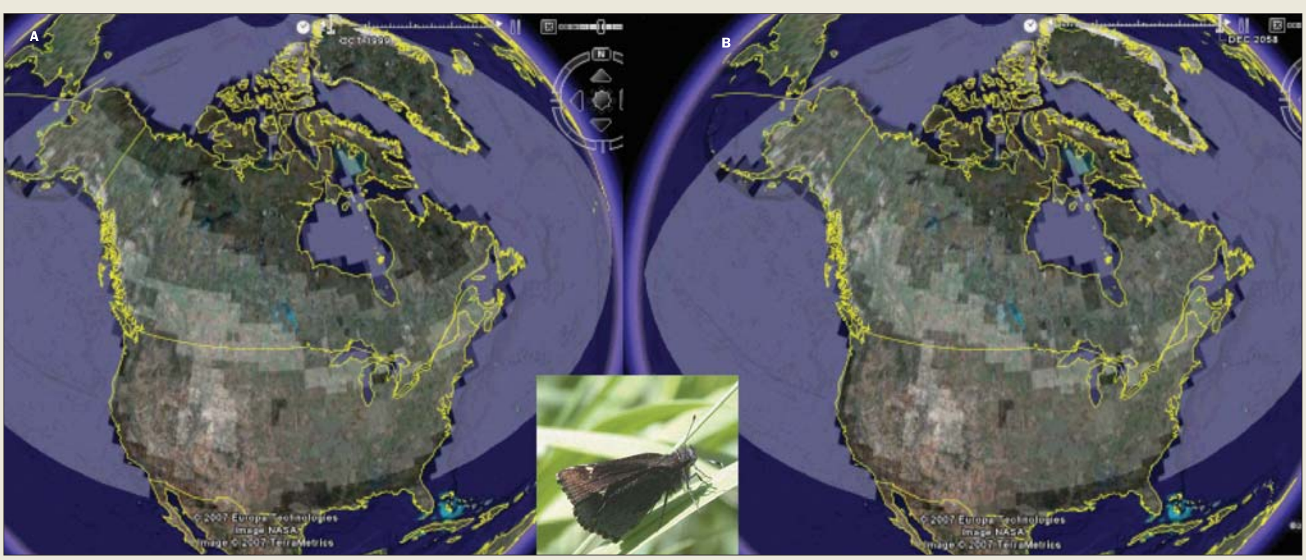
This scenario is but one example of a broad-scale application for biodiversity data. Biodiversity is also affected by other factors such as tropical deforestation, for which other scenarios can be produced. However, these additional scenarios also build on the same pool of primary biodiversity data as the described climate change scenario.

The overall prediction system architecture comprises five main components from the biodiversity and climate change Societal Benefit Areas, as follows:

1. A biodiversity data provider, such as the GBIF Data Portal (http://data.gbif.org) provides unified access to some 130 million primary species-occurrence records (both specimens and observations) from some 1000 databases and 200 data providers around the world, and covering a diverse range of taxa and ecosystems. A high proportion of these records are geo-referenced, and ongoing efforts in the data providing communities promote the necessity and value of providing an accurate geo-location for records. The GBIF virtual database represents a unique resource for Earth Observation studies which require ground-truthing data, whether historical (to study change over time) or contemporary. GBIF exposes the data through a web site and several web services.

2. A climatological data provider, such as the National Center for Atmospheric Research (NCAR) Geographic Information System (GIS) portal provides web access to free, global datasets of climate change scenarios. These data (spanning 50 years from 2000 to 2050) have been generated for the 4th Assessment Report of the IPCC by the Community Climate System Model (CCSM). Climate models are an imperfect representation of the earth's climate system and climate modellers employ a technique called ensembling to capture the range of possible climate states. A climate model run ensemble consists of two or more climate model runs made with the exact same climate model, using the exact same boundary forcings, where the only difference between the runs is the initial conditions. The NCAR portal provides several climate change scenarios. Of these, the constant 20th century scenario shows the least increase in future surface temperature, the B1 and A1B scenarios display moderate increases and the A2 scenario results in the largest

Tests using the common roadside skipper butterfly



A) The *Amblyscirtes vialis* distribution projected for the year 2000; B) The *Amblyscirtes vialis* distribution projected for the year 2050 under the IPCC B1 climate change scenario. Light markers corresponds to 100 per cent of presence probability; grey markers to 50 per cent of probability

Source: Nativi et al. 2007b. *Amblyscirtes vialis* photo by Erik Nielsen response. The interoperability experiments mainly considered the A1B scenario.

3. A catalogue, such as GI-cat[9,10] allows discovery of, and access to, the available biodiversity and climatological datasets. GI-cat provides a consistent interface for querying heterogeneous catalogues and accessing servers that implement international geospatial standards. In addition, GI-cat implements a mediation server, making it possible to federate non-standard servers by specifying 'interoperability special arrangements'. GBIF web services were registered at GI-cat, which required a formal mapping of the GBIF data model to the ISO 19115 core metadata profile, and the adaptation of GI-cat to the GBIF service protocols.

4. A model provider is a component which is able to run an ecological niche model on the selected biodiversity and climatological datasets. It supports selection of datasets, setting of parameter values and specifying of algorithm to be used. For example, the open source OpenModeller (http://openmodeller.sourceforge.net) software which is available as a stand-alone application (OpenModeller Desktop) and as a modelling kernel that is accessible through specific modules implementing external interfaces.

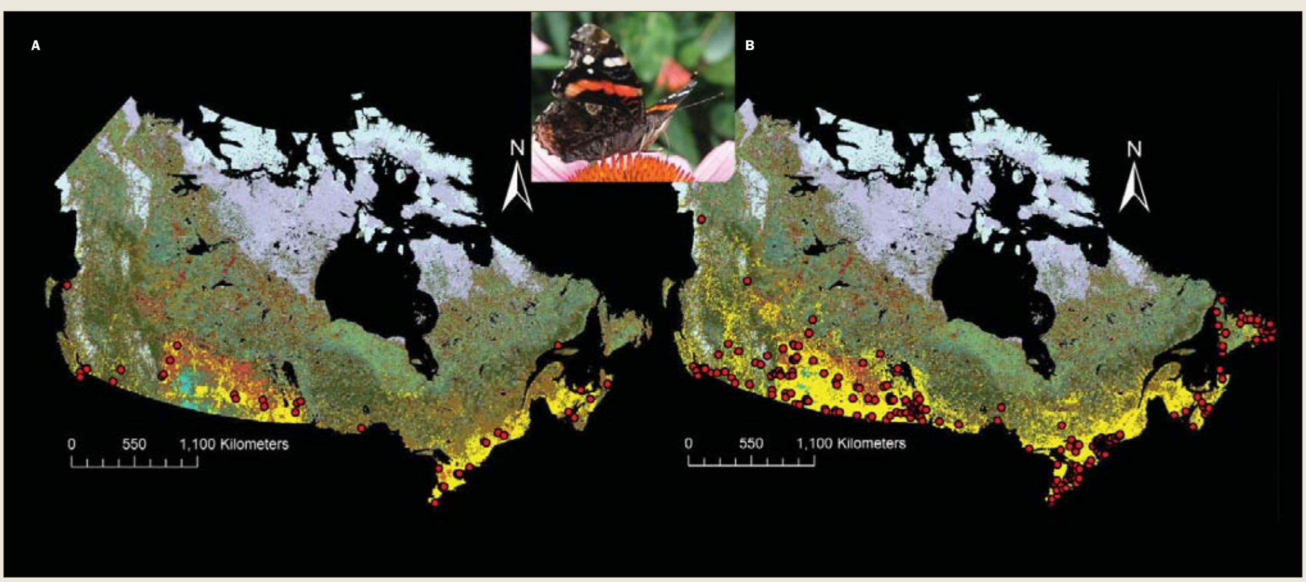
5. A Web-based Graphical User Interface (GUI) for the model provider acts as workflow controller; it allows the access to the GEOSS Clearinghouse to identify other needed services, implements the business process of the typical biodiversity scenario to be run and controlled by the user through the GUI. We have developed a client application running in a web browser environment using AJAX web framework technologies (www.w3schools.com/ajax). With this tool, the user is guided through the process of discovering data (by submitting queries to GI-cat), accessing selected data (through GBIF and Open Geospatial Consortium Web Coverage Services and NCAR data servers) and running ENM projections.

These components play the three typical roles of a Service Oriented Architecture (SOA) where 'Consumers' discover 'Providers' through a 'Registry'. In the example framework, data and model providers are the 'Service Providers', the GUI-controller pair acts as a 'Consumer', and the catalogue plays the role of the 'Registry'.

In this paper we have described how the distributed components needed for global change research can be linked together. In this scenario the GI-cat catalogue service has fulfilled the discovery and linking functions of the GEOSS clearinghouse and the portal as these were not available at the time this work was done in early 2007. The GIS portal and GBIF Data Portal were accessed directly. In the near future, these data services will be registered and discoverable directly through the GEOSS clearinghouse as well. GI-cat has been registered as a GEOSS component implementing an international standard (OGC CS-W) registered as a GEOSS service, making it interoperable with other GEOSS components.

Our experiment demonstrates the role played by international standards in supporting interoperability and the effectiveness of establishing interoperability special arrangements where these standards are not fully supported. This is particularly important in establishing crosswalks among different information communities. The catalogue has proven valuable in managing linkages and integration of highly distributed resources.

Tests using the Canadian butterfly species Vanessa atalanta



A) The distribution of *Vanessa atalanta* based on historical observations of climate, land use, and species location from 1900-1930. B) The distribution of the species has expanded over the course of the 20th century, as shown here from models run on the same data from the 1960-1990 time period. This use of the GEOSS framework demonstrates that species can be highly responsive to climate change and that forecasts for IPCC scenarios in the future are viable and can usefully inform policy

Source: Kerr et al. 2007. *Vanessa atalanta* photo by Jeremy T. Kerr

A possibility of land vegetation observation with SGLI/GCOM-C

Y. Honda, Center for Environmental Remote Sensing (CEReS), Chiba University; M. Moriyama, Nagasaki University; K. Kajiwara, CEReS; A. Ono, Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency

Continuous global observation is necessary for effective environment analysis. Satellite remote sensing is very useful for this purpose, and can provide spatial and temporal monitoring of the global environment. The Japan Aerospace Exploration Agency (JAXA, formerly known as NASDA) has developed a new plan, the Global Change Observation Mission (GCOM), for monitoring global environmental change and understanding its mechanisms, including global warming. Data obtained from GCOM are necessary for the monitoring of global climate change and the improvement of climate models, and this should result in a useful contribution to social benefits.

GCOM is a follow-on satellite observation mission incorporating the technology and results of the Global Imager (GLI) and Advanced Microwave Scanning Radiometer (AMSER) on ADEOS-II. The GCOM mission will consist of two series of medium-sized satellites: GCOM-C (Climate) and GCOM-W (Water). The GCOM-C satellite will carry the Second Generation GLI instrument (SGLI), which is the advanced version of GLI. In addition, the GCOM-W satellite will carry the AMSR follow-on instruments, for example a scatterometer like SeaWinds on board ADEOS-II. Three consecutive generations of satellite, each with a one-year overlap, will have been operated in an observing period of more than 13 years. GCOM is designed to establish long-term observation for monitoring global environment changes, improving knowledge of climate systems, developing climate forecast models and distributing environmental data.

GCOM-C and SGLI

SGLI optical sensors observe reflected solar radiation and/or infrared radiation from the surface of the earth including land, ocean and cloud using multiple channels for measuring biological contents (chlorophyll, photosynthetically active radiation and vegetation index), temperature, snow and ice cover, and cloud distribution. These data are useful for understanding the global circulation of carbon, estimating radiation budget, monitoring environmental changes, and they also help develop our comprehension of primary marine production.

SGLI has 19 spectral channels from near ultraviolet to thermal infrared. In particular, SGLI has some unique channels, which have been used rarely in previous years: a 380 nm channel for aerosol detection over land, 763 nm for oxygen absorption, and 1,380 nm for cirrus cloud detection. Eleven channels from near-UV to short-wavelength infrared (SWIR) have a resolution of 250 m at the nadir, and two channels in the MTIR have a resolution of 500 m, covering a large portion of the Earth's surface with various spatial scales. Various geophysical parameters consisting of atmospheric, oceanic, land and cryospheric parameters are retrieved from radiance data from SGLI. These parameters are used for tasks such as evaluating ocean and land biomass and primary production on a global scale; generating global fields of clouds, water vapour and aerosol parameters; or monitoring snow/ice properties around bipolar regions.

Simulation results of SGLI land products from existing data

Some original SGLI land products are estimated by using new and unique channels of the GCOM-C/SGLI sensor. These are expected to be of great use in understanding and improving climate change.

SGLI can observe surfaces of the earth on a slant in the red and near-infrared (NIR) region. This function improves the detection efficiency of vegetation biomass. Conventional biomass estimation methods using existing vegetation were unable to reflect the three-dimensional structure of the vegetation canopy.

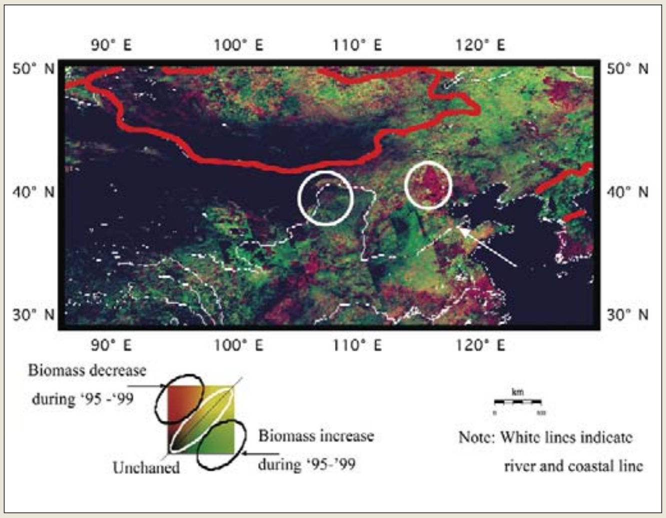
Shadow index

It is inevitable that satellite data will be influenced by shadow. In areas of vegetation, the ratio of visible shadow space varies widely with types of tree, plant growth, season, and so on, because the structures and textures of vegetation differ from each other. Thus, a new vegetation index, the shadow index (SI) has been developed to take into account the influence of shadow effect. SI expresses the difference between vegetation coverage and type, such as closed and open, or evergreen and deciduous broadleaf. It is therefore expected that SI will be useful for analysing vegetation in land-cover classification, vegetation-type classification, vegetation biomass estimation, and so on.

Water Stress Trend

Water is indispensable for animals and plants. Water shortages have serious consequences for many forms of life, but waterless areas are spreading due to the impact of global warming. By monitoring plant growth, it is possible to understand

Biomass change detection using multi-angle observation data

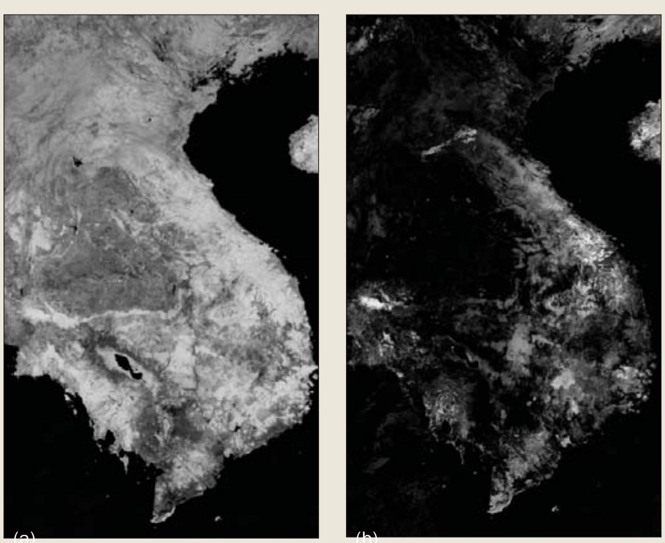


This image shows the change in vegetation biomass obtained from multi-angle observation of red and NIR during 1995 to 1999 in China. The regions enclosed by a white circle show large differences between 1995 and 1999. In these regions, vegetation cover changes significantly.

The observation used data NOAA/AVHRR data obtained from different paths. With the SGLI, different angles of observation are available with a long track — this means that SGLI can observe different angles of reflectance in almost the same atmospheric conditions

Source: NOAA/AVHRR data

Shadow index



Images of ADEOS-II/GLI 250 m data around the Indochina Peninsula on 7-22 April 2003, showing (a) the NDVI image and (b) the SI image in greyscale. The SI is estimated using the normalization method

Source: ADEOS-II/GLI 250 m data

the water stress state of land, and we have developed a new vegetation index, the Water Stress Trend (WST). Water is difficult both to warm up and to cool down, and this means that the temperature variation of vegetation depends on the quantity of water stress. Based on this water characteristic, the WST is estimated using the extent of changes in temperature.

Recently, drought damage has become a serious problem in Australia, and a WST analysis of 2005-2006 shows two distinct periods, with little water stress in 2005, but a lot in 2006. The WST is estimated from the accumulation of differences in radiant temperature, and is useful in detection of waterless areas.

Fire detection index (FDI)

SGLI does not have a 4 m channel, which plays a significant role to the detection of forest fire for MODIS and upcoming VIIRS data processing. However, it does have finer spatial resolution channels, such as 250 m for 1,600 nm and 500 m for 10.8 m. To detect the forest fire from SGLI data, a thresholding technique will be available for 10.8 m, 2,200 nm and 1,600 nm channels. These improvements in spatial resolution give SGLI an ability to detect forest fire detection that is comparable with that of MODIS and VIIRS.

Going forward

JAXA is developing a plan for GCOM, for the monitoring of global environmental change, to be launched in 2013. One aspect of this mission will see SGLI onboard the GCOM-C satellite, providing optical sensors from Near-UV to MTIR. Characteristic specifications of SGLI are as follows:

- Ultraviolet (380 nm)
- Three-direction polarization observation (red and NIR)
- 250 m resolution (from near-UV to SWIR)
- 500 m resolution (MTIR).

From these new and unique characteristics, SGLI Land products generate high-quality land surface reflectance data which correct atmospheric effects. Therefore, GCOM-C/SGLI data provides useful information for many fields of human benefit.

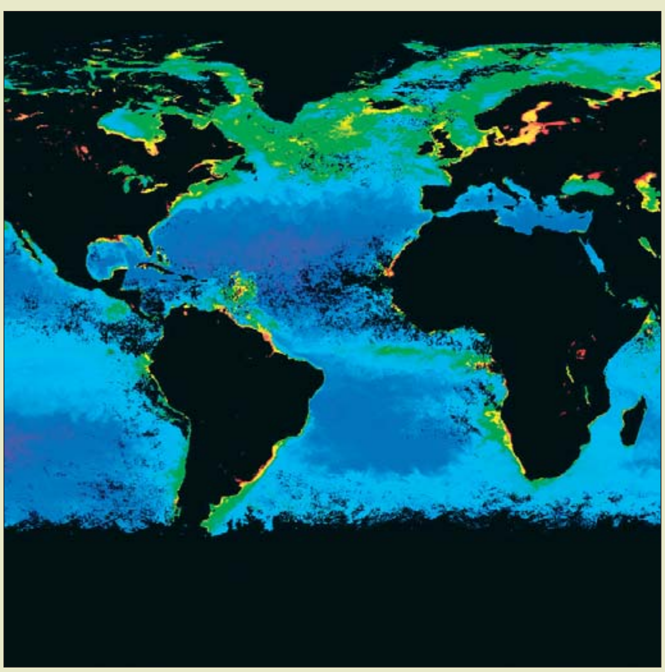
On 16 February 2005, the Kyoto Protocol entered into force, and the Third Earth Observation Summit has agreed the Ten-Year Implementation Plan for GEOSS. The social benefits of GEOSS mainly focus on nine areas: disasters, health, energy, climate, water, weather, ecosystem, agriculture and biodiversity. GCOM seeks to establish a long-term observation system for monitoring global environment changes, improving knowledge of the climate system and developing climate forecast models. GCOM-C/SGLI is a useful satellite that enables an understanding of the absorption levels of carbon dioxide in the land ecosystem, and the monitoring of forest areas. Therefore, SGLI is in a position to contribute effectively to the Intergovernmental Panel on Climate Change, the Kyoto Protocol, and GEOSS.

The green ocean — observations of marine biodiversity

D. James Baker, David Farmer and Kristen Yarincik,
Scientific Steering Committee, Census of Marine Life

From space, a green ocean appears where the chlorophyll of plankton reveals productive areas. But most ocean life, although a vital and connected part of our living planet, is largely hidden from view. Observations of marine biodiversity — from the surface to the bottom of the ocean — are thus a central concern of GEO. Fish have been an essential food source since prehistoric times. Marine life provides much of the oxygen we breathe and removes a significant fraction of the atmosphere's greenhouse gases. Despite years of research on fish and marine mammals, their feeding, breeding and migration patterns remain a mystery to us today. Our ignorance is even deeper when it comes to non-commercial species including the abundant marine microbes and viruses, most of which have yet to be identified.

The Green Ocean



Chlorophyll concentration evident in northern seas and coastal regions (indicated by colours from green to red) as measured by the NASA satellite instrument MODIS on Aqua (1 May-1 June 2007)

Courtesy NASA Goddard Space Flight Center

This ignorance contributes to deep uncertainty about human impacts on the ocean. Coastal pollution, the massive harvest of marine resources using modern techniques and, at ocean scales, the evolving chemical and physical properties associated with global warming, all affect the ocean and its life in unpredictable ways. We are only starting to learn about the interconnectedness of the marine web of life; but the more we learn, the better we understand that when something happens at one level or to one species, other species are impacted, throughout the food web. It is this interconnected character across the diversity of life that motivates our need to understand what lives in the ocean. Exploring and cataloguing this diversity is the central theme of the Census of Marine Life (the Census). The Census is a coordinated international effort to quantify what is known and to identify the unknown and the boundaries of what can be known about life in the world ocean.

The Census is the first international programme to systematically study the global ocean from a biological standpoint. It is providing information, technologies and approaches for critical understanding and management of marine ecosystems. The Census is identifying threatened species and important breeding areas and is helping authorities develop effective strategies for the sustainable management of marine resources. In short, it is both making scientific discoveries and helping society deal with the multiple threats to the ocean from human activity. The Census asks: what lived; what lives; and what will live in the oceans? By combining what we learn about historical trends with our knowledge of what lives there now, we can begin to formulate an answer to the core question of what will live in the ocean of tomorrow. Thus the Census scientific programmes and global database system are a critical contribution to the Global Earth Observing System of Systems (GEOSS).

What is the Census?

The Census of Marine Life is a growing global network of more than 2,000 researchers in more than 80 nations engaged in a ten-year initiative to assess and explain the diversity, distribution, and abundance of marine life in the oceans. The Census uses field projects, new tech-

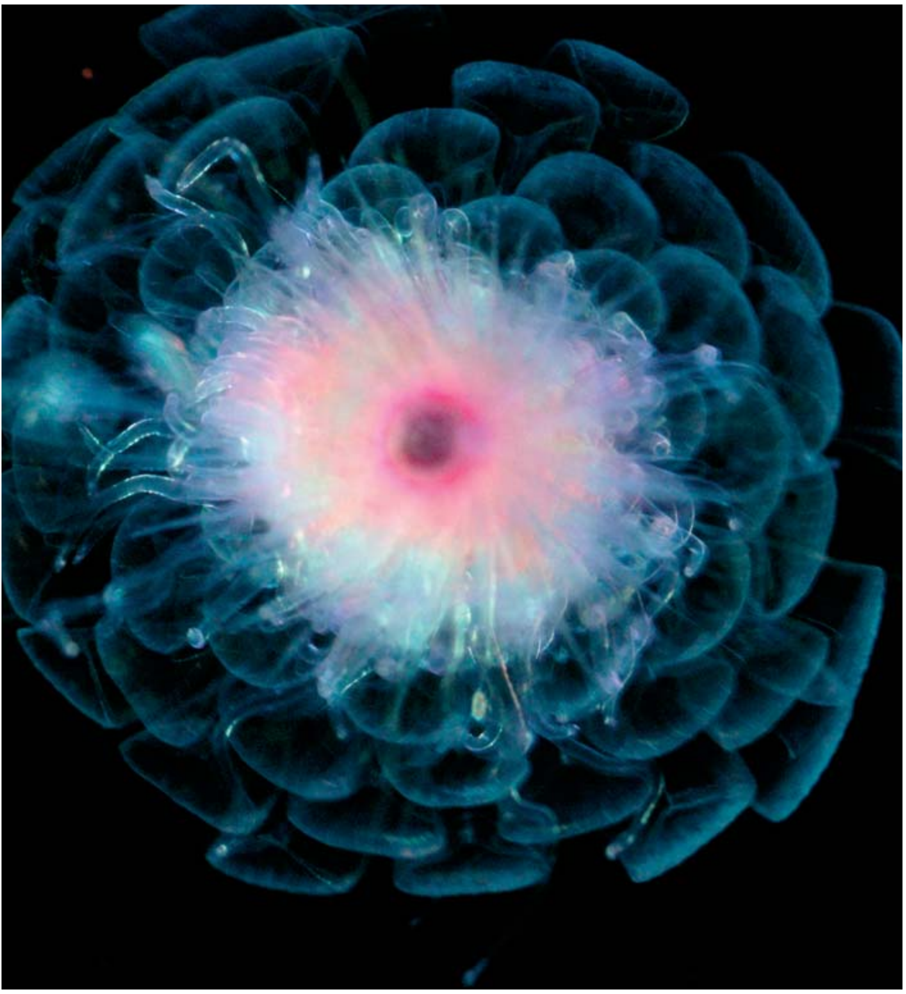
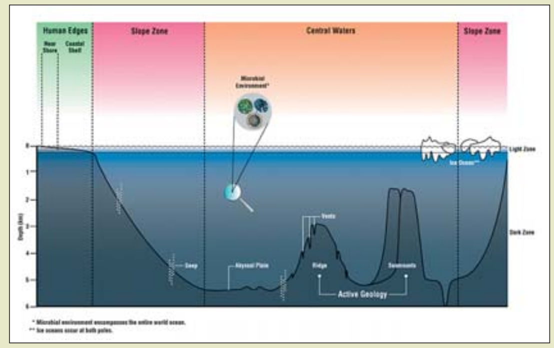


Photo: Larry Madin, Woods Hole Oceanographic Institution, US

Image of newly discovered species: *Athorybia rosacea*, an animal that looks like a flower, flapping its petal-like appendages to swim

Theoretical cross section of the ocean



An ocean basin cross-section illustrating the realms and zones of the world ocean as defined by the Census of Marine Life

Source: Census of Marine Life Communications Team, University of Rhode Island

nology, a data system, studies of historical data and future projections to understand the world of marine biodiversity. Since waters and animals move, the Census is organized by ocean realms. Each of the Census field projects focuses on a specific marine region, habitat, or oceanic community.

The human edge, hidden boundaries and central waters

The coastal projects at the human edge of the ocean are providing databases, collections and expertise allowing developing countries to take a more active stance in reporting and defending the natural biology of their coastal waters. Beyond the coastal zone, the Census studies biological systems at the continental margins and in the sediments of the abyssal plains. This information will help to identify the historical causes and ecological factors regulating biodiversity and global change. Census field projects reveal the biology of the deep Mid-Atlantic, and study the unique biology of deep-water vents and seeps from the sea floor. The Census tracks Pacific salmon and other migratory species that move through the upper ocean where sunlight penetrates.

History, future, data and technology

Current Census projects study microbes, plankton, coral reefs, continental margins, seamounts, and the Arctic and Antarctic to increase understanding of all factors influencing marine biodiversity. The Census also supports the study of historical records, projects through modelling and data analysis what the future is likely to hold, and maintains a major data system — the Ocean Biogeographic Information System (OBIS) — that brings together in an accessible format all of the data collected. New technology is being developed: advanced acoustic methods have been tested for tracking and mapping fish populations instantaneously over thousands of square kilometers, as have optical imaging of small and microscopic life forms, telemetric technologies for identifying and characterizing ocean hotspots for large predators and quantitative tracking approaches for global use. The Census also uses natural DNA labels to keep track of known and newly found species.

In summary, the Census of Marine Life focuses on providing a representative, quantitative record of biodiversity of organisms from microbes to large marine mammals through the 1.5 billion cubic kilometres of the ocean, looking back five hundred years through historical records and forward fifty years using forecasts of ecosystem patterns.

Management

The Census is coordinated by a Secretariat in Washington, DC and governed by an international scientific steering committee as well as several national and regional committees. Support for the Census comes from government agencies concerned with science, environment and fisheries in a growing list of nations as well as from private foundations and companies. The Census is associated or affiliated with a number of intergovernmental and non-governmental organizations.

Census achievements

The Census began in 2000 and its first comprehensive report on findings will be released in 2010. It has achieved several goals that will contribute to this.

Photo: US National Oceanic and Atmospheric Administration (NOAA)

A dense bed of hydrothermal mussels and shrimp covering the slope of the Northwest Eifuki volcano near the Mariana Arc in the western Pacific ocean

Comprehensive assessment of the state of estuaries and coastal ecosystems
Scientific assessments of the changing environment provide the foundation for sustainable management of resources. A Census study of human impact on ecological change traced changes from historical times to the present in species, species invasions, habitats and water quality in twelve estuaries and coastal seas in the US and Canada. This assessment determined how the decline of coastal seas accelerated in the last 150-300 years. This is the most comprehensive quantitative assessment of the state of estuaries and coastal ecosystems to date.

Basin-wide observations of migration patterns and ocean properties
As of 2007, researchers had tagged more than 2,000 animals and birds in the Pacific Ocean, providing unprecedented information on their behaviour. Tags attached to the animals transmit their positions and other information, revealing migration routes and areas where the animals gather to feed and breed. The data will help protect endangered species and help society better manage fisheries that are at risk of collapse.

An extraordinary and largely unexpected bonus of this programme is the transmission of important information about water properties. Temperature and salinity profiles, normally acquired at great cost from ships, are acquired by these 'animal oceanographers,' yielding a rich cache of data of interest to biologists as well as information sought by the oceanographic community — and the Global Ocean Observing System.

Establishment of the Ocean Biogeographic Information System
The Ocean Biogeographic Information System (OBIS) is an online, user-friendly system for absorbing, integrating, and assessing data about life in the oceans. OBIS is aimed at stimulating research generating new hypotheses concerning evolutionary processes, species distributions, and roles of organisms in marine ecosystems. Today, OBIS contains more than 13.4 million records of 82,000 species of marine life from 222 databases. All data are freely available over the Internet and interoperable with similar databases. Software tools are available for data exploration and analysis. Any organization, consortium, project or individual may contribute to OBIS. Given its strengths and global role, OBIS will be a key data management contribution to the overall framework of GEOSS.

How the Census contributes to GEOSS
The Census of Marine Life contributes to GEOSS by laying the groundwork for global biological monitoring in several GEO societal benefit areas.

Biodiversity
One of the goals of GEOSS is to develop a biodiversity observation network on land and for the ocean. The Census, through its various ocean realm projects, provides the information that will guide the development of such a global network. The Census work can facilitate the establishment of monitoring systems and help achieve consensus on data collection protocols and interoperability.

Another goal of GEOSS is to capture historical data on biodiversity from natural history collections in databases and museums as well as from field programmes — data that is critical to the design of observational systems and predictive models. The Census project on the History of Marine Animal Populations aims to improve our understanding of ecosystem biodiversity by focusing on long-term changes in stock abundance and the ecological impact of large-scale harvesting. It helps to answer the question 'what lived in the oceans?'

Agriculture and fisheries
Salmon provide an important economic and protein resource in some parts of the world, but little is known about their migration and life history. The use of acoustical tags is yielding new insights on the marine life history of Pacific salmon as well as promoting the application of new tagging technology. The tagging of an increasing variety of other valuable species is contributing to our understanding of their life history. An international exploration of the macrofauna of the northern mid-Atlantic Ridge ecosystem is revealing comprehensive information on the processes controlling their distribution and the community structures.

Ecosystems and habitat documentation
Through its work on ecosystems of coral reefs, oceanic ridges, the open ocean and the polar regions, the Census

is defining potential protected areas related to fish habitats, deep sea corals and predator hotspots and helps to answer the question, 'what lives in the oceans?' The ecosystem data collected through the Census is being used, for example, to establish areas of reduced fishing in the Northeast Atlantic. Coral reef information helps gauge the impacts of rising temperatures and ocean acidity on this habitat. Studies of past oceanic biodiversity and abundance provide information useful for management on the status of stocks prior to or in early stages of exploitation.

The ecosystems on shallower oceanic features such as seamounts and hotspots, both of which have become targets for unregulated over-exploitation, are also being studied by the Census. The UN Convention on the Law of the Sea is still dealing with defining regulations for the shallower parts of the open ocean. Census projects are providing crucial information and technologies to recognize and manage these ecosystems.

Forecasting what is likely to happen to ecosystems — what will live in the oceans — is being carried out by a network of statisticians and mathematical modellers. Models will focus on sampling design and assimilate data in order to understand the transformation of marine life in earlier times to present conditions, and to forecast the likely future.

Climate

Marine life is sensitive to climate change over a wide range of latitudes; the database developed through Census activities will contribute to charting its response. The Census has research programmes in both polar regions that will guide long-term biological monitoring beyond the International Polar Year. The Census is surveying the Southern Ocean to understand the biological diversity of this unique and poorly understood environment. Global warming is transforming the Arctic sea: the year-round ice realm may cease to exist within the next 50 to 100 years. The Census includes an international collaborative effort to inventory biodiversity in the Arctic sea ice, water column and sea floor.

Status of the Census today; plans for the future

Having begun in 2000, the Census of Marine Life is now in its seventh year of studying life in the sea. Each of the projects is mature and providing new insights and information, and OBIS is collecting and disseminating information as required. Because of its very nature, this work must continue well beyond the end of currently planned field and ocean realm projects.

The principal goal of the Census in 2010 is to have a representative record of global marine biodiversity patterns, available through OBIS, that can be used to enable commercial, legal and conservation interests to deal sustainably with ocean biodiversity. For example, the data in OBIS is proving valuable as nations develop Marine Protected Areas to preserve biodiversity and increase sustainability of fisheries. In addition to this information, the Census will provide legacies of proven technology and science input to management principles and international cooperation. Especially important is the legacy of demonstrating that a coordinated, multifaceted effort to explore ocean biodiversity can make real inroads on this seemingly overwhelming but vitally important task.

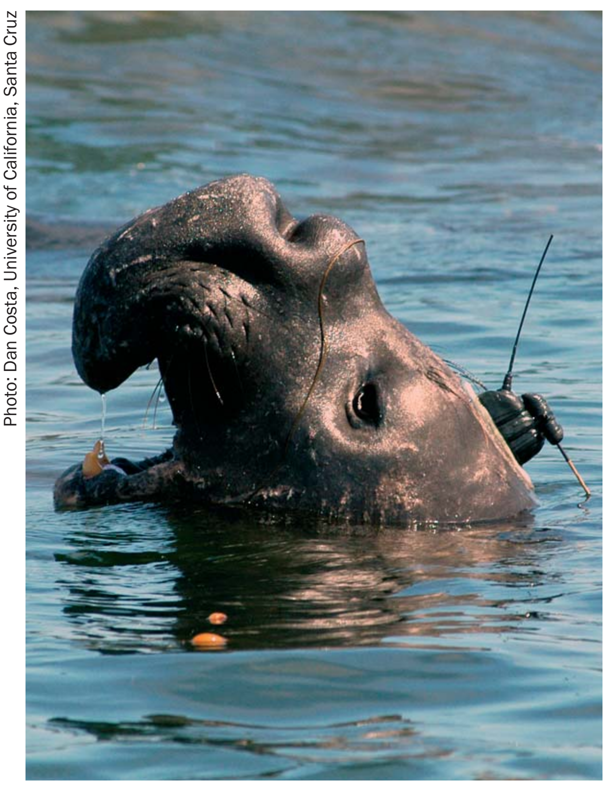
In 2010, the Census fieldwork will end and its first comprehensive report on the status of knowledge of marine biodiversity will be released, with a focus on integration, synthesis and visualization. The work of the Census will have provided both the knowledge and technology for future marine biological monitoring systems.

The UN General Assembly has called for regular Global Marine Assessments, and the Census intends that its realm projects and OBIS will become standards for these. Similarly, agencies around the world have called for an 'ecosystem approach' to sustainable fisheries management within their Exclusive Economic Zones. What could be more important to managing an ecosystem than knowing what lives there?

It is important to note that the Census has been funded as a research programme. Long-term monitoring of ocean biodiversity will depend on long-term support within an operational GEOSS framework. By emphasizing the societal benefits of global systematic biodiversity measurements and associated data systems, GEO can bring awareness at the ministerial level of the green ocean and all life in the sea, and the critical need for long-term stable funding for these observations. At the same time, the breadth of GEO will encourage collaborations among the Census and related biodiversity programmes to identify and fill remaining gaps so that the societal benefits of GEO can be met.

Looking beyond 2010, the Intergovernmental Oceanographic Commission of UNESCO has initiated discussions with the Census to develop a strategy for building a long-term biological monitoring programme. Such a programme will eventually be an integral part of GEOSS, and will provide it with the marine biodiversity data essential to society's needs.

Photo: Dan Costa, University of California, Santa Cruz



An elephant seal with a satellite tag attached

Reliable Earth observation systems for science and sustainable development in Southern Africa

J. C. Pauw, South African Environmental Observation Network

The Southern African environment is characterised by high levels of variability and biodiversity. Rainfall is a primary driver of the terrestrial ecosystems, but its high variability limits its usefulness as an indicator of environmental change. Rainfall outcomes are complicated by the timing, frequency and intensity of rainfall events, as well as conditions of surface temperature, humidity, soil, slope and vegetation. These complexities, coupled with differential responses by thousands of species, cause uncertainty about the direction and extent of rainfall-induced change.

Southern Africa's indigenous biodiversity, landscapes and oceans are continuously changed by diverse and adjoining land uses such as mining, farming, conservation, forestry, urban sprawl, communal resource management, fishing and golf estates. Time-series data covering the spectrum of spatial scales is essential for reliable data on significant environmental change, some of which are slow, while others may be sudden. Data obtained over short periods from a single area offers only limited value.

Photo: JC Pauw

The Succulent Karoo area of South Africa is an example of a global biodiversity hotspot

The advance of climate change is already being observed, but how and where it will impact on Southern African society remains uncertain. Rural communities, commonly desperate for resources and information, are particularly vulnerable to climatic variability. This is often further pronounced by unsustainable agricultural and fishing practices, conducted not only by the communities themselves, but also by commercial and illicit enterprises. Earth observation science is thus urgently required to bring more certainty about environmental change, and to enable formulation of adaptive and mitigating management policies and practices, for themes ranging from food production to population health.

A forum for Southern African Earth observation

While ecosystems and environmental issues are not constrained by political boundaries, Earth observation science in Southern Africa is yet deficient in its cohesion, capacity and infrastructure. With this in mind five countries (Botswana, Malawi, Mozambique, Namibia and South Africa) formed observation networks and joined to form the Environmental Observatories of Southern Africa (ELTOSA). ELTOSA was launched in 2003 to create synergy among the countries and to create sufficient critical mass in human and infrastructural capacity for Earth observation.

ELTOSA countries collaborate to increase the effectiveness of regional Earth observation and information. Governments readily appreciate that pertinent priorities, such as climate change, food security, population health, land reform, economic development, waste and pollution management, energy supply and environmental security, rely on sound Earth observation to underpin guidelines for sustainable development. ELTOSA's vision is for integrated observations of regional environmental processes (eg desertification, land degradation, climate change) and events (eg droughts, floods). The resulting data enables the delivery of adequate information to maintain productive ecosystems; a fundamental requirement for sustainable development.

Photo: JC Pauw

Southern Africa's environment is continuously changed by diverse and adjoining land uses, here separated by only a fence and illustrating very different impacts on the same ecosystem

Photo: JC Pauw

The firewood and charcoal trade

Integrating Earth observation systems

The most advanced observation network in the Southern African region is the South African Environmental Observation Network (SAEON), formally established in 2002 after a few years of deliberation among the research community. The Department of Science and Technology took the lead among relevant government departments by mandating and funding the National Research Foundation to develop SAEON as an institutionalised network of departments, science councils, universities, research institutes and industrial partners. The Department of Science and Technology's vision was to establish an Earth observation platform supporting the various mandates of the different participating organisations. These organisations range from departments with environmental concerns (Environmental Affairs and Tourism, Water Affairs and Forestry, Agriculture, Minerals and Energy, Provincial and Local Government) to the cohort of science councils, universities and large commercial and parastatal businesses, and overall, for public good.

SAEON operates on a number of guiding principles. It aims to be comprehensive in scope by covering terrestrial, atmospheric and oceanic systems, inclusive of recent-past environmental conditions that may be inferred from geological and palaeontological observations. Observations of human interactions with, and impact on nature (eg settlements, recreation), human use of goods (eg firewood, food) and services (eg water, biodiversity) obtained from ecosystems are prerequisites for understanding environmental change. 'Comprehensive' also implies collating, archiving and interpreting data over long periods, as well as covering important eco-regions at multiple scales, from point observations to remotely-sensed landscape observations.

Photo: JC Pauw

The SAEON team promotes the archiving and accessibility of environmental data

The South African government recognises that a national Earth observation system must be durable in its design and management. Hence, SAEON's network design promotes the integration of existing environmental observation systems. Stabilised by core funding and the institutional capacities of its diverse range of participants, SAEON stands neutral and resilient to the internal dynamics of individual participants, and leverages contributions to the system.

SAEON coordinates Earth observation systems through three tiers of stakeholder advisory committees, namely political, technical and operational. Its scientific design is continuously refined to be responsive to emerging environmental issues and corresponds largely with the societal benefit areas of GEO. The current SAEON themes are water, soil, nutrient cycling, biodiversity, disturbance regimes and climate change. Six SAEON nodes have been designated at distributed locations for geographical spread. These nodes are offices coordinating and facilitating observation and information systems for four terrestrial regions, the coastal zone and offshore marine systems. Once established, they attract worldwide research interest.

Developing information systems for Earth observation

In addition to its nodes, SAEON also coordinates domain-specific data centres (for example, Southern African Data Centre for Oceanography). To connect the distributed data holdings of nodes and data providers, Photo: JC Pauw

Settlement poverty

SAEON developed an online information management system with spatial analytical capability. Users are able to obtain and integrate data from a variety of data providers via the SAEON data portal. The data policy determines that SAEON data is by default publicly accessible and therefore available through GEOSS. The system accommodates external data for which the data provider determines the conditions for access, ranging from immediate full and open access to a legacy upon retirement or death. Non-SAEON data holders may also provide access to individuals of their choice. At its base, the policy aims to gradually overcome the pervasive resistance to data sharing in the research community.

The information system is largely based on open-source software allowing for continuous upgrading and interoperability. This strategy is particular to South Africa's developing economy status, wherein the cost of electronic capability is often prohibitive. Bandwidth for the transfer of bulk research data also remains a limiting factor, but is presently being addressed by the Department of Science and Technology.

Developing human capacity for Earth observation

South Africa's science system is seriously deficient in human capacity. SAEON engages with scientific capacity building at two levels, namely secondary (grades 9 to 11) and tertiary education, to form a pipeline that delivers potential future Earth observation scientists. An education-outreach programme focuses on providing support for science teachers through training workshops and interaction with research scientists. Science awareness is also advanced by staging annual science events. SAEON-designed environmental monitoring projects support the official education curriculum and are performed by schools under the guidance of SAEON nodes. Meritorious learners are annually engaged in a winter school where they enjoy interactive science education.

At university level, a graduate student network was launched in 2006 for research students active in the SAEON domain, some of whom work at SAEON nodes. A website connects students working in different parts of the region so that they can share data, knowledge and opinions. There is also an annual winter school for students to present their work, to debate research issues, to interact with experts in the field and to be exposed to disciplines other than their own. Those young Earth observation scientists appreciate integrative Earth observation science and are poised to take SAEON forward.

Strategic considerations

ELTOSA and SAEON enjoy government endorsement and are considered critical and strategic elements of GEOSS. Without them, large volumes of Earth observation data will be lost and local observation systems will continue to be fragmented and inaccessible, and thus converse to the democratic principle of data and information accessibility. Likewise, GEOSS enables the repatriation of data from international sources to national networks.

Due to their Southern African location, on a continent challenged by human and infrastructural capacity, these networks require continuous support through funding, training and research equipment. International workers on location, and through GEOSS, make important contributions to the data and information base. However, indigenous capacity must be nurtured if politically legitimate and contextual knowledge-based advice is to benefit national governments.

Notes & References

The following are notes and bibliographical references to the articles contained within *The Full Picture*, as provided by the individual authors. For further information on any article or author, please contact the publisher.

I
National and Regional Reports

GMES and GEOSS: towards a new era in Earth observation

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Earth observations - JAXA's role

Japan Aerospace Exploration Agency

1. See NOAA's Role in Space-Based Global Precipitation Estimation and Application, National Academy of Sciences, August 2006

The INM's Izaña Atmospheric Research Centre, a GEO-oriented experience

The Izaña Atmospheric Research Centre (Izaña-ARC) is managed by the Instituto Nacional de Meteorología (INM; the National Meteorological Institute of Spain). The Izaña-ARC has operated a super-site (28ºN, 16ºW, 2400 m a.s.l.) since 1984 where atmospheric monitoring, research is carried out, and where GEO-oriented multidisciplinary projects, with scope over large regions of the Earth, are developed.

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3. http://aeronet.gsfc.nasa.gov
4. www.bsc.es/projects/earthscience/dream
5. Data is available at www.polarvortex.org

The UK piece of the GEO puzzle

1. Further information with links to BNSC partners' websites can be found at: http//www.bnsc.gov.uk

II
The Global Earth Observation System of Systems Components

Observing systems

The blue planet — observations of the global ocean

1. The GOOS writing team is: Keith Alverson, Pierre Bahurel, Peter Dexter, Paul DiGiacomo, Jean-Louis Fellous, John Field, John Gould, Richard Graham, Ed Harrison, Tom Malone, Jose Muelbert, Bob Weller and Stan Wilson.

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Appendix 1. CTFS Network Partners

The Americas

Brazil – National Institute of Research of the Amazônia (INPA), Universidade de Sao Paulo; Louisiana State University (USA).

Colombia – Instituto Humboldt, Instituto Amazonico De Investigaciones Cientificas (SINCHI), University of Medellín (UNALMED).

Ecuador – Universidad Catolica de Ecuador, University of Aarhus (Denmark), Chicago Field Museum (USA).

Panama – STRI (USA), Canal Authority (Panama), University of Georgia (USA).

Puerto Rico – University of Puerto Rico, USDA Forest Service.

Africa

Cameroon – Bioresources Development and Conservation Program, Oregon State University (USA), University of Buea (Cameroon).

Democratic Republic of Congo – Centre de Formation et de Recherche en Conservation Forestière (CEFRECOF), Wildlife Conservation Society.

Asia

China – Chinese Academy of Sciences, Xishuangbanna Tropical Botanical Garden.

India – Indian Institute of Science.

Malaysia – Forest Research Institute of Malaysia, Sarawak Forest Department, Osaka City University (Japan), Kyoto University (Japan), National Institute of Environmental Studies (Japan), Harvard University (USA).

Philippines – University of Philippines, Diliman Campus, Manila, (Philippines), Isabela State University, Plan International, Conservation International (Philippines), Harvard University (USA).

Singapore – National Institute for Education at Nanyang Technological University, Singapore National Parks Board, National University Singapore.

Sri Lanka – University of Peradeniya, Sri Lanka Forest Department, University of Sri Jayawardenepura.

Taiwan – Tunghai University, Taiwan Forestry Research Institute.

Thailand – Royal Forest Department, National Institute of Environmental Studies (Japan), Harvard University (USA), National Parks and Wildlife Department, Kyoto University (Japan).

European geological surveys and GEOSS — observing the Earth beneath our feet: why does it matter?

1. Full information on GeoSciML and access to the operational test bed is available at https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/GeoSciML
2. A Directive is a law applicable in all EU member states, to which national laws must conform after a transition period of two years in the case of INSPIRE.
3. The International Year of the Planet Earth and One Geology websites are respectively available via these links: http://www.esfs.org/ (IYPE) and http://www.onegeology.org/ (OneGeology).
4. The European Geochemical Atlas and its underpinning data are freely downloadable here: http://www.gtk.fi/publ/foregsatlas/index.php
5. The list is available for download here: http://www.eurogeosurveys.org/_STUDIOEMMA_WWW/uploads/File/EGS%20Research%20database%2020.06.07.xls

NSF's observing systems: platforms for large-scale environmental research

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Acknowledgments:

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Dissemination/Information systems

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Prediction systems

The socio-economic and environmental benefits of a revolution in weather, climate and Earth-system analysis and prediction

1. This document was prepared by scientists from the World Weather Research Programme (WWRP), World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP) and the natural-hazards and socioeconomic communities. The authors' individual affiliations are as follows:
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   Rick Anthes, President of the University Corporation for Atmospheric Research, USA
   Zoltan Toth, NOAA/NCEP Environmental Modeling Center, USA
2. The Earth system encompasses the atmosphere and its chemical composition, the oceans, land/sea-ice and other cryosphere components; the land-surface, including surface hydrology and wetlands, lakes; and short-timescale phenomena that result from the interaction between one or more components, such as ocean waves and storm surge. On longer timescales (e.g. climate), the terrestrial and ocean ecosystems, including the carbon and nitrogen cycles and slowly varying cryosphere components, e.g. the large continental ice sheets and permafrost, would also be considered to be part of the Earth system.
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III
GEOSS Societal Benefit Areas

Disasters

Disaster risk management: an investment in development

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3. Approved by the WMO Congress in May 2003

About the authors:

Dr. Golnaraghi joined the WMO in 2004 to head up its new Disaster Risk Reduction Programme. In this capacity, she has (i) developed Programme's strategic goals and implementation plan, with particular focus on building international cooperation programmes in risk assessment, early warning systems and financial risk transfer markets, which was adopted by 188 countries, (ii) built bi- and multi-lateral partnerships among UN and international agencies and private sector, and (iii) initiated fund raising with international financial and development institutions to support national and regional projects in developing and least developed countries. Dr. Golnaraghi serves in a number of international committees and advisory groups. Prior to WMO, she was the CEO of Climate Risk Solutions, Inc., a consulting firm headquartered in Boston, Massachusetts, providing innovative risk management solutions for energy, agricultural and financial sectors with a focus on Catastrophe Insurance and Weather Risk Management, based on the latest scientific and technological developments in the fields of climate and meteorology. Dr. Golnaraghi holds a B.Sc. in Chemical Engineering from Cornell

University, a Masters of Science in Applied Physics and a Ph.D. in Physical Oceanography from Harvard University. She can be contacted at mgolnaraghi@wmo.int
Mr Jean-Baptiste Migraine is a Junior Professional Officer working with the WMO DRR Programme.

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Acknowledgments

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Acronyms

CryoSat-2 Second Cryospheric Satellite
GCOS Global Climate Observing System
GFO GeoSat Follow-on Satellite
GLONASS Global Orbiting Navigation Satellite System
GLOSS Global Sea Level Observing System
GNSS Global Navigation Satellite System
GOCE Gravity Field and Steady-State Ocean Circulation Explorer Satellite
GPS Global Positioning System
GRACE Gravity Recovery and Climate Experiment Satellite
ICESat Ice, Cloud, and Land Elevation Satellite
InSAR Interferometric Synthetic Aperture Radar
SLR Satellite Laser Ranging

Health

Applications of remote sensing technologies for monitoring human health

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The contents of this article are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of WMO, NOAA or the US Government.

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The ECMWF portal URL is: http://tigge-portal.ecmwf.int/d/tigge

Acknowledgements:

The TIGGE-Working Group is composed of representatives from forecasting centres and the academic community, and has held several meetings to agree on the formats and the content of the initial archive. The IT teams at ECMWF, NCAR and CMA have invested considerable work to initiate the routine exchange and accumulation of data in good technical conditions. Baudouin Raoult of ECMWF and Doug Schuster of NCAR are especially acknowledged for their contribution to the project. The willingness and diligence of the ten providing centres to share their ensemble forecast data is also acknowledged. Jim Caughey and Len Barrie provided useful comments on an early draft of this paper.

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Roger Sayre, U.S. Geological Survey, and GEO Task Lead and POC for EC-07-02
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Douglas Muchoney, Group on Earth Observations/U.S. Geological Survey, and GEO Task Sponsor

Global land cover observations

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Agriculture

The business of capacity-development

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Sustainable agriculture and earth observation

Time-series visualization products and imagery used in the crop condition assessment process, previously only available to the crop analyst, are available to the public on the CropExplorer web site http://www.USDA Foreign Agricultural Service.fas.usda.gov/cropexplorer/ and satellite imagery is available via the USGS web site http://edc.usgs.gov/.

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