Global Earth Observation System of Systems GEOSS

10-Year Implementation Plan Reference Document

Ad-hoc Group on Earth Observations

FINAL DRAFT

Acknowledgement

The Group on Earth Observations would like to thank the members of the ad hoc GEO Implementation Plan Task Team, the ad hoc GEO subgroups, and the many scientists and technical experts who contributed to the development of this document.

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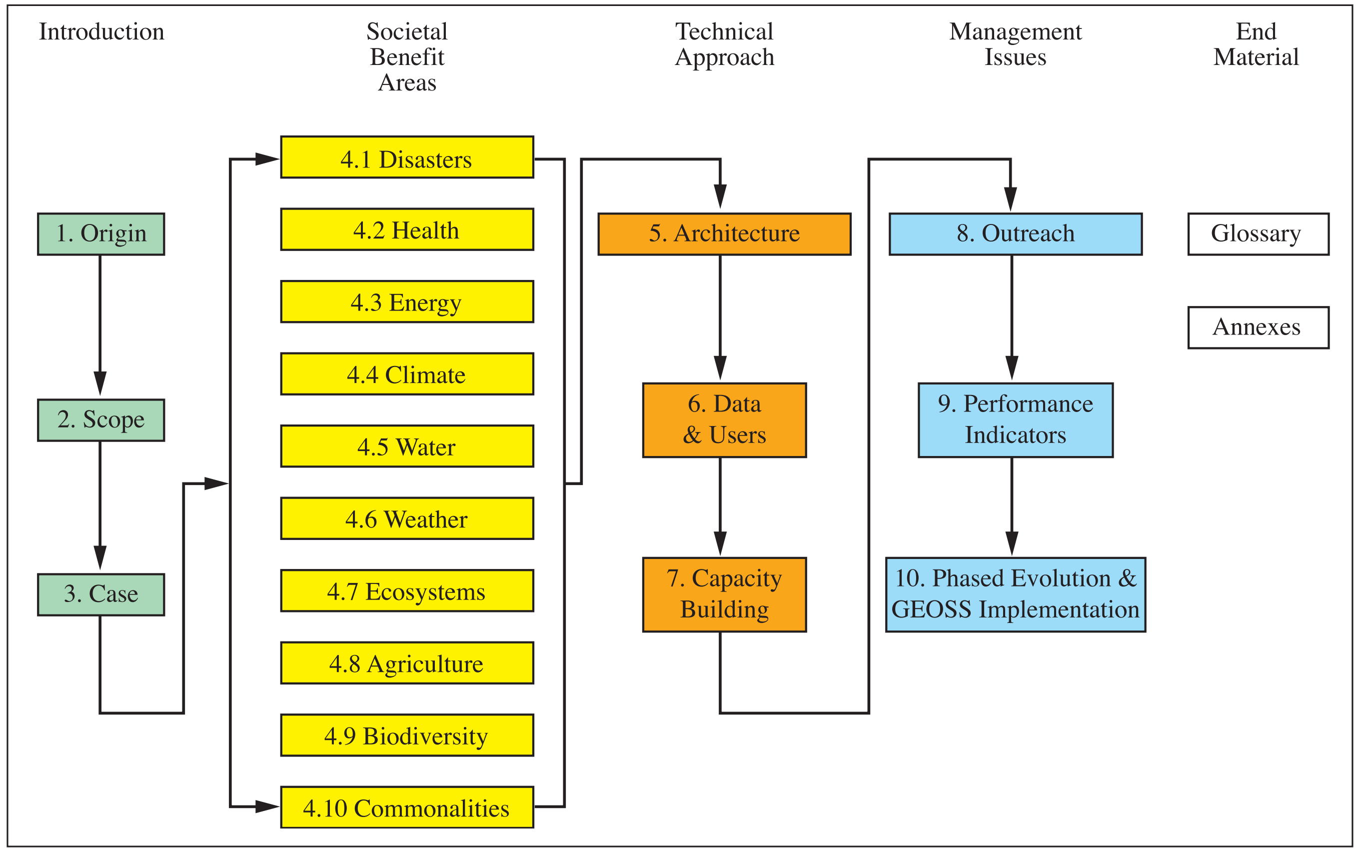
GEO 204/ESA SP-1284, February 2005
Published by: ESA Publications Division
ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands
Editor: Bruce Battrick
Design and Layout: Jules Perel

ISSN No.: 0379-6566
ISBN No.: 92-9092-986-3
Printed in the Netherlands

CONTENTS

DOCUMENT PLAN



1

ORIGIN AND PURPOSE

1 Origin and Purpose of this Plan

The World Summit on Sustainable Development, Johannesburg 2002 (WSSD), highlighted the urgent need for coordinated observations relating to the state of the Earth.[1] This Plan is a step toward addressing the challenges articulated by the WSSD and fulfilling the Millennium Development Goals. It will also further the implementation of international environmental treaty obligations.[1]

A meeting of the Heads of State of the Group of 8 Industrialized Countries Summit in June 2003 in Evian, France, affirmed the importance of Earth Observation as a priority activity. The first Earth Observation Summit convened in Washington, DC in July 2003, was attended by high-level officials from 33 countries and the European Commission and 21 international organizations involved in Earth observations.[2] Governments adopted a Declaration signifying a political commitment to move towards development of a comprehensive, coordinated, and sustained Earth observation system of systems. The Summit established the *ad hoc* intergovernmental Group on Earth Observations (*ad hoc* GEO), co-chaired by the European Commission, Japan, South Africa, and the United States, and tasked it with the development of an initial 10-Year Implementation Plan by February 2005. The *ad hoc* GEO established five technical subgroups and a small secretariat. A series of subgroup meetings and a plenary meeting led to a Framework Document,[3] negotiated at GEO-3 in Cape Town and adopted at the second Earth Observation Summit in Tokyo in April 2004 by 43 countries and the European Commission, joined by 25 international organizations. The Framework defines the scope and intent of a Global Earth Observation System of Systems (GEOSS). A small task team was charged by the *ad hoc* GEO with the drafting of an Implementation Plan, building on inputs from the subgroups and other sources.

The GEOSS 10-Year Implementation Plan establishes the intent, operating principles, and institutions relating to GEOSS. It is supported by a longer Reference Document (this document), which is consistent with the Plan, and provides substantive detail necessary for implementation. The Plan was negotiated by the *ad hoc* GEO in Ottawa in November 2004, and adopted at the third Earth Observation Summit in Brussels, in February 2005. The Reference Document was extensively reviewed by technical experts, countries and international organizations.

The third Earth Observation Summit established the Group on Earth Observations (GEO). Membership in GEO is open to all member States of the United Nations and to the European Commission. GEO welcomes as Participating Organizations intergovernmental, international, and regional organizations with a mandate in Earth observation or related activities, subject to approval by Members. GEO may invite other relevant entities to participate in its activities as observers.

[1] *The Johannesburg Declaration on Sustainable Development and Plan of Implementation, World Summit on Sustainable Development, September 2002. See http://www.johannesburgsummit.org/. See also Millennium Declaration, September 2000, and Road Map towards the Implementation of the United Nations Millennium Declaration, September 2001. See http:/www.developmentgoals.org*
[2] *Declaration of the First Earth Observation Summit, July 2003. See Annex 1. See also: http://www.earthobservationsummit.gov/declaration.html or http://earthobservations.org/declaration.asp*
[3] *Framework Document, April 2004. See Annex 2. See also: http://www.mext.go.jp/english/kaihatu/earth/resume/framworkdocument_e.htm*

2

SCOPE

2 Scope of the GEOSS Implementation Plan

The Washington Summit Declaration establishes the objective *"to monitor continuously the state of the Earth, to increase understanding of dynamic Earth processes, to enhance prediction of the Earth system, and to further implement our international environmental treaty obligations",* and thus the need for *"timely, quality, long-term, global information as a basis for sound decision making*". The Framework Document adds that to move from principles to action, a *"10-Year Implementation Plan for establishing the Global Earth Observation System of Systems (GEOSS)"*, which should be *"comprehensive", "coordinated",* and *"sustained"* is needed.

The vision for GEOSS is to realize a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive, and sustained Earth observations and information.

The GEOSS 10-Year Implementation Plan defines a sequence of actions and responsibilities, commencing from the third Earth Observation Summit in February 2005. GEOSS has an indefinite lifetime, subject to periodic review of its continued effectiveness.

A global…

GEOSS aspires to involve all countries of the World, and to cover *in situ* observations as well as airborne and space-based observations. The focus of GEOSS is on observations relevant to large parts of the World and issues that require comprehensive information to be addressed optimally.

In the GEOSS context, the word 'global' thus has two meanings. In the first sense, GEOSS aspires to be as inclusive as possible, embracing all countries and parts of the World and all organizations with Earth Observation mandates. In the second sense, the priority focus of GEOSS is Earth system processes that operate at scales greater than the individual country, for instance the global climate system or regionally shared river basins. Phenomena for which the causes and consequences are mostly expressed at lesser scales are the primary responsibility of local and national observing systems, but *may* be included in GEOSS if any of the following three conditions are met:

- They have global consequences in aggregate (e.g. desertification).
- They have significant global-scale causes (e.g. biodiversity loss).
- Their observation is enhanced by global systems (e.g. natural hazards).

…system of systems…

GEOSS will be a "system of systems" with components consisting of existing and future Earth observation systems across the processing cycle from primary observation to information production. The Earth observing systems that participate in GEOSS retain their existing mandates and governance arrangements, supplemented by their involvement in GEOSS. Through GEOSS, they will share observations and products with the system as a whole and take such steps as are necessary to ensure that the shared observations and products are accessible, comparable, and understandable, by supporting common standards and adaptation to user needs.

GEOSS thus makes it possible to combine information from currently unconnected sources, in order to obtain a view that is sufficiently comprehensive to meet user needs.

The change in comparison with the current situation will be:

a) GEOSS will, in cooperation with participating systems and with the various user communities, attempt to identify gaps and unnecessary duplications, redirect or initiate activities to optimize the system, and ensure the necessary continuity in observations. By cooperating on new missions, it will encourage a more effective overall fulfilment of user observational needs.

b) GEOSS systems will abide by interface specifications with respect to the portion of their data systems that they agree to share, which will provide meaningful links between systems, and will help to make their products more compatible with those of other systems and thus of use to a wide community.

GEOSS will provide the overall conceptual and organizational framework to build towards integrated global Earth observations to meet user needs. GEOSS does not mean an attempt to incorporate all Earth Observing systems into a single, monolithic, centrally controlled system. It is intended to improve the data supply to users and not as a justification for annexing existing observation and data distribution systems into a new international organization. GEOSS systems are themselves often 'systems of systems'. It is desirable to organize in this way in order to remain closely in touch with dynamic observational requirements within particular societal benefit areas and geographical domains. GEOSS is an attempt to address some of the disadvantages of such an arrangement when it occurs without coordination. The principle of subsidiarity applies: decisions need to be taken at the lowest level in the system hierarchy that is competent to take them.

…for Earth Observation

GEOSS will facilitate access to direct *observations* as well as *products* based on the collation, interpolation, and processing of observations. It will also conduct the *activities* necessary for such a coordinated system, such as the maintenance of data requirements, data description, and exchange standards. The observations provided through GEOSS will originate entirely from contributing national, intergovernmental and non-governmental systems. They will include observations made outside the territory of any nation, for example of open oceans or Antarctica, and from space. GEOSS will give priority to the continuity and adequacy of, and access to, observation-based products critical to identified user needs within the nine societal benefit areas, and to the development of those that are not currently available.

The content of GEOSS will be defined, from time to time, through its governance structures. Initially it covers the nine societal benefit areas identified by the second Earth Observation Summit to be beneficial to many countries, and included in the Framework Document. GEOSS should be built step-by-step through cooperation among existing observing and processing systems, while encouraging and accommodating new components as needs and capabilities develop. The plan includes the actions needed to build capacity, particularly in developing countries, that will allow all to contribute, and permit the system to be useful to all.

The scope and focus of GEOSS, as implemented by its component systems, is illustrated in Figure 2.1.

GEOSS, collectively, has several functional components:

- to address identified common user requirements
- to acquire observational data
- to process data into useful products
- to exchange, disseminate, and archive shared data, metadata and products; and
- to monitor performance against the defined requirements and intended benefits.

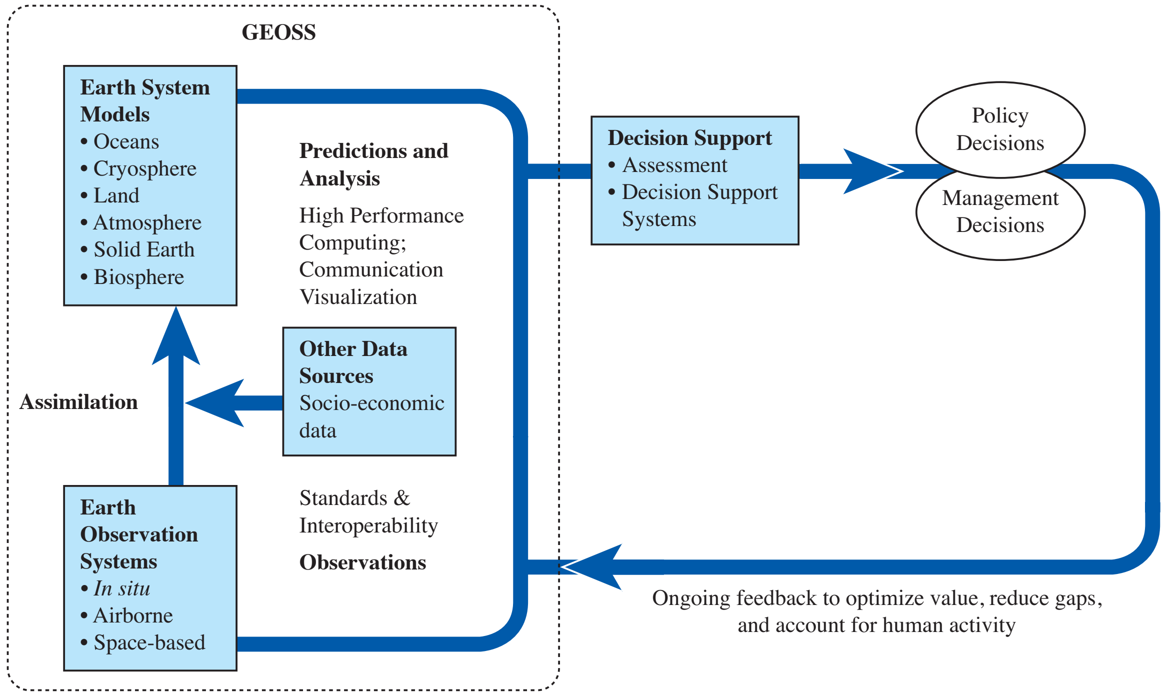


Figure 2.1. This diagram demonstrates the end-to-end nature of data provision, the feedback loop from user requirements, and the role of GEOSS in this process. The primary focus of GEOSS is on the left side of the diagram.

GEOSS builds upon current cooperation efforts between existing observing and processing systems, while encouraging and accommodating new components. Across the processing cycle from data collection to information production, participating systems maintain their mandates, their national, regional and/or intergovernmental responsibilities, including technical operations and ownership.

For required new components, GEO Members and Participating Organizations will establish, or encourage the establishment of a responsible entity, preferably within an existing organization. They may also coordinate with non-participating commercial, academic, and other organizations. Local, national, regional and international authorities, operating within their mandates, may access and use GEOSS data and products in the preparation and issuance for guidance resulting in societal benefits.

The GEOSS 10-Year Implementation Plan, together with this Reference Document, addresses not only cost effectiveness and technical feasibility, but also institutional feasibility.

The design approach for GEOSS builds on existing systems and data, as well as existing documentation describing observational needs in these areas.

GEOSS is based on several key principles:

- GEOSS is to be driven by user needs, support a broad range of implementation options, and be able to incorporate new technology and methods.
- GEOSS is to address planned and existing observation systems required to make products, forecasts and related decisions.
- GEOSS is to include observing, processing, and dissemination capabilities interfaced through interoperability specifications established and adhered to by all contributing systems.
- GEOSS observations and products are to be observed, recorded and stored in clearly defined formats, with metadata and quality indications to enable search and retrieval, and archived as accessible data sets.

- GEOSS is to provide a framework for securing the future continuity of observations and initiating of new observations.
- GEO Members and Participating Organizations and the components they support are to be documented in a catalogue that is publicly accessible, network distributed, and interoperable with major Earth Observation catalogues.
- GEOSS will work closely with research initiatives that may use GEOSS data and products, as well as improve the effectiveness of future observing systems.
- GEO Members and Participating Organizations will provide training, education, and capacity building to facilitate GEOSS adoption and long-term use.

3

THE CASE FOR GEOSS

3 The Case for a Global Earth Observation System of Systems

Rational management of the Earth system, in both its natural and human aspects, requires information that is both relevant and timely. Ensuring that such information is available to those who need it is a function of governments and institutions at all levels. Despite laudable efforts in some domains, the current situation with respect to the availability of Earth observations is far from satisfactory, particularly in terms of coordination and data sharing between countries, organizations and disciplines, to meet the needs of sustainable development. There is therefore a need, as agreed at the World Summit on Sustainable Development, in the Framework Document, and in many other fora, for targeted, collective action to bring observing systems in line with the requirements for addressing a range of issues of concern to society.

The following shortcomings are neither universal nor exhaustive, but apply to varying degrees across the range of existing systems:

- For many users, appropriate data are hard or costly to access, or are in a form that is difficult to interpret, or are of uncertain quality.
- There is insufficient exchange of data among agencies and countries, partly due to incompatible data policies.
- There is inadequate involvement of data users in specifying the information requirements.
- Delays in data access sometimes prevent the timely use of information that could save lives or minimize loss of property.
- The generation and dissemination of products using large volumes of data often lag far behind the collection of observations.
- Spatial and temporal coverage is not optimized, leaving large parts of the globe under-sampled, diminishing the effectiveness of sampling systems in regions with adequate observations.
- Observations of the same variable in different places or by different agencies may not be able to be combined, because the methods used to measure it are different, do not follow agreed standards or are not adequately intercalibrated, or because the time and space resolution or the data structures in which the observations are stored have significant incompatibilities.
- There is unnecessary redundancy in observation effort resulting from lack of coordination and an inability to use one observation to serve a number of different users. Observation systems and networks are planned separately by different domains, and the economic and scientific benefits of co-location are rarely realized.
- Many observations derive from research projects lacking the long-term stable funding and staffing needed to collect and manage consistent observations over long periods of time.
- Entire topics of vital interest to society are missing crucial observations taken on a sustained, systematic, and operational basis.
- Some existing systems are not operating at their designed capacity.

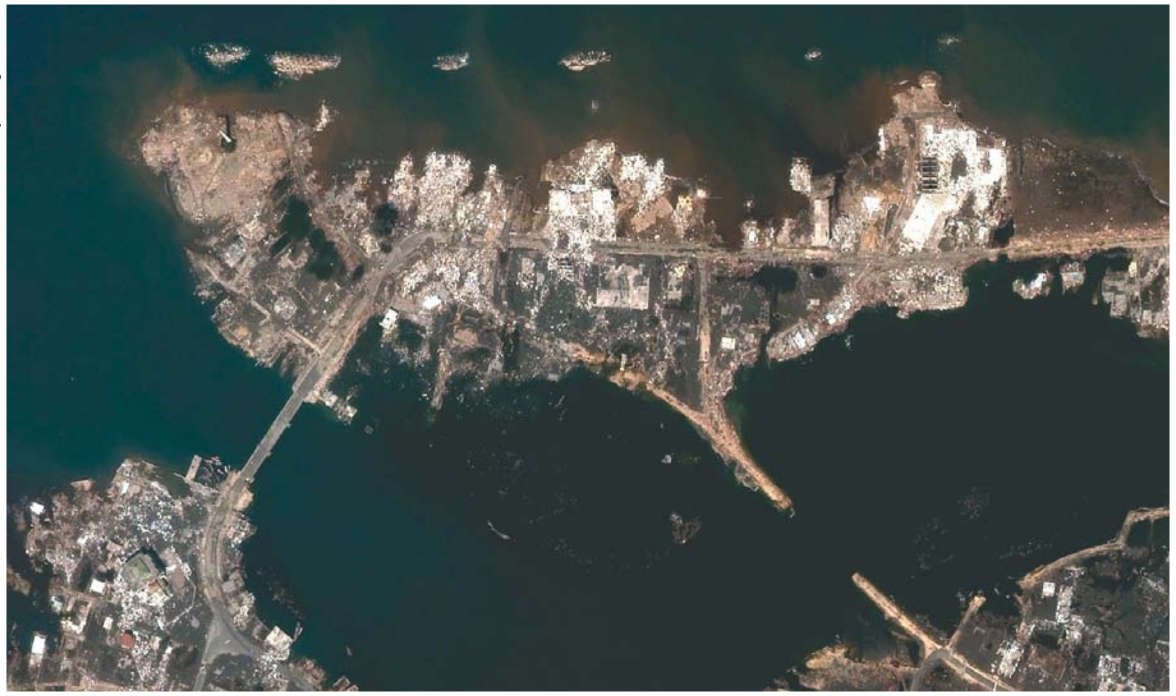
The established Earth observation systems, through which many countries cooperate as members of the United Nations Specialised Agencies and Programmes and as contributors to international scientific programmes, provide essential building blocks for GEOSS. GEO will seek to ensure effective consultation and coordination with the UN system and other international agencies sponsoring or co-sponsoring the major component global observing systems on which GEOSS will be built. For example, a major lesson learned from the tsunami of 26 December 2004 is that an international observation and prediction system closely coordinated with national emergency services is needed in order for the public to receive timely warning (see box).

Courtesy of DigitalGlobe

23 June 2004

28 December 2004

Courtesy of DigitalGlobe



QuickBird satellite images of the Banda Aceh shoreline in Indonesia before and after the tsunami

GEOSS Could Help Nations Save Lives in the Event of a Tsunami

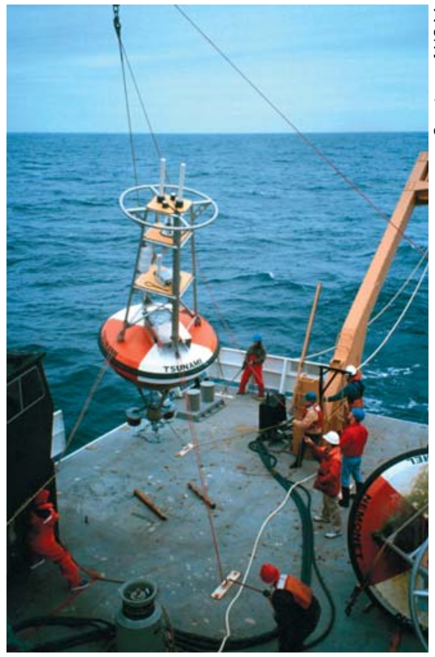
On 26 December 2004, an extreme undersea earthquake was recorded by the Global Seismographic Network, one of the systems participating in GEOSS. When such an event occurs, a worldwide system of regional tsunami warning centres should be ready to send an early warning to pre-designated authorities in nations that might be affected by the earthquake or by an estimated potential tsunami. To confirm if the quake had generated a tsunami, seismic data would be further refined and combined with data from coastal tide gauges and buoys giving deep-ocean sea level. Based on numerical models, a tsunami forecast could be prepared for areas not yet affected. That information, along with probable tsunami arrival times, would be sent to the same authorities.

Wherever a general tsunami threat exists, tsunami hazard zonation maps showing areas vulnerable to tsunami run-up, areas of safety and evacuation routes should have been prepared. These maps are based on numerical models of various scenarios and require high-resolution shoreline topography and near-shore bathymetry, as called for in GEOSS. In each of the potentially affected nations, national emergency managers would have close cooperation with regional centres to facilitate rapid data exchange and coordination of warning information.

National emergency managers would interpret the alert in their local context, and decide upon a course of action. They might decide to trigger an integrated warning system that can activate multiple communications media with a single alert message. Alerts then would be converted automatically into forms suitable for available communication technologies: voice on radio and telephones, text captions on television, messages on highway signs, or signals for sirens. A common public warning system with simple instructions for action would minimize the public confusion that occurs during emergencies, especially if the system is in routine use not only for tsunamis, but also for severe weather, fire, and other threats. This all-hazard public warning technology could be implemented using the GEOSS architecture that encourages system interfaces using international standards such as the Common Alerting Protocol (CAP).

Rapid response of the alerted public is necessary to save lives when a dangerous tsunami arrives. People would move to safety and await an all-clear signal, given signs along the seashore and emergency sirens, plus prior public awareness, preparedness, and education on the tsunami threat, as well as hazard zonation and evacuation maps. After the event, relief efforts could be focused by rapidly generated estimates of populations affected. Also, certain observation satellites could be re-tasked to image the likely affected coastal areas. Overviews of affected areas would be useful to national authorities in organizing efficient disaster response actions.

Disaster reduction demands greater sharing of Earth Observation data and information that are timely, of known quality, long-term, and global in nature. GEOSS will facilitate such sharing. GEOSS will also facilitate the international collaboration among countries and organizations essential to minimize losses from disasters.



Courtesy of NOAA

Deployment of a tsunami measuring buoy in the Pacific Ocean

There are clear improvements that can be made to existing Earth observations through adopting a coherent global approach that will guide the expansion of observing systems to meet society's needs. The incremental cost of bringing the systems up to specification and linking them together is small relative to the existing expenditure, and very small relative to the potential benefits that can accrue. In most cases, global information arises from the voluntary contribution of data collected by national systems, for national purposes.

The global, comprehensive, integrated and sustained effort outlined in the GEOSS 10-Year Implementation Plan would address these shortcomings in the following ways:

- arrangements to make systems interoperable and to share data
- collective optimization of the observation strategy
- cooperative gap filling
- commitments to observational adequacy and continuity
- data transfer and dissemination
- collaboration on capacity building
- harmonization of methods and application of observation standards.

These are expanded on below and in subsequent sections of this document. Consistent with its structure as a 'system of systems', the goals and targets of GEOSS are mostly achieved through and with the component systems. This Plan distinguishes, as far as possible, between actions that are the primary responsibility of GEOSS (by using verbs such as 'GEOSS will *produce*…'), those undertaken jointly ('GEOSS will *facilitate*…') and items where the GEOSS role is more indirect ('GEOSS will *advocate*…').

3.1 Arrangements to make systems interoperable and to share data

The capacity to combine data from different sources substantially increases the number and type of observations available for analysis, as well as their spatial and temporal coverage, in a cost-effective way. GEOSS provides a mechanism through which partial or full data sharing can be negotiated and a technical process by which it can be achieved. The Global Biodiversity Information Facility (GBIF) is an example of the power of this approach. The vast collections in museums and herbaria around the World were mutually inaccessible before an agreement was reached to share information, and a set of database protocols designed to make it possible. This topic is covered in detail in Section 5.

3.2 Collective optimization of the observation strategy

For any topic of societal concern, there is a minimum sampling design required to meet the accuracy specifications appropriate to that application. In the absence of collaboration, each observing system needs to do this calculation individually, and deploy its own network and associated space-based systems to satisfy the requirement. By cooperating, such redundancies are avoided. Rapid technical progress is making hybrid observation systems the norm (combining, for instance, the spatial coverage advantages of satellites with the precision of *in situ* measurements). The optimal configuration of the sampling system is therefore continuously changing. An integrated observation strategy (i.e. one that is coordinated, co-designed and shares data) is both more effective and more efficient than stand-alone strategies. This principle is exemplified by the work of the Integrated Global Observing Strategy Partnership (IGOS-P).

Optimization of sampling is only possible with a degree of knowledge of the distribution and dynamics of the system being observed. This is one reason why it is essential to maintain close and interactive relationships among observation systems, research programmes, and user communities.

A second aspect of this point is the opportunity to gain synergies and cost savings by using one observational infrastructure for more than one purpose. For example, validation of land cover products requires a distributed network of ground locations. These can be co-located with existing stations currently set up for weather and climate observations, ecosystem measurements or geodetic monitoring, for example, saving additional overheads and providing a better data set to both parties (a concept sometimes referred to as 'super-sites').

GEO will create a collaborative forum for technical analysis and observation strategy development.

An example is provided by the atmospheric carbon-dioxide observation system designed by the many collaborating organizations in the Global Carbon Project of the Earth System Science Partnership. By combining space-based observations of the land and sea surface conditions, air movement data from weather observation system data assimilation models, and a limited number of strategically placed, highly accurate, inter-calibrated surface stations, a specified accuracy can be obtained globally at minimum cost. This topic is addressed in Section 6.

3.3 Cooperative gap filling

Because many Earth-system processes operate at large scales, deficiencies in observation in one area have an impact in other areas. It is recognized that the primary responsibility for observations within the territory of individual countries belongs with those countries, but reliance on independent efforts alone has deficiencies. Large parts of the globe (specifically the open oceans, Antarctica and space) are outside the territory of individual countries. It is to the benefit of all that these areas are adequately observed and that the burden of doing so is equitably shared to the best of each contributor's capacity. Similar arguments apply to new observation needs, for instance around emerging diseases. GEOSS provides a mechanism for identifying the gaps and mobilizing the resources needed to fill them. An example is the global system of Argo floats, already partly implemented, that provides information on ocean temperature, salinity, and ocean currents – all of which are essential for long-term meteorological forecasting and oceanographic studies and climate assessment, monitoring and prediction. The logistics of deploying the system throughout the global oceans and the costs of doing so are daunting for a single nation, but much more feasible if undertaken as a cooperative action by many countries for the common good.

There is further information on this topic in Section 6.

3.4 Observational adequacy and continuity

None of the above actions will be effective in the long term unless there is a fundamental commitment to continuation of observations at an acceptable level of accuracy and coverage for all targeted users. Participation in GEOSS implies an acceptance of this need for adequacy and continuity. In some cases, the achievement of adequacy within the participating systems will require additional resources. The incremental costs of achieving linkage and coordination within the 'system of systems' will also require resources over and above the current budgets of existing systems.

An example is the network of hydrological gauging stations worldwide, which has been in decline since the 1960s, due largely to inadequate provision for maintenance. For many basins, the network is now below the minimum required for adequate engineering design of flood protection structures, bridges, dams, and water supply schemes. Ongoing investment is needed to keep the network functional and up to date with technical advances.

A further example is the need for continuity of moderate- to high-resolution, space-based observations of the land and sea surface in the visible and near-infrared wavebands, such as is provided by the Landsat and SPOT platforms. This requires a planned migration of some sensor platforms, demonstrated to be of benefit to users, out of the research domain and into operational agencies, with a schedule for regular replacement, an operational budget separate from the research budget, and commitment to backward compatibility of observations and inter-calibration when new systems are implemented. Similar transfers of research instruments and measurements to operational agencies are critical in many other domains, including among others atmospheric composition, ocean temperature and salinity and biodiversity observations.

Much has been achieved by current systems, but failure to take the opportunity afforded by GEOSS to rectify identified observation system deficiencies will mean that the opportunity to obtain substantial added value from the global observational network will be lost for the foreseeable future. In certain important aspects (e.g. in surface climate, upper atmosphere, and hydrological observations) the observational capacity is likely to continue the decline that has been evident for several decades unless a decisive intervention is made. With respect to new observation areas just emerging (e.g. around issues of health), future coordination will be hampered by the failure to establish and adhere to interoperability standards at this stage. In others, such as aspects of climate change, land degradation and desertification and biodiversity loss, failure to establish a comprehensive observation baseline at this time, and a commitment to continuity of observation systems, will hamper the ability to detect and quantify changes and the achievement of treaty targets.

3.5 Data transfer and dissemination

Enabling all users globally to receive the relevant data in a timely fashion is imperative for maximizing the successful exploitation of the data observations and products. This involves the collection of global data, particularly from *in situ* networks, the transfer of data and products between agencies responsible for observations and products, and the dissemination of data and products to users. In some domains, such as the World Weather Watch programme, much effort has already been invested in the achievement of this objective.

The technology to support these activities is evolving rapidly and includes the Internet, commercial telecommunication satellites and broadband land connections. The solution is not simply one of adopting Internet. This can have timeliness problems, particularly if data is required with tight time-scales that cannot be breached, e.g. in weather forecasting, disasters. There are also significant access issues to be resolved in many developing countries, particularly in the rural areas. Commercial telecommunication satellites can resolve some of these problems, but introduce cost issues that need to be resolved.

3.6 Collaboration on capacity building

The most efficient means to improve the geographic coverage of the Earth observing system is to encourage wider participation from all countries, both as providers and users of information. Some types of observations are hard to justify, particularly in developing countries, in terms of immediate local benefit, and are therefore of low priority for national support by those countries alone. The benefits of making and sharing these observations are collective. There are significant advantages to taking a coordinated, focused, co-financed and partnership-based approach to capacity building.

The GEO definition of capacity building includes three observation system elements: human resources, infrastructure, and institutional capacity.

It is recognized that a variety of organizations have, over a long period of time, made excellent efforts in capacity building, and the degree to which we currently have global coverage is an inspiration to what can be achieved, but in most cases it remains insufficient.

Capacity building needs and targets are addressed within each societal benefit area in Section 4, and in Sections 5 and 6. The overarching considerations are contained in Section 7.

3.7 Harmonization of methods and application of observation standards

The combination of data from different sources is essential to advance our knowledge of the Earth system, but is in many cases constrained due to incompatible observations, missing standards and insufficient operational data assimilation capacity. GEOSS can provide a mechanism for achieving the convergence or harmonization of observation methods, the use of standards and references, and the promotion of intercalibration and operational data assimilation.

This topic is elaborated in Sections 4.10 and 6.

4

SOCIETAL BENEFITS AND REQUIREMENTS

4 Societal Benefits, Requirements, and Earth Observation Systems

The Framework Document set out nine societal benefit areas on which there was recognition that clear societal benefits could be derived from a coordinated global observation system.

Some of these societal benefit areas are themselves complex clusters of issues, with many and varied stakeholders. In each area there are observational needs for many variables, with requirements for their accuracy, spatial and temporal resolution and speed of delivery to the user. It is also clear that there is considerable commonality of observation needs among societal benefit areas. This is the powerful argument for implementing GEOSS.

The societal benefit areas are at widely varying levels of maturity with respect to establishing user needs, defining the observation requirements, and implementing coordinated systems. For example, the Weather area is very mature while the Health area is relatively immature in the context of Earth Observation. In the former case, the activities to be undertaken through GEOSS are largely in the areas of data sharing, advanced products and the coordination of future technologies. In the latter case, GEOSS activities commence with assisting the users to define their requirements, which in turn will lead to better use of existing data in the mid-term and new operational coordinated observation systems and synthesis products only towards the end of the initial ten-year GEOSS implementation period.

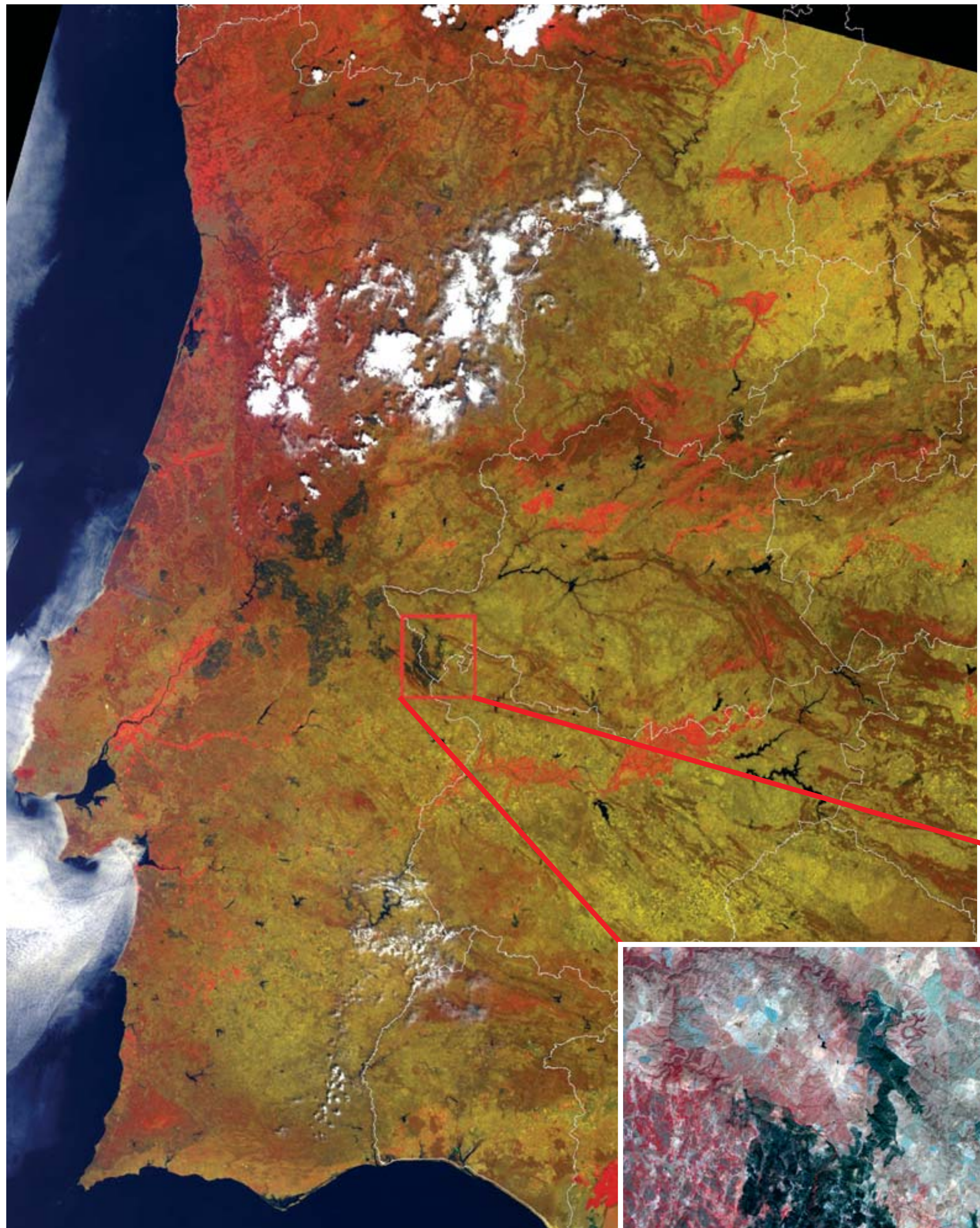
It is anticipated that each of the nine societal benefit areas will evolve over time, and it is also probable that entirely new societal benefit areas may be added, in time. Mechanisms are established in later sections of this Plan to allow for orderly growth, review and revision.

In each of the societal benefit areas, GEOSS will work with the appropriate societal benefit area community to facilitate execution of the target actions delineated below. Achievement of these actions is necessary to realize the outcomes by societal benefit area as adopted in the Implementation Plan. The targets introduced in the nine societal benefit areas should not be understood as representing the activities of GEO Members and Participating Organizations alone. Entities currently pursuing many of these targets will continue to do so, and they become GEOSS targets by virtue of the fact that the primary responsibility falls within observing systems that are participants in the 'system of systems'. The additional role of GEOSS will be, in consultation with system providers and users, to identify measures still needed to achieve the targets, and feasible ways of implementing them through cooperation among participants. Direct and active contribution by GEO to some targets is not excluded, where appropriate and as approved by GEO.

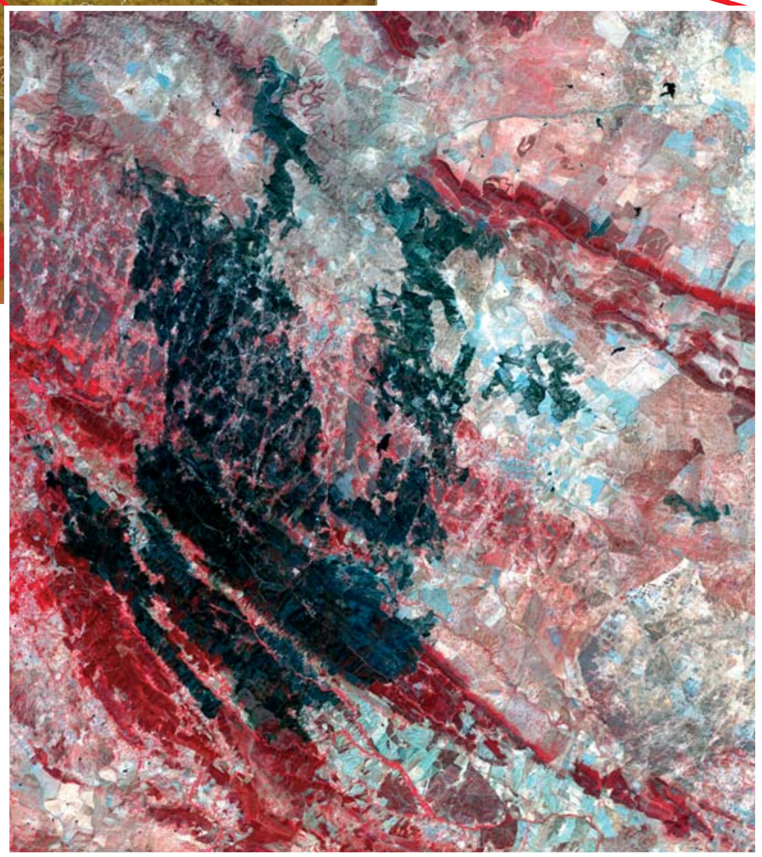
The sequence in which the societal benefit areas are presented in the following sections corresponds to the sequence presented in the Framework Document, and does not have any connotation of importance or priority.

The nine societal benefit areas are:

- Reducing loss of life and property from natural and human-induced disasters.
- Understanding environmental factors affecting human health and well-being.
- Improving management of energy resources.
- Understanding, assessing, predicting, mitigating, and adapting to climate variability and change.
- Improving water resource management through better understanding of the water cycle.
- Improving weather information, forecasting, and warning.
- Improving the management and protection of terrestrial, coastal, and marine ecosystems.
- Supporting sustainable agriculture and combating desertification.
- Understanding, monitoring, and conserving biodiversity.



The fire-scarred landscape of Central Portugal and Spain, as seen by Envisat's MERIS instrument on 8 August 2003, with the Valencia de Alcántara fire outlined in red



The scars from the Valencia de Alcántara fire as recorded by SPOT-5's HRG1 instrument on 21 August 2003

4.1 Reducing loss of life and property from natural and human induced disasters

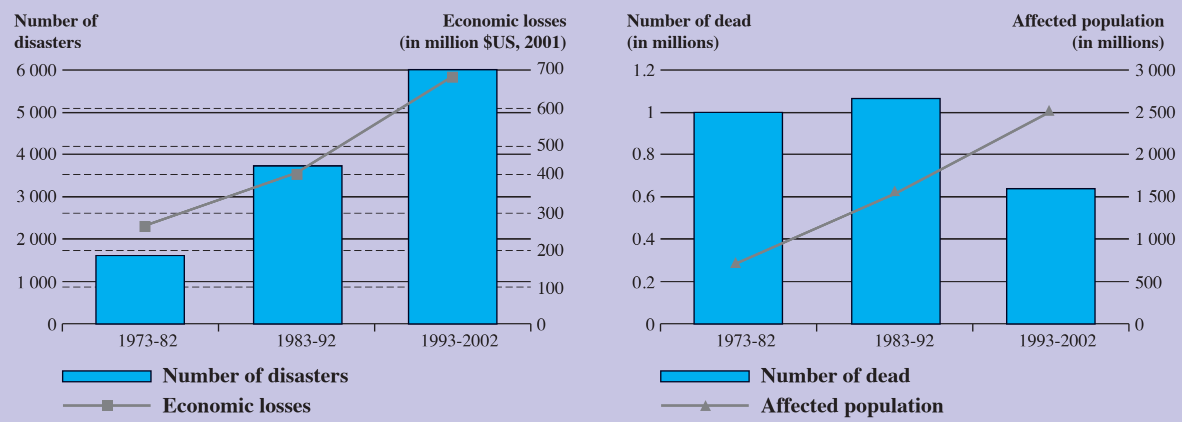
4.1.1 Statement of Need

Disasters killed 500,000 people and caused $750 billion of damage over the decade 1990-1999, according to data presented in the *"Living with Risk"* report of the UN International Strategy for Disaster Reduction (ISDR).[4] Although damage cannot be completely avoided, better coordination of observation systems and data will reduce these losses and help protect biota and other resources. Improved monitoring of hazards and delivery of information about them are critical for preventing hazards from becoming disasters.

Natural hazards such as wildland fires, volcanic eruptions, earthquakes, tsunamis, subsidence, landslides, avalanches, ice, floods, extreme weather, and pollution events, coupled with a wide range of events that are at least partially human induced, impose a large and growing burden on society. Hazard events can trigger a cascade of further disasters, for example disease outbreaks that commonly follow floods or earthquakes. These events are a major cause of loss of life and property, and often affect key natural resources (e.g. the ecological impact of a major oil spill). Natural hazards have a disproportionate impact on developing countries where they are major barriers to sustainable development. Recent wildland fires in the United States and Australia, the millennium flood in Central Europe, and the earthquake in Iran where over 30,000 lives were lost, underline the vulnerability of all societies to natural hazards.

As both human population and the complexity of our infrastructure increase, the risk to our collective well-being posed by hazards increases. The possibility of complex disasters, with human-related accidents being triggered by a natural event, escalates. Improving our ability to monitor, forecast, mitigate, and respond to natural, human-induced, and compound hazard events is crucial to reducing the occurrence and severity of disasters. Progress relies heavily on the use of information from well-designed and integrated Earth observation systems. This requires extensive integration of diverse data streams, an improved predictive modelling capability, and the generation and dissemination of timely and accurate information needed by decision makers and the public. It also requires improved understanding of the underlying natural and human systems gained through basic research. Such relevant scientific research itself also requires enhancements to the exchange of Earth observations and related data, information, and knowledge.

Economic and human impacts of disasters*, 1973-2002



Source: EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium, 2004

*Note: Includes drought, earthquake, epidemic, extreme temperature, famine, flood, industrial accident, insect infection, miscellaneous accident, land/debris-slides, transport accident, volcano, wave/surge, wildfire and windstorm.

[4] *Living with Risk: A global review of disaster reduction initiatives, 2004 version, Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR) http://www.unisdr.org/eng/about_isdr/bd-lwr-2004-eng.htm*

Example: A Wildland Fire Hazard System for Early Detection of Fire Outbreaks

Some years from now, enhanced *in situ,* airborne, and space-based observations of dry fuel load (biomass with low water content) in East Kalimantan, Indonesia, indicate a high potential for severe fires. Weather data indicate that lightning strikes could ignite uncontrollable fires in the next few days. Increased satellite surveillance detects a possible wildland fire, which is quickly confirmed by airborne observers. Maps showing areas at risk are generated and local authorities issue specific alerts to the affected population, government officials, and media. Tactical maps and evacuation routes are generated as response crews deploy and people are removed from immediate danger. Equipment requests and optimal deployment plans are generated, based on specific local weather and smoke prediction models, including effects of the fire itself. Wind profiles at higher levels and weather at larger scales are factored into predictions of potential for spread and the relative effectiveness of fire management options. When the fires are brought under control within two days, the event is reviewed, with all players involved, to improve future preparedness and response for such events.

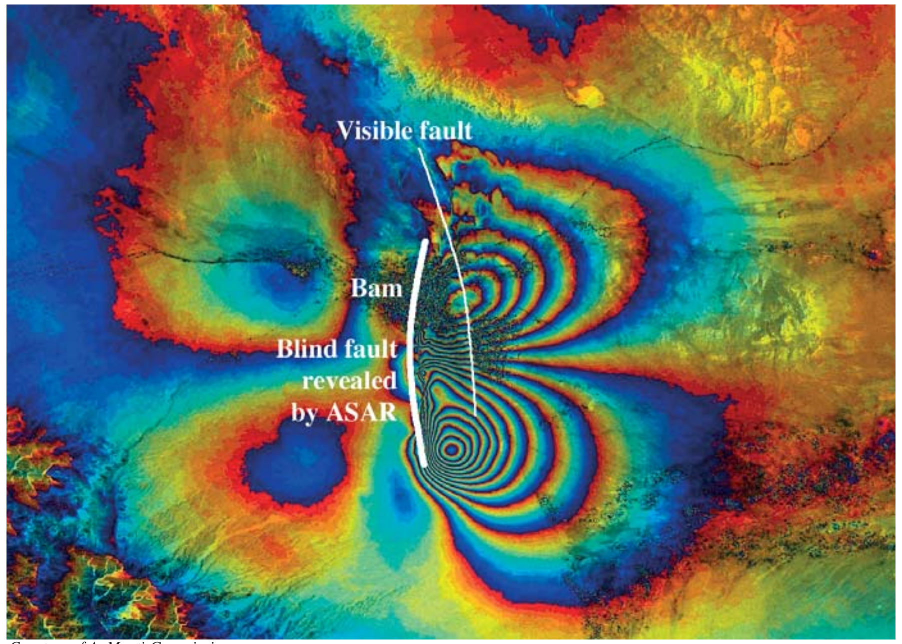
4.1.2 Vision and How GEOSS Will Help

The overarching 10-year vision in the societal benefit area of Disasters is to further enhance coordination among operational observing systems with global coverage. These need to be capable of supporting effective disaster warnings, responses, and recovery, and of generating information products that enable planning and mitigation, in support of sustainable development. Disparate, multidisciplinary, basic, and applied research must be integrated into operational systems. Gaps must be filled in observations, in knowledge, in technology and in capacity, but above all in organization. Providing this collaborative framework to permit free exchange of and efficient use of data, together with support for continuity of operations for all essential systems, is precisely the purpose of GEOSS.

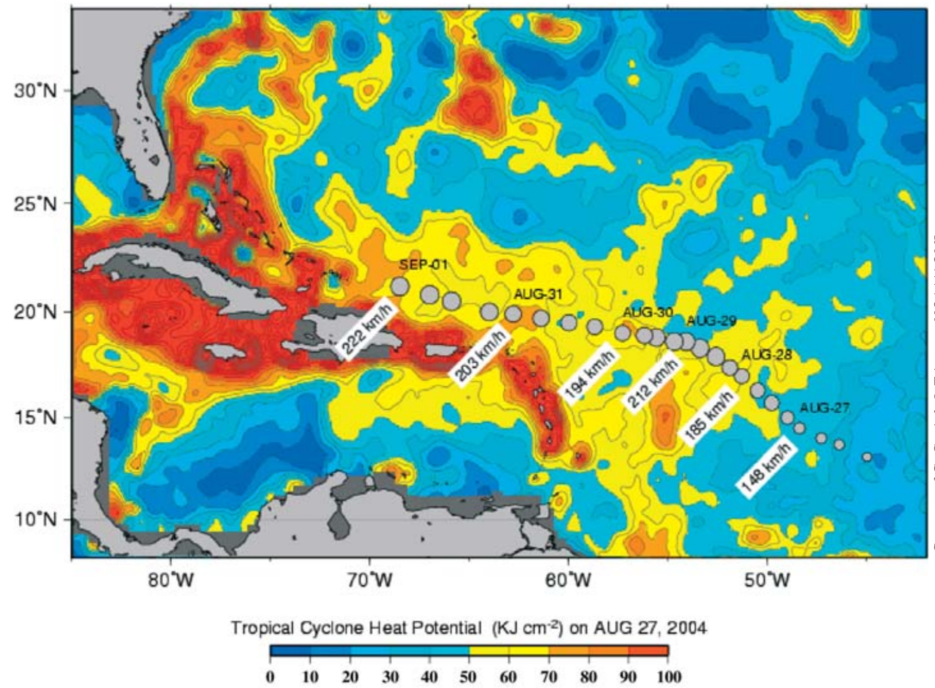
For fire detection and monitoring, GEOSS can facilitate rapid tasking of the available moderate-resolution to high-resolution infrared imaging satellites to revisit areas of concern as frequently as possible. Geostationary weather satellites can view a given area on hourly repeat cycles or better, but lack the spatial resolution needed for detecting wildland fires while they are small. For the next 10 years, fire monitoring will depend on polar-orbiting satellites with appropriate bands and spatial resolution supporting the geostationary data. The best intermediate solution will be robust international coordination of satellite tasking, along the lines of the present International Charter on Space and Major Disasters, but allowing for pre-event tasking where appropriate (as is the case for wildland fires and volcanic eruptions).

Another area of benefit of GEOSS will be to facilitate cross-checking and evaluation of real-time and other data streams. This will aid in earthquake disaster mitigation based on real-time strong ground motion estimation, identification of possible precursor signals for earthquakes, determination of the circumstances under which a significant tsunami may be generated, and better recognition of the difference between geothermal and magmatic unrest at volcanoes.

The Bam earthquake region in 2003 as seen by Envisat's ASAR instrument



Courtesy of A. Monti-Guarnieri



Courtesy of G. Goni & J. Trinanes, NOAA/AOML

Upper ocean thermal conditions during hurricane Frances as observed by Envisat

Most aspects of weather related hazards are covered in Section 4.6 (Weather), with some also addressed in Sections 4.4 (Climate), 4.5 (Water), and 4.8 (Agriculture). Beyond improvements in our current tracking of large weather systems such as tropical cyclones, aspects important for disaster management include improvement of short-range and medium-range forecasts. Such forecasts are especially critical for local, severe weather such as heavy rain (triggering flash floods or debris flows) and tornadoes. These weather events still cause loss of life and local but severe damage because of insufficiently detailed forecasts and warnings. Biological hazards (disease, toxic algae, etc.) are covered in Sections 4.2 (Health) and 4.7 (Ecosystems).

4.1.3 Existing Situation and Gaps

A large number of agencies and organizations deal with disaster issues at national, regional, and global levels. The key issue for GEOSS is to ensure that relevant data and products are produced and that the data and information are received in a timely fashion. WMO has mechanisms that enable the provision of weather data and forecast and warning services to areas suffering from disasters, and the International Charter on Space and Major Disasters focuses the efforts of participating satellite data providers on responding to specific requests in cases of floods, oil spills, earthquakes and other hazards.

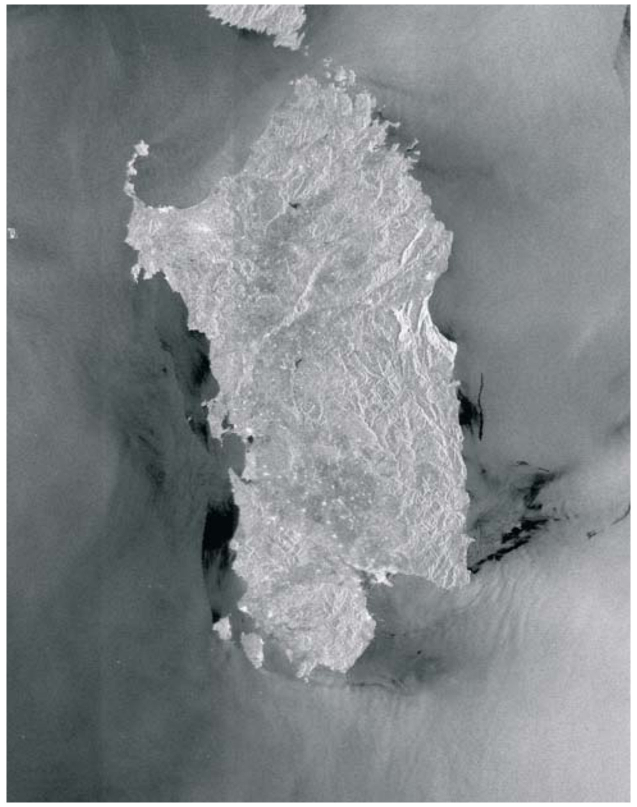
Our capability to monitor hazards needs to be improved in order to provide early warnings, which can prevent hazards from becoming disasters. An approach that includes data from many different sources from both the natural environment and human infrastructure is essential. To provide timely and accurate information, it is necessary to integrate *in situ* measurements, airborne and satellite remote sensing, and predictive models. It is also essential to have basic Geographic Information Systems (GISs) to facilitate the analysis of these data, and many varieties of socio-economic and other relevant data.

GEOSS must address a number of issues to realize solutions, including filling technical and organizational gaps, as well as continuity issues. Major technical gaps are summarized in Table 4.1.5, which shows that few of the observational requirements of the ten hazards listed are adequately met on a worldwide basis. For instance, there is a lack of worldwide, high-spatial-resolution terrain models. There are efforts to develop a global terrain model, e.g. using the Shuttle Radar Topography Mission (SRTM) results, but even when fully available these results have horizontal spatial resolutions no better than 30 metres. Effective monitoring of crustal deformation using InSAR (Interferometric Synthetic Aperture Radar) requires 10 metre horizontal spatial resolution, and this is currently not available routinely. Floods, storm surges and tsunami in areas of low relief raise the requirement for DEMs (Digital Elevation Models) with vertical resolution of less than 1 metre. This resolution is achievable with airborne SAR (Synthetic Aperture Radar) and LiDAR (Light Detection and Ranging).

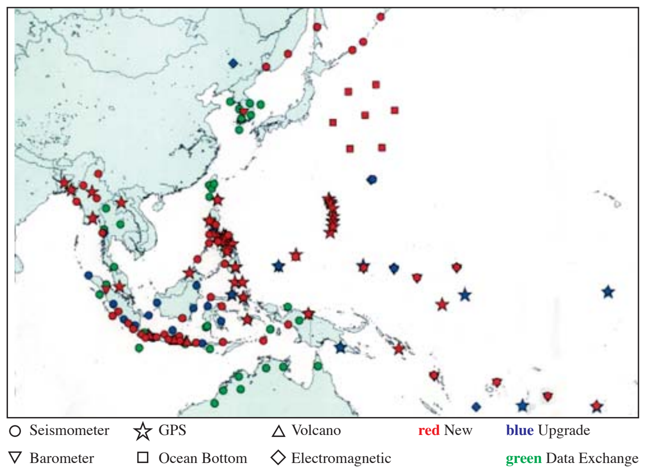
Existing regional-scale geologic maps of volcanic areas, seismically active zones, landslide-prone areas, flood plains, and low-lying coastal areas, together with current data on land cover, land use and population distribution, are inadequate to support disaster reduction strategies. This background information, plus knowledge of the frequency of hazard events and maintenance of appropriate databases of historical hazard events, is required in order to generate meaningful hazards zonation maps (e.g. fuel distribution maps, seismic hazard maps). Hazards zonation maps and supporting GIS databases are key tools for disaster preparedness and mitigation. These maps depend on interoperable databases and services provided by existing national and international Spatial Data Infrastructures (SDIs).

There are monitoring gaps relative to specific hazards. For instance, the study of geohazards requires integrated, multi-disciplinary research focused on particular groups of volcanoes or high-priority tectonic zones for earthquakes. Deployment of *in situ* instruments, such as broadband seismometers and accelerometers, is incomplete. Remote sensing support, especially SAR imagery critical for deformation monitoring, has no guarantee of continuity, and the data supply is inadequate for real-time monitoring. Limitations on access to SAR data also impact the monitoring of ice hazards, oil spills, and inundation from flooding. Wildland fire detection depends in most areas on direct human observation on the ground or incidental observation from aircraft, in the absence of satellite sensors with appropriate temporal and spatial resolutions.

The long, thin, dark features in the bay near Cagliari on Sardinia's southeastern coast are due to oil dumped illegally by shipping, and seen by Envisat's day-and-night ASAR radar



Coordination and data exchange between observation organizations and research communities remains weak. Earth Observation information, whether from in-situ, airborne or space-based systems, is not used consistently or optimally for disaster management decision-making. GEOSS has a role in building the bridge between the communities. Demonstrations showing the usefulness of such information in an operational, integrated manner would be helpful and achievable within a two-year horizon.



Current DAPHNE in-situ monitoring configuration for earthquakes and volcanoes in southeast Asia

4.1.4 Targets

2 Year Targets 4.1 Disasters

Working with the disaster management community, GEOSS will:

Advocate strengthening of the International Charter on Space and Major Disasters and similar support activities to enable better response to and documentation of effects of disasters, such as floods, earthquakes and oil spills. Its scope may be expanded to allow for pre-event tasking where forecasting is adequate to justify the effort (wildland fires, some floods and coastal disasters, volcanic eruptions). An expanded scope may also encompass Earth Observation training and capacity building of local users in affected areas, particularly in developing countries.

Facilitate global access to the 100-metre (C-band) and 30-metre (X-band) horizontal resolution digital terrain information produced during the Shuttle Radar Topography Mission (SRTM).

Advocate expansion of seismic monitoring networks, plus expansion of the present network of ocean-bottom pressure sensors, and upgrade existing global networks (e.g. the GSN) so that all critical instruments relay data in real time, in support of better tsunami warning worldwide.

Facilitate focused pilot studies in under-served hazardous areas, for example Japan's Deployment of Asia-Pacific Hazard-mitigation Network for Earthquakes and volcanoes (DAPHNE).[5]

Facilitate ongoing capacity building, with a focus on transferring technologies and best practices. Also essential are best practices for the dissemination of real-time information and early warnings to end users and the public. Specifically, improvements in real-time flood forecasting for developing countries should be a priority, in concert with efforts by UNESCO and WMO to expand and improve flood-related information systems.

Facilitate effective monitoring from existing geostationary satellites, launched primarily for weather monitoring, for non-weather applications such as volcanic eruptions and volcanic ash clouds, forest fires, aerosols, and other hazards that require a high observation frequency.

Advocate integration of InSAR technology into disaster warning and prediction systems, in particular related to floods, earthquakes, landslides and volcanic eruptions. The ERS (European Remote Sensing) and Envisat missions of the European Space Agency have pioneered these applications and should be continued for global, long-term applications. Also, the Canadian Space Agency's Radarsat-1 mission with its InSAR capability contributed significantly to the development of applications related to geohazard monitoring and research. In this respect, Radarsat-2 should be a data source for geohazard InSAR applications. As part of this effort, efficient exploitation of data from Japan's upcoming Advanced Land Observation Satellite (ALOS) should also be facilitated. Its L-band SAR sensor is the first such sensor since 1998.

Produce an inventory of existing geologic and hazards zonation maps and identify areas and types of hazards where they are most critically lacking, or where maps need to be digitized.

[5] *Deployment of Asia-Pacific Hazard-mitigation Network for Earthquakes and volcanoes (DAPHNE) http://www.daphne.bosai.go.jp*

Advocate further development of the Global Spatial Data Infrastructure (GSDI) and draw on GSDI components as institutional and technical precedents.

Produce a comprehensive gaps analysis to assess the status and regional distribution of existing disaster management capacity-building programmes and initiatives.

6 Year Targets 4.1 Disasters

Working with the disaster management community, GEOSS will:

Facilitate widespread use of LiDAR and InSAR technologies for topography in areas of low relief. For floods and coastal hazards, the most crucial need is for high vertical resolution (less than 1 metre) topographic data, plus good shallow-water bathymetry.

Advocate continuity and interoperability of all satellite systems providing global positioning, such as the United States Global Positioning System (GPS), European GALILEO, Russian Global Orbiting Navigation Satellite System (GLONASS) and Japanese Quasi-Zenith Satellite System (QZSS). This includes support of the global geodetic network services such as Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR), that define the orbits of the GPS satellites and thereby enable the use of GPS for precise geo-location. Applications of GPS essential to disaster response include precision topography, mapping support, and deformation monitoring, as well as geo-location for search and rescue operations.

Advocate that the international satellite community, coordinated through the Committee on Earth Observation Satellites (CEOS), plan for assured continuity of critical sensing capabilities. For example, certain research systems should become operational systems and the projected lifetimes of some systems should not result in service gaps of key satellite sensor data. Longer-term actions for monitoring of geohazards include realization of an integrated observation system of SAR interferometry and GPS.

Advocate enhancements of the automatic processing and evaluation of satellite imagery, to facilitate production of digital topography, and to support rapid detection of fires, oil spills, or other hazards.

Advocate more rapid SAR processing for interferometry to enable strain mapping over large seismically active zones and to monitor landslides and subsidence in populated areas and along transportation corridors.

Advocate systematic expansion of the inventory of geologic and hazards zonation maps and expansion of Geographic Information Systems (GIS) as a critical tool for managing spatial information for disaster management. In this context, digital maps based on distributed systems and data sources and conforming to recognized international GIS standards (e.g. International Organization for Standardization standards and Open Geospatial Consortium specifications).

Facilitate the development and sharing of critical airborne sensors and capabilities, such as hyper-spectral sensors, high-resolution infrared sensors and LiDAR.

Advocate the development of models to better support disaster response. One area of particular interest is the dispersion of pollution plumes in the atmosphere or in water (including the spread of oil spills in the marine environment).

Establish a process for monitoring of capacity-building efforts in disaster management to enable building upon strong existing programmes in the continuing efforts to integrate and share resources.

Advocate access to data from seismic and infrasound networks operated by the Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) that are useful and relevant for monitoring earthquakes and volcanic activity.'

Facilitate access to real-time data analyzing technology and real-time access to critical data for all hazards.

Advocate real-time monitoring of submarine seismic and volcanic activities and tsunami propagation.

10 Year Targets 4.1 Disasters

Working with the disaster management community, GEOSS will:

Facilitate further expansion of real-time monitoring of submarine seismic and volcanic activity and of tsunami propagation by use of surface and subsurface sensors, including re-use of submarine telephone cables.

Facilitate further expansion and integration of regional projects like DAPHNE [6] and Global Monitoring for Environment and Security (GMES),[7] and the development of efficient interfaces between these and other such programmes.

Advocate meeting various unmet needs for classes of satellite sensors. Of particular importance for the area of hazards and disasters is the global need for a significant increase in SAR satellites (C-band, L-band, and X-band). The disaster management community needs an L-band system optimized for interferometry, and an expanded L-band capacity for better forest and fuel characterization. Monitoring the range of smoke and pollution plumes in the atmosphere around the globe requires expanded hyper-spectral capability, which is currently limited to airborne sensors. A passive microwave capability would help in determining soil moisture repeatedly over broad areas.

Advocate development of systematic methods for rapid determination of shallow bathymetry, especially in turbid water. Such research is vital to characterizing near-shore bathymetry, whether for improved modelling of tsunamis and storm surges or for documenting changes produced during such events.

Produce an evaluation of the effectiveness of its capacity-building activities for the disaster management sector, including an assessment of the effectiveness of building the needed inventory of geologic and hazards zonation maps.

[6] *Deployment of Asia-Pacific Hazard-mitigation Network for Earthquakes and volcanoes (DAPHNE) http://www.daphne.bosai.go.jp*
[7] *Global Monitoring for Environment and Security (GMES) http://www.gmes.info/*

4.1.5 Table of Observation Requirements

In the table on the following page, several types of hazard or disaster are charted as examples. Certain hazard types are absent here as they are treated elsewhere within this report. For instance, droughts are addressed within the Agriculture area.

Legend for Table 4.1.5

- **0 -** Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
- **1 -** Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide
- **2 -** Not yet widely available or not yet monitored globally, but could be within two years.
- **3 -** Only locally available or experimental; could be available in six years.
- **4 -** Still in research phase; could be available in ten years.

Disasters
Table 4.1.5

	Observational Requirement	Wild land Fires	Earthquakes	Volcanoes, Volcanic Ash and Aerosols	Landslides, Subsidence	Floods	Extreme Weather	Tropical Cyclones	Sea and Lake Ice	Coastal Hazards, Tsunami	Pollution Events
1	Digital topography–broad, regional	2	2	2	2	2		2	2	2	2
2	Digital topography, bathymetry – detailed or high-resolution	3	3	3	3	3	3	3	2	3	3
3	Paper maps with natural (terrain, water) and cultural features (includes geographic names, all infrastructure and transportation routes)	1	1	1	1	1	1	1	1	1	1
4	Detailed mapping, dating of bedrock, surficial deposits, fill, dumps		3	3	3	3			3	3	3
5	Documentation/assessment of effects during & after event	2	2	2	2	2	2	2		2	2
6	Seismicity, seismic monitoring		1	2	3					1	
7	Strong ground shaking, ground failure, liquefaction effects		2		4					2	
8	Deformation monitoring, 3-D, over broad areas		3	3	3					3	
9	Strain and creep monitoring, specific features or structures		2	2	2						
10	Measurement of gravity/ magnetic/electric fields – all scales		3	3							
11	Physical properties of earth materials (surface and subsurface)		3	3	2					3	
12	Characterize regional thermal emissions, flux – all time scales	2	3	2							
13	Detect, characterize local thermal features, varying time scales	2		2							2
14	Characterize gas emissions by species and flux		3	2							3
15	Detect, monitor smoke or ash clouds, acid and other aerosols	2		1							3
16	Water chemistry, natural and contaminated		3	2		2				2	2
17	Detect/monitor sediment, other discharges (oil, etc.) into water	3		2		1				2	2

	Disasters Table 4.1.5 **Observational Requirement**	Wild land Fires	Earthquakes	Volcanoes, Volcanic Ash and Aerosols	Landslides, Subsidence	Floods	Extreme Weather	Tropical Cyclones	Sea and Lake Ice	Coastal Hazards, Tsunami	Pollution Events
18	Water levels (groundwater) and pore pressure		2		3	2					3
19	Stream flow: stage, discharge and volume	2			2	2	2	2		2	2
20	Inundation area (floods, storm surge, tsunami)					2	2	2		2	2
21	Soil moisture	4	4		4	4	4	4		4	4
22	Precipitation	1		1	2	2	2	2		1	1
23	Snow/ice cover: area, concentration, thickness, water content, rate of spring snow melt, ice breakup, ice jams				1	1	1		1	1	2
24	Coastal erosion or deposition, new navigational hazards or obstructions, icebergs					3	3	3	3	3	2
25	Waves, heights and patterns (ocean, large lakes), currents						1	1	2	2	2
26	Tides/coastal water levels					1	1	1	1	1	1
27	Wind velocity and direction, wind profile	1		1			2	1	2	2	2
28	Atmospheric temperature, profile	1					1	1	1	1	
29	Surface and near-surface temperature (ground, ice and ocean)	1					1	1	2		2
30	Air mass differences and boundaries	1					1	1			
31	Moisture content of atmosphere	1					2	2			
32	Vegetation and fuel characteristics (structure, load, moisture content)	3									

Sources: IGOS-P Geohazards Report (earthquakes, volcanic activity, landslides and subsidence), http://ioc.unesco.org/igospartners/geohazards.htm; CEOS Disaster Management Support Group Report (same, plus wildfires, floods, sea ice, oil spills), http://disaster.ceos.org/pdf/CEOSDMSG.pdf

4.2 Understanding environmental factors affecting human health and well-being

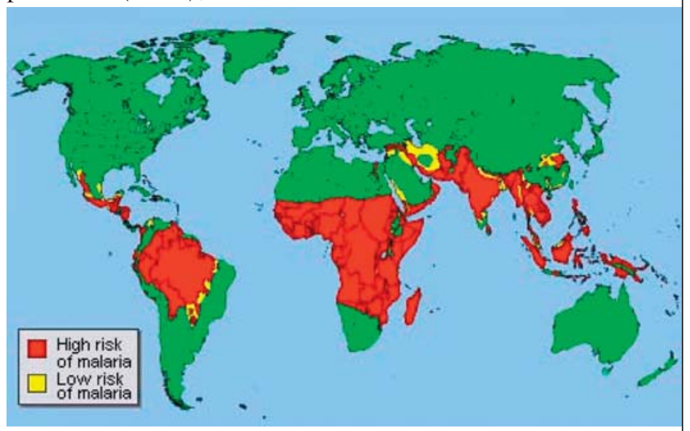
4.2.1 Statement of Need

People born in the 21st Century in most regions of the World can expect to live significantly longer and healthier lives than those born just over a century ago. A significant factor in this increase has been gains in environmental management including improved sanitation, purified water, more effective control of disease vectors and reservoirs, cleaner air, and safer use of chemicals in our homes, gardens, farms, factories, and offices. Continued improvement in quality of life and longevity depends on understanding a complex array of factors that determine human health conditions.

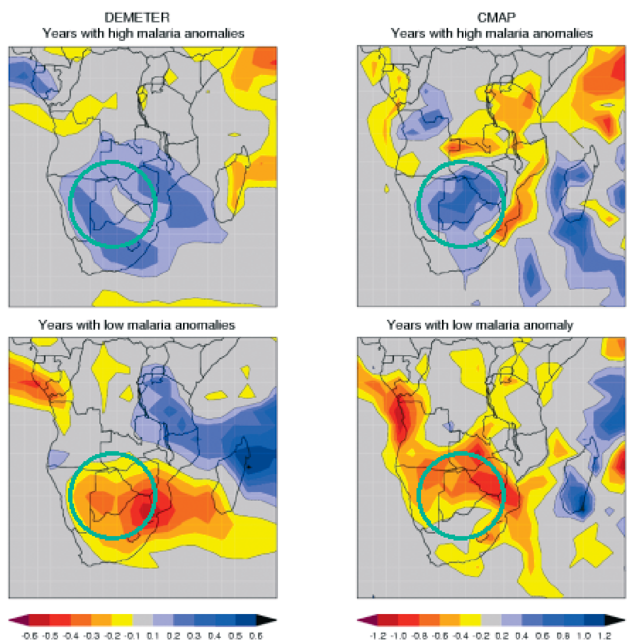
Significant differences in the health and well being of people in various regions of the World still exist. One person in five does not have access to good quality drinking water. The rapidly-growing global population is creating numerous stresses with serious health impacts, such as increased release of chemical emissions into the environment, and special attention needs to be paid to an observing system which can track indicators for these chemicals, especially persistent organic pollutants (POPs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. The demands of this ever-increasing global population call for the development, communication, and fulfilment of user requirements for data and data products to aid in satisfying our fundamental needs for clean air and water, food, and shelter and in enhancing our present quality of life and the sustainable development necessary for our future.

GEOSS will contribute significantly to human health for prevention, early warning, and rapid problem-solving by facilitating better data on environmental factors such as exposure factors like air and water contaminants, pathogens, and ultraviolet radiation; nutritional factors such as price and availability of food; extreme weather events and noise; and indicators of the stresses of overpopulation. Health service providers, researchers, policy makers, and the public in developed and developing countries as well as indigenous communities need such data products for providing the services, science, and decisions that affect human health and well-being. For example, data on population distributions, production and transport of chemicals, as well as hurricanes and floods are factored into emergency management decisions that save lives and property. Data on conditions that increase mosquito populations are factored into prevention measures in areas where malaria is endemic. Data on the transport of air pollution are factored into early warnings for cardiovascular and respiratory responses as well as remediation efforts. Data on weather and stream flow are factored into the management of drinking water.

Key health and environment indicators include factors such as forecasts of famine/food security, quality and quantity of water and soil for human use, occurrence of vector-borne and water-borne diseases, harmful algal blooms and seafood contamination, wildland fires, and severe weather. Another set of indicators includes air quality, recreational water quality and ultraviolet radiation indices. Health and well-being policy development requires a broader set of change indicators, such as land use, urban environment, transportation infrastructure, transportation patterns, energy use, agricultural-chemical use, long-range trans-boundary pollution, and waste management.



The global distribution of malaria. The factors determining the distribution include both, climatic and human influences



Seasonal malaria incidence related to anomalous seasonal rainfall. This figure shows composite maps of DEMETER rainfall predictions and corresponding CMAP rainfall verifications composited for years with high malaria incidence (top) and low malaria incidence

Example: A Future When the Ocean Warns of a Cholera Epidemic

Some years from now, *in situ* and remote sensing of the Bay of Bengal identifies increasing sea surface temperatures. Experience and models suggest the development of conditions conducive to increased ocean productivity. In the following days, ocean colour measurements indicate strongly increasing concentrations of chlorophyll-a, and the proliferation of phytoplankton. Epidemiological information from international researchers in Dhaka, Bangladesh, reports novel serogroups of cholera pathogens that can evade vaccine-derived immunity. Time remains, however, to prepare in case the cholera-bearing copepods approach the Ganges Delta, home to over one hundred and fifty million people.

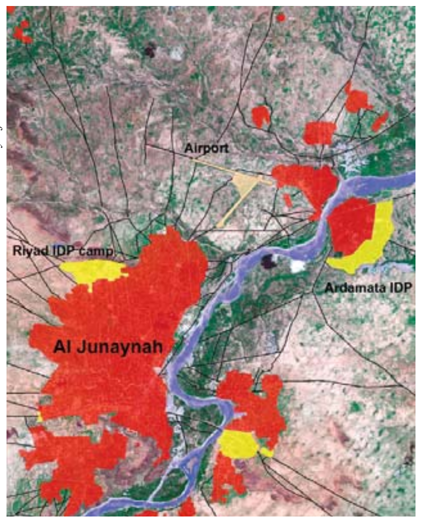
A major public health effort, coordinated by the Ministry of Health with significant international support, provides hospitals, clinics and healthcare providers in the threatened areas with immense stocks of pre-packaged oral rehydration salts with instructions for use. Meanwhile, sea-surface height increases, and high-resolution imaging tracks large populations of plankton being carried into the delta. Geographic Information Systems with global positioning coordinates from the long-standing vaccine field trial sites are used to identify the communities at risk and health care centres in the track of the pathogen that need additional medical supplies.

Shortly thereafter, an explosive epidemic occurs, and cholera cases pour into the hospitals and clinics. Patient numbers rapidly increase, and cholera cots are set in the corridors and parking lots of clinics. Microbiologists identify a new antibiotic-resistant cholera strain. In previous years this would have been a recipe for disaster; however, early warning and pre-placement of adequate medical supplies minimize cholera casualties to near zero.

4.2.2 Vision and How GEOSS Will Help

The vision is for Earth Observation to make a significant contribution to the continued improvements in human health by enabling improved understanding of the linkages between the environment and human health, as well as prevention, early warning, and more rapid problem-solving. It will be achieved through the development of a system of *in situ*, airborne, and space-based systems integrated through assimilation and modelling tools with census data on health, and building upon developing systems such as the international Earth System Science Partnership (ESSP) and the U.S. CDC Public Health Information Network (PHIN). The outputs will be to identify environmental conditions, health hazards, and at risk populations, and to establish epidemiological associations between measurable environmental parameters, chronic and infectious diseases, and health conditions. To accomplish this, the available data will be identified, processed into a useable form, and disseminated to all users, including the health community represented by relevant international bodies such as the World Health Organization, ESSP, and PHIN. Models relating environmental hazards to health condition/disease will be developed and tested in appropriate areas. Data delivery mechanisms to get the information to public health officials, connecting to well developed decision support systems for health care planning and delivery is an essential component and an especially pressing need in developing countries and indigenous communities.

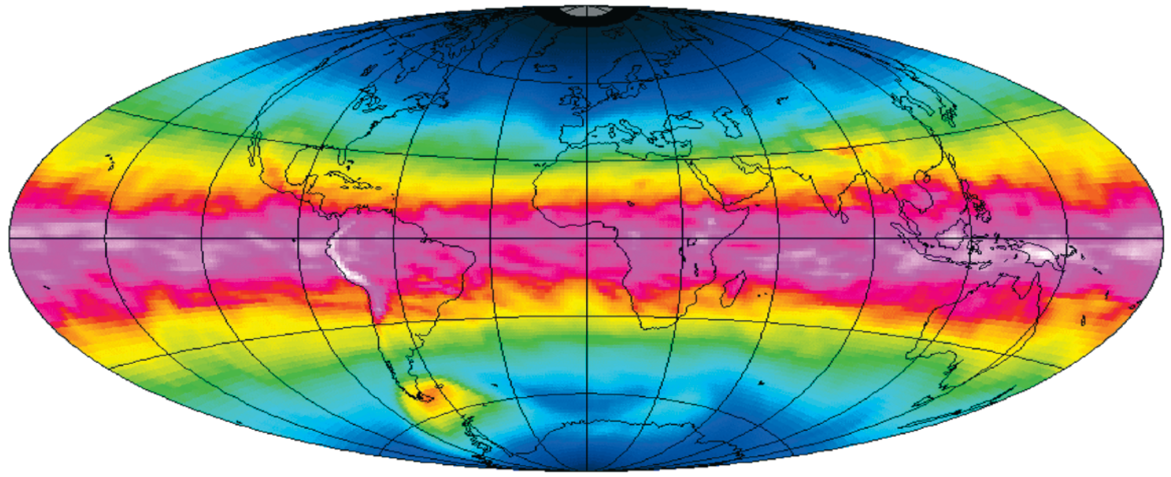
GEOSS will be a vital means of bringing useful environmental data to the health community in a user friendly form. Comprehensive data sets are powerful tools that support prevention, early warning, research, epidemiology, health care planning and delivery, and provide a variety of timely public alerts. For example, by linking weather, air quality data and the urban heat island effects, air quality forecasts can help protect asthmatics, the elderly and young from cardiovascular and respiratory



Courtesy of SERTIT and DLR

Satellite-based flood map of Al Junaynah city and Wadi Kaja in Darfur, Sudan, showing the locations of the Riyad and Ardamata refugee camps. The image is a composite of Radarsat, Envisat and SPOT satellite data

problems resulting from air pollution episodes. These data can also provide linkages to longer-term air quality impacts such as cancers, respiratory diseases, asthma and birth defects. Also, by connecting the environmental requirements of pathogens with remote sensing observations of land parameters, weather and other data, it can be possible to predict outbreaks of infectious diseases such as malaria, and reduce the impact and severity of the outbreak. By using remotely sensed land use data, it is possible to predict areas of probable water quality impairment, which allows local communities to better target *in situ* water quality/drinking water monitoring and remedial efforts. Better UV-B measurements and warning systems will reduce the incidence of skin cancer and cataracts around the World.



UV index forecast for 21 March 2002 derived from ERS's GOME instrument

GEOSS will bring a focus to predictive and preventative aspects of health, particularly with respect to environmental conditions such as pollutants and contaminants. Thus, at the global level, the availability of remotely sensed and *in situ* environmental data creates the opportunity for applying powerful new tools to discovering early indicators of adverse conditions, thereby alerting the community and providing time for hazard avoidance or disease mitigation. This contrasts with the focus of most of the health care today, which is primarily a treatment-based system coupled with research on the processes underlying chronic and infectious diseases.

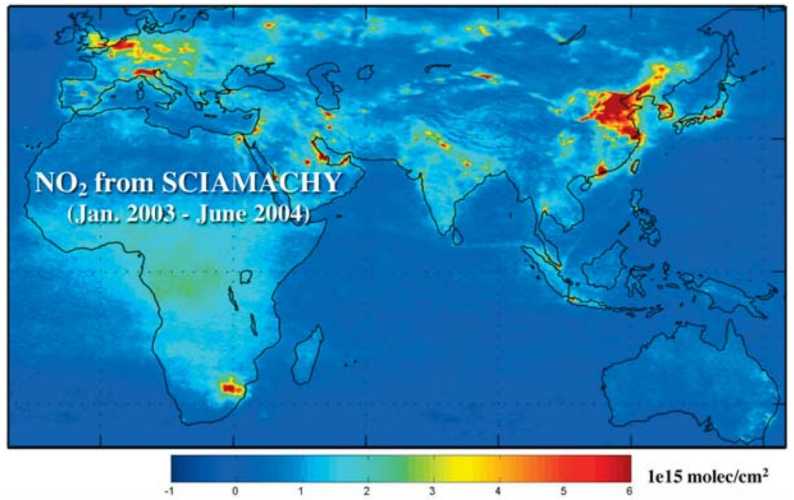
Currently, the work being conducted with remote sensing technologies and disease is through interdisciplinary research groups involving scientists with varied backgrounds such as remote sensing, epidemiologists, and atmospheric scientists (e.g. the international ESSP). The science of epidemiology involves observing factors that might be associated with disease, and then calculating the degree of significance in the association. The true value of Earth Observation data will become more fully realized when simple, user-friendly data products are prepared that are easily overlaid onto disease/dysfunction maps. For example, if an epidemiologist wishes to investigate factors associated with childhood asthma, it will be useful to model the physical location of patients with real-time and cumulative local airborne particulates over the study period. GEOSS can make a significant contribution to this class of activity by ensuring data are available and developing the modelling capability.

It is essential to be able to relate the results of disease studies conducted in different times and locations. Historical data from satellites on the effects of land use and land cover changes are needed to track, model and predict changes in ozone, particulate matter, chemical emissions, disease vectors, cancers, and birth defects to evaluate improvements in health conditions related to public well-being. GEOSS will be invaluable in allowing exposure and disease data to be related among populations. For example, the aerial particle pollution and health consequences among the World's major cities could be compared and contrasted, and degenerating environmental conditions that could lead to the emergence of infectious diseases could be identified and reversed before a new epidemic occurs.

4.2.3 Existing Situation and Gaps

The most pressing need for improved human health and well-being is to bring together into one system the many disparate entities with health and environment data and observations to better understand the links between the environment and health, as well as to enable prevention, early warning, and more rapid problem solving. All countries have a capability to provide health support, and a number of government, inter-government, and non-government organizations provide global support. What are not well developed are the linkages between these efforts and the agencies making environmental observations. Equally, there is insufficient systematic work on the integration of environmental data with health statistics and information.

There is a large gap in knowing and communicating what the needs are of the public/human health community and those that can be provided by the remote sensing/GIS/spatial analysis and technologies community. Training and educational venues need to be organised to enhance a better understanding of what the needs of the human health community (e.g. epidemiology) are versus what can be provided by the space technologies community.



Courtesy of S. Bierle, IUP Heidelberg

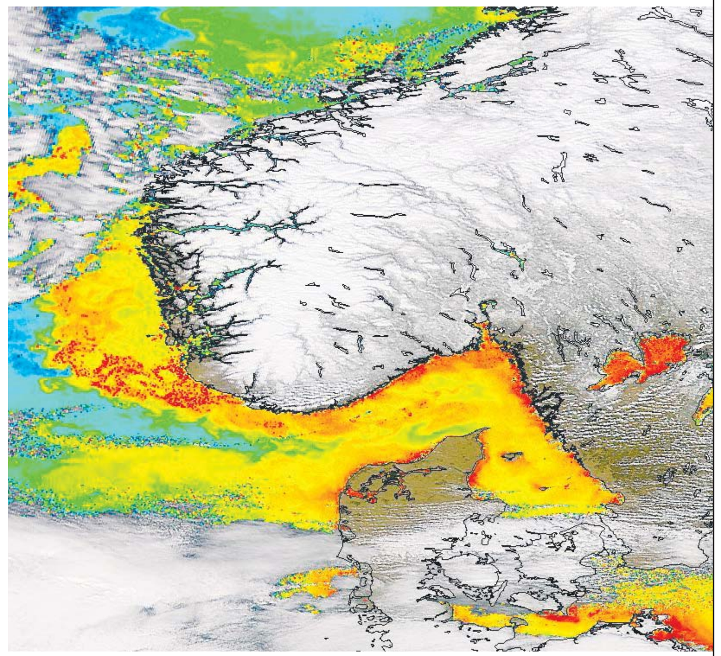
NO_2 concentrations derived from Envisat's SCIAMACHY instrument

An important step is the need for better interaction between the GEOSS community and the health community. Relatively few individuals are able to bridge this gap, and the full value of Earth Observation data being used with health data will not be realized until there are more individuals trained in this area. For example, training for both the malaria teams and those charged with developing predictive models for climate and other factors, which influence mosquito populations, and therefore the transmission of the parasite, will be a major goal. Universities and funding agencies will be encouraged to strengthen support for interdisciplinary research and scientific training to provide and use GEOSS data and data products.

Observations exist for meteorology (precipitation, temperature, etc.) and there are census data, and through established techniques these can be transformed into useful data and products. There are also space-based observations collected for parameters such as wind-blown dust and ground cover/land use. Data on emissions inventories and other environmental releases are extensive, although the accuracy of the data is often unknown and more work is needed. Effort is also needed to improve the systems for reducing the data into useful information and for distributing and archiving the data. Monitoring of air, soil, and water pollution, and of food contamination (such as harmful algal blooms and contaminated seafood), is patchy and is considered adequate only for some contaminants. Some countries collect extensive data on pesticide and chemical use; in others there is little or no data collection. For air, soil, and water quality, information on chemical composition in real time is limited. There is a need for routine global scale pollution chemistry and measurements for the atmosphere, land and water. In general, there is lack of observations of pollutants, chemicals, and airborne particles at the necessary spatial and temporal resolution to be able to directly relate these factors to human health. Observation systems for collecting human activity or human exposure data are insufficient; data is generally only available for individual studies. Innovative approaches are needed for routinely observing individual activities across most of the globe.

In order to integrate *in situ* health data and remotely sensed data for health use, improved capacity in terms of modelling and analysis techniques is necessary. Information is needed at a level that enables the accurate assessment of health issues

and correlation with the environment observations and products. Gaps also exist in the integration of relevant existing observation systems, for example integrating the global urban land observations with data that characterizes the built environment, chemical emission, and with indicators of environmental quality, health and disease. There are also gaps and challenges ahead to produce a more comprehensive set of indicators, for example the tracking of pollutant and pathogen occurrences, as well as patterns of human activities. This will enable the establishment of indicators showing, for example, the possible adverse exposures to the health of specified populations. Assimilation and modelling techniques can enable epidemiologists to relate physicochemical, geochemical, microbiological, pollutant and chronic or infectious disease to Earth observations for prediction purposes. These models could also be used to predict or forecast some of these indicators for use by the public-service and environmental managers to modify behaviours, both to avoid exposure and to produce less pollution.



Courtesy of Dundee Univ/NASA-GSFC/ORBIMAGE

SeaWIFS chlorophyll-a image of a large harmful algal bloom along the Norwegian coast, on 25 March 2001

There is an ongoing need in all countries to provide education and training for people who design, build, and operate observing systems, who analyze data, and who produce data products. This needs to be seen as a parallel activity to the building of institutional willingness and capacity in public health, to move beyond surveillance and response by having a focus on prediction and prevention. This capacity building will help people everywhere – especially those for whom poverty has a direct impact on health – to gain a better understanding of the effects of environmental exposure on health and well-being and how to prevent or reduce harmful effects. Capacity building in the tools for collection, processing and use of data and data products will help significantly in improving public health by providing integrated information for the health research, provider, and policy-making communities.

Demonstration projects will be of value where associations are implicated between Earth Observation data and the epidemiology of disease; high-resolution imaging could be used to test the hypothetical association. For example, Airborne Visible and Infra-Red Imaging Spectrometer (AVIRIS) imaging of phytoplankton blooms could be conducted in regions of the World such as Mozambique and Peru at the earliest stages of seasonal cholera outbreaks, or for harmful algal blooms that threaten seafood resources. Other instruments could be used to evaluate surface temperature, habitation patterns, soil moisture, and surface water when unusual outbreaks of malaria are being experienced. For instance, re-analyzed meteorological data for health-related applications is being used by the WHO Global Environmental Monitoring Strategy (GEMS) programme. Also, remotely sensed data could be used to show when storm outflows from rivers are causing adverse quality threats to drinking water, or problems that would necessitate beach closures to protect public health.

4.2.4 Targets

2 Year Targets 4.2 Health

Working with the human health and environment community, GEOSS will:

Advocate new, high-resolution Earth observations relevant to health needs.

Facilitate the establishment of exchanges between health care experts in developed countries, developing countries, and indigenous communities to ensure a global perspective of the challenges and some coordinated development of a network to address problems and to leverage Earth Observation systems where appropriate.

Facilitate mechanisms that help to translate the needs of health data users into requirements that Earth Observation data providers can address.

Promote the development of an integrated public health information network database that includes information relevant to human health officials and agencies, and includes multi-scaled, multi-temporal spatial data collected from remote sensing data sources, to provide better predictive models of the effects of environmental factors affecting human health and well-being.

Facilitate development of data products and systems that integrate Earth science databases with health and epidemiological information. This includes social and infrastructure data needed in decision support systems for health care planning and delivery. For example, in places having no water quality data but large populations with a reduced life span, the best way to improve health may be to monitor water quality/drinking water, implement water purification, and inform the public about the need to use purified water.

Advocate enhancements to international networks and systems needed to support Earth Observation data sharing in areas of human health.

Produce a comprehensive gaps analysis of existing capacity building programmes and aggressively promote initiatives for improved coordination.

Advocate, within its field of competence, an increase in collaborative research programmes between developed and developing country scientists and indigenous communities, to their mutual benefit.

Facilitate the ability to overlay on epidemiology maps the variety of relevant inventoried and processed data, including meteorological, aerosol, ocean and land features, demographic, and infrastructure. This kind of overlay map will be created through interoperable databases and services provided by existing national and international Spatial Data Infrastructures (SDIs).

Facilitate reductions in the lag time in the temporal collection and assimilation of human health data (in some cases, this can mean years) and the "real-time" synoptic data that is collected by remote sensing systems.

Facilitate provision of historical remote sensing data that can be used for tracking or monitoring environmental changes as precursors for what exists today and for modelling future human health scenarios.

Facilitate identification of technical needs in terms of instrumentation and data products that will yield useful epidemiological data at the community level.

Facilitate identification of "paradigm environments", such as vaccine field sites that have strong epidemiological and demographic data, and demonstrate the utility of overlaying high resolution remotely sensed data as a way to correlate environmental factors and specific infectious diseases (e.g. cholera and malaria).

Facilitate development of models relating remotely sensed and *in situ* data to the epidemiology of environmentally related infectious and chronic diseases.

6 Year Targets 4.2 Health

Working with the human health and environment community, GEOSS will:

Produce an inventory of available Earth remote sensing and ground-based databases that can be associated with known health problems such as asthma, pollutant exposure, birth defects, seafood contamination and certain infectious and vector-borne diseases. This includes remote sensing and ground-based databases, historic data sets encompassing well characterized epidemics, and gaps in human health related environmental data (e.g. places where water, soil, or air quality are not measured.) To accomplish this, GEOSS will develop the tools, architecture and infrastructure for a public health information network data base that can be accessed and used by the public health community at large to obtain historical and current health data for better predictability of environmental effects on human health.

Facilitate further development of remotely sensed maps describing the global system for sources, transport and sinks/deposition of gasses and aerosols, and systems characterizing atmospheric, soil, river and coastal pollution.

Facilitate human health community input to the technical specification of new major environmental observation capabilities, including *in situ* and remotely sensed observations.

Facilitate the development of sets of environment and infrastructural determinants of health, e.g. sanitation, transport, energy, communications, traffic management systems, and housing.

Facilitate the development of the tools and processes needed to address health concerns and develop a useful regional network of experts and information databases, working primarily through the GEOSS coordination group for health described above.

Facilitate the establishment of a coordinating group focused on health organizations as users of Earth Observation data and information. This outreach and information-sharing group must engage developed and developing country health communities to ensure a global perspective of the challenges and to catalyze a global network to address problems.

Advocate the development of indicators of human health based on environmental measurements.

Facilitate the development of monitoring methods and systems to detect early evidence of health-related changes and to further inform epidemiological modelling studies.

Facilitate coordinated approaches to the integration of environmental monitoring parameters with vectors, animal reservoirs of disease, and clinical admissions.

Facilitate the development of mechanisms for alerting public health professionals to hazardous conditions identified by environmental monitoring.

Facilitate the availability of wide-area health parameters derived from satellite data, e.g. sanitation, transport, energy, communications, traffic management systems, and housing.

Facilitate the development of geochemical baseline data and maps, such as trace-element toxicity and deficiencies.

10 Year Targets 4.2 Health

Working with the human health and environment community, GEOSS will:

Facilitate access and usability of data needed to assess health vulnerabilities of human populations and support decisions at the local, regional and global scales.

Facilitate the early detection and control of environmental risks to human health through improvements in the sharing and integration of Earth observations, monitoring, and early warning systems, databases, models and communications systems.

Advocate the formation of a global community of operational and academic researchers who use remote sensing data in a standard format to characterize epidemiological associations with disease.

Advocate better on-ground disease surveillance, linked with open national reporting practices, for better understanding and documentation of environmental influences on infectious, chronic and other diseases and disorders.

Facilitate improved methods to fill in gaps from *in situ* to remote sensors. For example, improved methods may be appropriate to integrate data from *in situ* water and soil quality monitoring at specific points with remotely sensed water and soil characterizations of whole watersheds.

Advocate community-based research that involves the collaboration of people living or working in a community with scientists to design and execute research projects to solve community environmental health problems.

Facilitate sharing of environmental monitoring data and collection methods. This may stimulate greater environmental protection and improved health at all levels and in all settings.

Legend for Table 4.2.5

- **0 -** Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
- **1 -** Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
- **2 -** Not yet widely available or not yet globally monitored, but could be within two years.
- **3 -** Only locally available or experimental; could be available in six years.
- **4 -** Still in research phase; could be available in ten years.

4.2.5 Table of Observation Requirements

Health

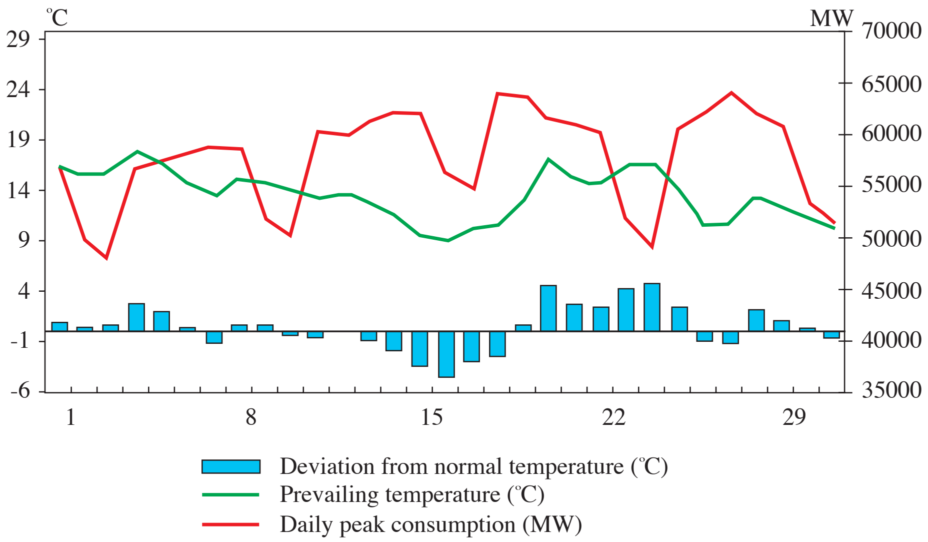
Table 4.2.5

	Observational Requirement	Infectious Diseases	Cancers	Respiratory Problems	Environmental Stress	Nutrition	Accidental Death & Injury	Birth Defects
1	Air quality (e.g., ozone, sulfur dioxide, particulates [PM2.5/1], nitric oxide, carbon monoxide, volatile organic compounds, allergens)		3	3				1
2	Drinking water quantity				2	2		
3	Access to food (e.g., carbohydrates, protein, micronutrients)					2		
4	Drinking water chemical quality (e.g., salinity, metals, nitrate, fluoride, POPs and PCBs)		3		3			3
5	Geology and geochemistry of soils and water (e.g. arsenic, fluoride, radon and iodine)		3		3	3		
6	Pathogens in domestic and recreational water	2						
7	Contaminants in food (e.g., persistent organic pollutants, metals, pathogens)	3	3					1
8	Ultraviolet radiation levels and stratospheric ozone thickness		2					
9	Maximum and minimum temperature, wind, humidity	1			1		2	1
10	Wind direction and speed	2						1
11	Coastal current direction and speed	1						
12	Drainage basin flows	1						
13	Human movements (e.g., air, land and sea transport, refugees)	2						
14	Trade flows	2						
15	Precipitation and soil moisture	1			1		2	
16	Topography	1					1	1
17	Land cover	1					1	1
18	Disease occurrence and cause of death statistics	2	2	2	2	2	2	2
19	Population density, by age and socio-economic class	2	2	2	2	2	2	2

4.3 Improving management of energy resources

4.3.1 Statement of Need

Without exception, energy underpins all aspects of every nation's economic and social development policy. The energy sector includes a wide range of industrial activities such as energy resources exploration, extraction and production, transportation, power (electricity) production, transport and distribution. The optimal management of this diverse, global trillion-dollar sector, which includes non-renewable resources such as coal, oil and gas, as well as renewable resources such as solar, wind, geothermal, biomass and hydropower generation, is of critical concern to all countries.[8]



Courtesy of C. Fil, EDF, France

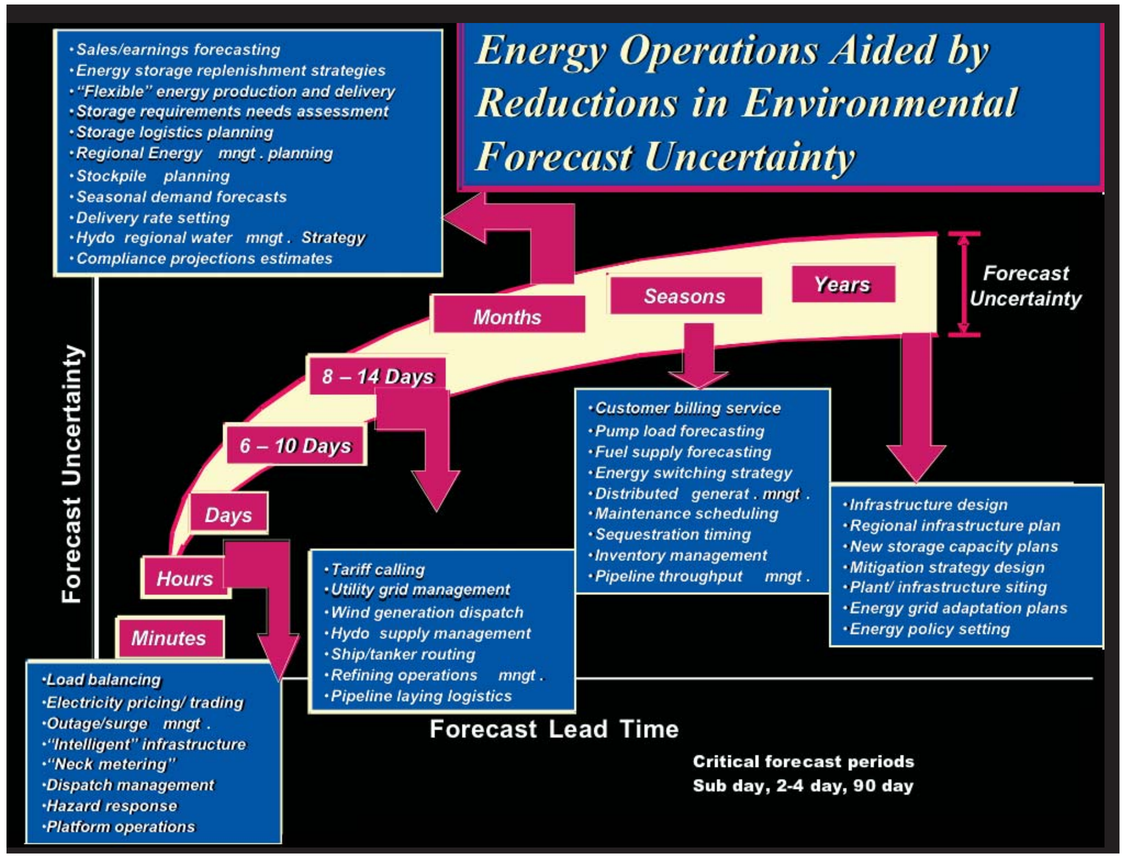
The correlation between outside temperature variation and energy consumption in France for October 2004

Perhaps no other illustration of the critical dependence upon energy of countries is more striking than the "blackout" in eastern North America in August 2003. It occurred during summer peak energy use periods when air conditioning demand was at its highest. Impacts extended to potable water loss, loss of sanitation, food spoilage due to heat, defense industrial base shut down, intermittent telecommunications failure, transportation shut down, banking and finance interruption, mail service disruption, and tourism industry closures. The four-day outage affected an area of 50 million people and 61,000 megawatts of power, with an estimated total cost for North America of between $5.8 and 11.8 billion US dollars.[9] The Canadian GDP was down 0.7% in August, with a net loss of 18.9 million working hours. Manufacturing shipments in Ontario were down $2 billion Canadian Dollars (1.8 billion US).

Major issues for the energy industry include fuel supply, type, and sustainability, as well as power efficiency, reliability, security, safety, and cost effectiveness. Countries need reliable and timely information in order to manage the risks associated with uncertainty in supply, demand, and market dynamics. Sound resource management practices and strategies are needed by both industry and government. As weather and climate directly influence most of the energy sector, access to accurate, reliable, affordable real-time data from observation systems, as well as predictive information derived from the modelled data, is critical for the continued stability and growth of the economies.

[8] *World Development indicators 2001, The World Bank group; World Development Report 2000/2001, Attacking Poverty, IBRD, The World Bank. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTPOVERTY/0,,contentMDK:20194762~pagePK:148956~piPK:216618~theSitePK:336992,00.html*

[9] *US-Canada Power System Outage Task Force report: August 14th Blackout: Causes and Recommendations, April 2004, https://reports.energy.gov/*



Courtesy of M.G. Altalo, Science Applications International Corp.

Energy operations aided by reductions in environmental forecast uncertainty

According to OECD and IEA analyses, global primary energy demand is likely *to expand by approximately 60 percent over the next 30 years,* with two-thirds of the increase occurring in the developing World, notably in China and India. To date, some 1.6 to 2 billion people have no access to electricity and a further 2 billion are severely under-supplied or rely on unstable energy resources. The UN has targeted development goals to enhance the quality of life through cost-effective supply of energy to these societies. In developing countries, therefore, major issues are energy access and reliability, with efficient energy management being a secondary issue. Observing systems that provide information enabling countries and regions to meet their development and sustainability goals will be of critical value, in particular for the detection of new fossil fuel reserves, for more efficient management of existing non-renewable energy resources and for the development of renewable energy systems which will play a growing role in the World's primary energy mix.

Equally important are the requirements for governments to reduce or stabilize their greenhouse gas (GHG) emissions resulting from the burning of fossil fuels for transportation, for industrial manufacturing and for the production of electricity with major consequences for human health and climate (see Section 4.2 on Health and 4.4 on Climate). The 1992 UN Convention on Climate Change committed most industrialized countries to seek to return their emissions to 1990 levels by 2000 and the Kyoto Protocol, adopted in December 1997, committed signatory countries to reduce all GHG emissions to on average 5% below 1990 levels by 2012. National and regional environment authorities require accurate and timely information on levels of GHG emissions to meet their reporting obligations in the context of international treaties, protocols and directives.

The first beneficiaries of GEOSS will be the end-user populations: (1) through the reliable and safe provision of energy and the impact on prices and tariffs, and (2) in contributing to sustainable development, food security, irrigated agriculture, health, education for youth (women in particular), gender equity. In addition, the energy industry will benefit from improved safety for critical energy operations, and from optimized energy resource management. Furthermore, industrial activities dependent upon continuous and reliable energy availability will also improve their performance and results. The impact of energy efficiency on national economies resulting from GEOSS will facilitate delivery of further social benefits in areas such as education, health and tourism. GEOSS will also contribute to the protection of the environment by providing objective information on the rate of sequestration of GHG and the extent to which emerging regulations need to be addressed by energy producers.

Examples: Power Outages Due to Extreme Weather

In September 2003, the impacts from winds and floods of Hurricane Isabel on the energy infrastructure of the east coast of the US resulted in widespread power outages to 5.5 million customers due to downed power lines and the loss of water supplies due to the lack of electricity to run the pumps. Sales at major retail stores fell 1.8%. The cost of repairing damage to the power grid in Virginia alone was over $40 M.[10]

In another instance, unanticipated extreme weather events such as droughts or floods seriously affected the energy resources of Ethiopia, where 97% of the hydroelectric power comes from theKoka Dam. Major strategies need to be developed to mitigate risks due to flash flood and periods of water scarcity. The Ethiopian Electric Power Corporation (EEPCo) reported drought induced hydroelectric power failure leading to revenue losses of $8 M.[11] While this dollar loss is modest for a developed country, for Ethiopia it is enough to destabilize the economy. Thus the relative value of the vital observing system data to the developing nation is orders of magnitude higher.

In Kenya, where hydropower makes up 75% of the generation (Kenya Power and Lighting Company and Ken Gen), drought-induced rationing decreased the overall production of electricity to 40%. Emergency power credits were issued to purchase fuel, since there are no internal sources of fossil fuel. The World Bank contributed $47 M to import and operate generators. The economic losses due to rationing and failure were estimated at $2 M/day. KPLC lost $20 M/6 months with expenditure of $141 M for fuel. It was estimated that the loss to the economy approached $100 M/month. Incorporation of weather and climate forecasts as well as soil and evaporation data for the calculation of water loss could help mitigate these types of disasters.[12]

4.3.2 Vision and How GEOSS Will Contribute

The vision is to balance the supply and the demand of energy of the planet in a sound, equitable, sustainable and environmentally responsible way, enabling countries to meet and further their economic, social and environmental agendas and/or obligations. This requires involvement of both the leaders of countries and of the energy industry. The implementation of GEOSS will offer unique capabilities for the global industry to meet these goals through delivering accurate "Situational Awareness" of both current and future states of the energy system and their environmental context.

At regional level, differences in energy management are influenced by availability, cost, and impacts on ecology, environment, and human health and well being. GEOSS and its associated modelling capabilities will allow energy management actions to be taken to reduce risk due to weather, climate, water, oceanic, geological and human threats. Using the observing systems and modelled products, coupled with energy decision support models and tools, industry will create "Action Plans" to improve the management of energy resources in a safe, efficient, cost effective, reliable, secure and socially responsible manner.

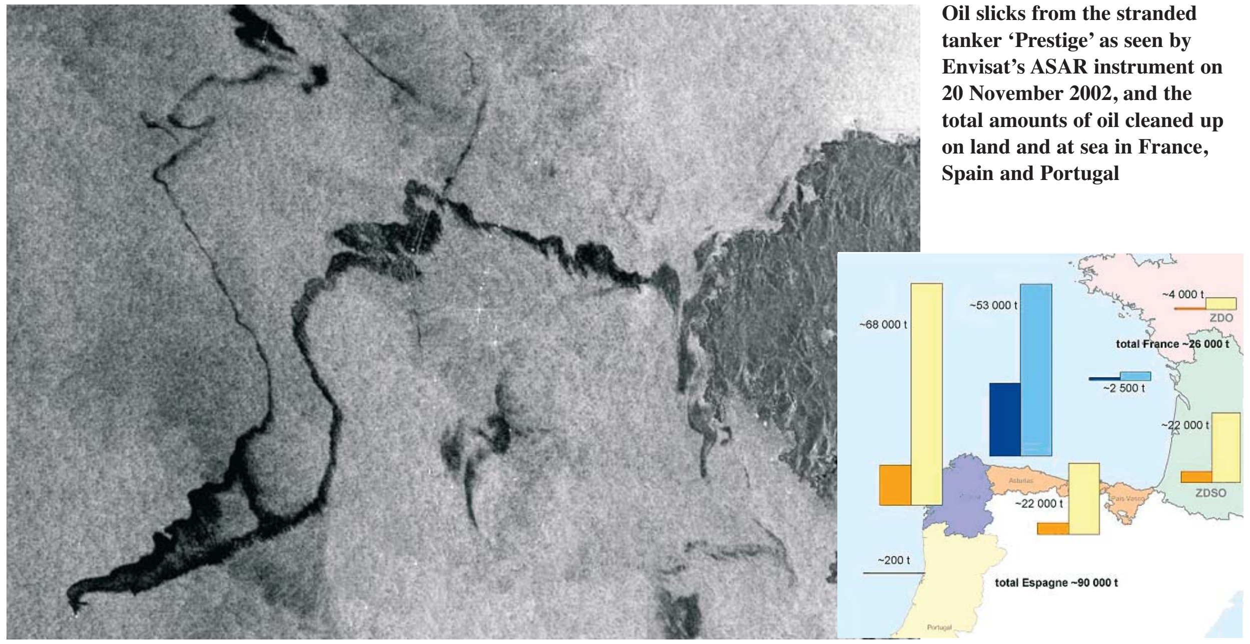
The objective is to create informed "proactive" strategic energy planning together with tactical management based on accurate situational awareness and prediction. This will supersede the "reactive" management practices currently in use in much of the World today. GEOSS will play an important role in providing data and information relevant to planning, developing and controlling power and pipeline distribution systems, hydropower dam operations, wind power generation commitment, traffic congestion management, city lighting, and building heating/cooling, to name just a few.

In addition, GEOSS will contribute significantly to the development of renewable energy systems and their incorporation into the grid and, as a consequence, will decrease the demand on and extend the life expectancy of non-renewable energy sources. For instance, on the basis of reliable climatological information, GEOSS will help in the selection of optimum sites for the production of wind and solar energy and for the determination of areas where the potential for hydropower or tidal power is more favourable. GEOSS will also facilitate the determination of locations with good geothermal energy production capabilities.

4.3.3 Existing situation and gaps

The energy industry is already an important user of Earth Observation-derived information and products. Weather and climate data over various timescales, as well as data related to extreme events such as heat waves or droughts, are vital for energy usage forecasts. Climate statistics and predictions are important for long-term supply planning. Marine forecasts are essential for the offshore drilling business, providing information on sea-state conditions, wind, wave, surface temperature, and extreme events such as severe storms, freak waves and hurricanes.

Assessment of greenhouse-gas (GHG) emissions and the monitoring of air pollution and air quality are key requirements for energy producers and require further improvements. The need for systematic detection of marine oil pollution (not only for major disasters, such as the sinking of the 'Prestige', which in total represent



Oil slicks from the stranded tanker 'Prestige' as seen by Envisat's ASAR instrument on 20 November 2002, and the total amounts of oil cleaned up on land and at sea in France, Spain and Portugal

Courtesy of Ministerio de Fomento & CEDRE

[10] Infrastructure Interdependencies associated with Hurricane Isabel. Argonne National Laboratory, 8 October 2003
[11] IRI assessment studies
[12] IRI Assessment studies

less than 10% of World marine oil pollution) and oil drift monitoring for coastal zone protection is also critical. Managing pipelines through weather data and terrain movement is also important. Exploration of new fossil fuel energy reserves also benefits from Earth Observation applications in primary geological mapping.

Real opportunity exists for information from Earth Observation to contribute to the optimization of renewable energy systems for power production, and to the provision of information for optimal integration of traditional and renewable energy supply systems into electric power grids. Data provided through GEOSS data can also contribute to the modelling needed for improved prediction of electric power supply and demand, thus mitigating power shortages. In addition, the energy industry must ensure the minimization of GHG emissions and other pollutants from energy production (e.g. for Kyoto Protocol verification). Effective management of the above energy issues requires a broad variety of data, information, models and decision support systems. Whilst some of these needs can be met, the tools and products are often proprietary or suffer from inadequate inter-operability.

A large fraction of the observations required for improving the management of energy resources is essentially that set out under Weather and Climate. Gaps still exist in the data and information products needed for efficient exploration, production, transportation and use of energy, while minimizing associated environmental risks. There is a need for better and more informative indicators of the factors influencing energy demand (including socio-economic trends) which decision-makers and stakeholders can use to assess the current situation and to take both short-term and long-term corrective actions. These will result from improved forecast models for predicting environmental conditions (weather, air quality, water quality, etc.) as well as a better integration of data, information, and models into spatial/temporal databases and decision-making tools (e.g. GIS).

The energy industry’s operational requirements listed in the Table 4.3.5 identify, for the main energy sub-sectors and operations, the information requirements necessary to take action. This table is based on a one-year study examining the diversity of needs of the industry, ranging from utility operations to policy development[13].

4.3.4 Targets

To provide improved strategic and tactical energy-management information, GEOSS will promote wider use of existing environment-related energy-management tools, foster R&D on improved tools, and facilitate wider access to significantly better and more reliable weather and ocean forecasts on a wide range of time scales (hours to months, years and decades or even centuries) and geographical scales (from local to regional and global), all of which will have substantial impacts on the energy industry. GEOSS will also encourage the development of new tools (observing systems, models…) for detecting and monitoring the impacts of energy utilization on the environment with a view to reducing these impacts and aiding compliance with international regulations and treaties.

[13] *Requirements of the energy industry for weather, climate and ocean information by Altalo et al., Technical Report to NOAA OAR, 2000*

Short term (2 years)

The short-term goal in the energy industry must be to promote the use of existing data and forecast information. Preparing the industry to receive and use the new GEOSS products when available is critical to the early success of GEOSS. To this end, it is essential that countries foster investments at local, national, and regional level in improved energy management through use of Earth observation data and information products. Actions are needed as follows:

2 Year Targets 4.3 Energy

Working with the energy community, GEOSS will:

Facilitate the exchange and use of existing data/products and forecast information through specific initiatives and actions in coordination with the energy community: (i) to raise awareness about the importance and potential of environmental information; (ii) to facilitate access to the existing information and products; and (iii) to develop training and encourage the development of decision-support tools for optimal energy use.

Produce, in coordination with the energy community, a strategic 5-10 year plan for exploitation of the benefits of the new generation of operational observing systems - both space-based and *in situ* - which comes on-stream in this decade. The plan should include efforts on: (i) operationalizing existing research capabilities to meet the needs of the energy industry; (ii) research and development in advanced end-to-end modelling and forecasting techniques (such as ensemble-based methods) covering both environmental and energy processes, and with an emphasis on issues of risk assessment; (iii) the improvement of information networks by linking existing systems and making them inter-operable; (iv) continue efforts to raise awareness of, facilitate access to, and operationalize improved methodologies for exploitation of GEOSS data and information products for the industry

Medium term (6 years)

In the medium term, progress and improvement of energy resources management activities, ranging from exploration to exploitation, transport and distribution, will be largely related to the improvement of short- to medium-term (up to 8-10 days) weather predictions, as well as progress in seasonal to inter-annual climate forecasts resulting in particular from the utilization of a new generation of satellites coming on-line and improved models allowing better matching between demand and supply as well as improved safety operations.

The continuous monitoring of atmospheric pollution and the improvement of air quality will result from the availability of operational daily global analyses of greenhouse gases, monthly estimates of the sources and sinks of CO_2 (implying sustained observations of ocean carbon at regional and global scales) plus daily global/regional analyses complemented by available chemistry-transport modelling for the forecasting of reactive gases and aerosols.

The development of new renewable energy systems will also benefit from existing and new Earth Observation techniques and satellite data to define optimum operating conditions/locations for sites and minimize environmental impacts.

6 Year Targets — 4.3 Energy

Working with the energy community, GEOSS will:

Produce an evaluation of the Plan's progress with regard to energy and revise strategy as needed. The revised Plan will also include an assessment of the needs of the energy sector for new and/or enhanced GEOSS observations and products.

Facilitate the exchange of data and products for efficient energy management.

Facilitate the use of improved weather and climate products for the development of new energy tailored products and services.

Long term (10 years)

Energy management needs and opportunities for improvement vary globally. However, in view of the increasing demand for energy and the simultaneous need to reduce environmental impacts, the energy sector will rely increasingly in the long term on improved, tailored products and services derived from operational Earth Observation systems and modelling. The energy sector will also further support the development of renewable energy systems relying on products available through GEOSS.

10 Year Targets — 4.3 Energy

Working with the energy community, GEOSS will:

Facilitate the implementation of appropriate *operational* observing systems – space-based and *in situ* - for the continuous and sustainable provision of reliable and timely data in support of energy operations.

Advocate the development of new generation (higher resolution, additional variables…) weather and climate forecasting models.

Facilitate capacity building in order to bring energy management at the local level to equivalent high (national and regional) levels of efficiency.

Facilitate the development of renewable energy systems taking advantage of products available through GEOSS.

4.3.5 Table of Observation Requirements

Legend for Table 4.3.5

- **0 -** Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
- **1 -** Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
- **2 -** Not yet widely available or not yet globally monitored, but could be within two years.
- **3 -** Only locally available or experimental; could be available in six years.
- **4 -** Still in research phase; could be available in ten years.

Energy
Table 4.3.5

	Observational Requirement	Oil & Gas Exploration, Development & Production Operations (onshore & offshore)	Refining & Transport Operations (at sea and over land), Environmental Impact of Emissions & Transport	Renewable Energy Operations, Environmental Impact of Plant Siting & Operations, Biomass Crops Optimization	Electricity Generation, Transmission & Distribution Energy Load Demand, & Supply Forecasting	Global Energy Management, Emissions Trading, Impact of Climate Change, Treaties & Regulations
	Land Requirements					
1	Digital terrain model / digital topography maps*	2	2	2	2	
2	Land use / Land cover maps*	2	2	2	2	2
3	Geological maps*	3	3	3		
4	Soil maps & variables	3	3	3		3
5	Subsidence maps	3	3	3		
6	Urban extent	2	2	2	2	2
7	Hydrological variables**			3 (see Water)		3 (see Water)
8	Crop variables**			2 (see Agriculture)		

*Depends on geographical scale and accuracy required.
**Depends on types of variables required.

	Observational Requirement	Oil & Gas	Refining & Transport	Renewable Energy	Electricity	Global Energy Management
	Atmosphere Requirements					
9	Weather and short-term climate forecasts*	1 (for 1 to 3-day forecast), 1 (for 3 to 10-day forecast), 3 (for climate forecast)				
10	Extreme weather & climate event forecasts*	3 (for 1 to 5-day forecast)				
11	Measurements and forecasts of air pollutants	4	4	4	4	4
12	Climate statistics for atmosphere variables**	3	3	3	3	3

*See Weather and Climate societal benefit areas for detailed information.
**Depends on types of variables required.

	Observational Requirement	Oil & Gas	Refining & Transport	Renewable Energy	Electricity	Global Energy Management
	Ocean Requirements					
13	Sea surface temperature*	1	1			(see Climate)
14	Sea ice*	2	2			(see Climate)
15	Sea-level*	1	1	1		(see Climate)
16	Tides*	1	1	1		(see Climate)
17	Surface currents*	2	2	2		(see Climate)
18	Sub-surface currents*	3	3			(see Climate)
19	Eddies*	3	3			(see Climate)
20	Salinity*	3	3			(see Climate)
21	Ocean color*	2	2			(see Climate)
22	Sea state*	1	1	1		(see Climate)
23	Surface wind speed and direction*	1	1	1		(see Climate)
24	Extreme event: Hurricanes*	2	2	2	2	
25	Extreme event: Tsunami*	4	4	4	4	
26	Extreme event: ENSO*	3	3	3	3	3
27	Bathymetry*	4				

Energy Table 4.3.5 **Observational Requirement**	Oil & Gas Exploration, Development & Production Operations (onshore & offshore)	Refining & Transport Operations (at sea and over land), Environmental Impact of Emissions & Transport	Renewable Energy Operations, Environmental Impact of Plant Siting & Operations, Biomass Crops Optimization	Electricity Generation, Transmission & Distribution Energy Load Demand, & Supply Forecasting	Global Energy Management, Emissions Trading, Impact of Climate Change, Treaties & Regulations
Ocean Requirements (continued)					
28 Climate statistics for ocean variables*	3	3	3		3

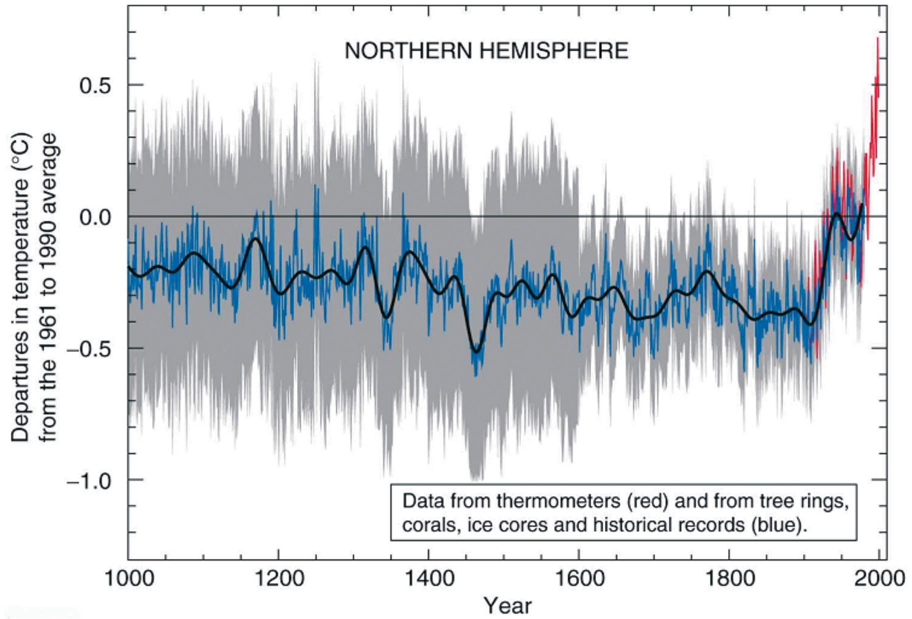
*Depends on the accuracy required for various forecasting timescales.

Solid Earth Requirements					
29 Seismic surveys	4		4		
30 Gravity field anomaly data	2				
31 Magnetic field data	3				

4.4 Understanding, assessing, predicting, mitigating and adapting to climate variability and change

4.4.1 Statement of Need

All societies and ecological systems are affected by climate change (including long-term climate change, natural climate variability and extreme weather and climate events). Improved knowledge of climate change underpins many other societal benefit areas. As the state of the "climate system" is described by statistical properties, usually with a 30 year base period, obtained from sufficiently long

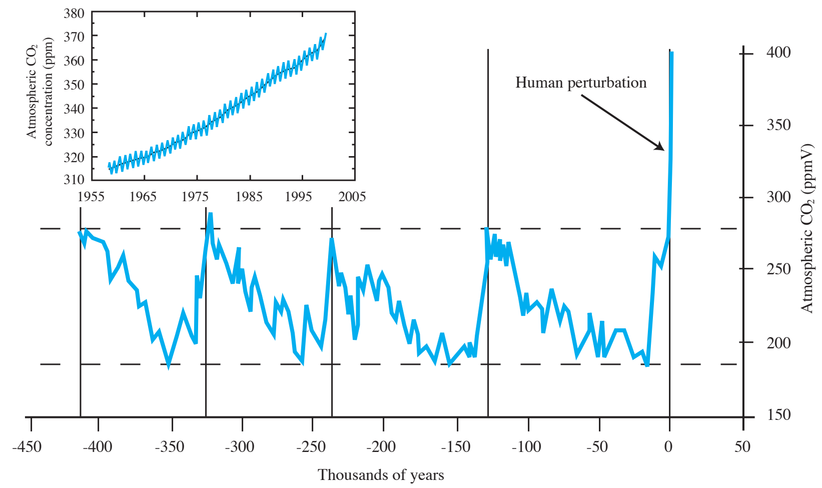


Variations in the Earth's surface temperature over the past 1000 years (From IPCC Third Assessment Report, Technical Summary of WG1 Report)

observations of the state of the atmospheric, oceanic, and terrestrial domains, there is a need, firstly, to have long and homogeneous time series of the required observations in each of these domains. Furthermore, it is necessary to identify the underlying dynamic processes to improve our knowledge of the changing climate. Risks associated with the observed trend of global warming and other changes, including extreme events, are often poorly known or not fully recognized when planning for socio-economic development. For adaptation to be effective, governments as well as the private sector need information about past and current climate conditions, and their variability and extremes. In addition, they need sound projections of future conditions, not only on a year-on-year basis, but also for many decades into the future.

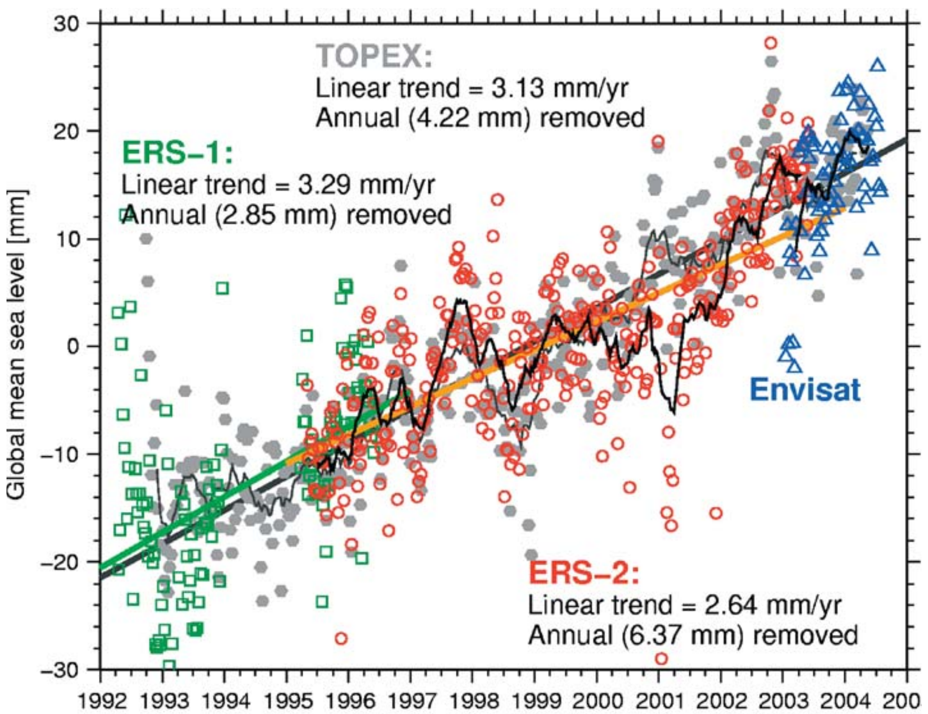
The climate system responds to both external forcings (such as volcanoes, solar radiation, etc.) and to perturbations of internal processes. Evidence from IPCC assessments indicates that human activities are leading to changes in our climate. Furthermore, available observational evidence demonstrates regional changes in climate, particularly increases in temperature. It is therefore important to track climate change in such a way that causes can be determined, both in external and internal processes, that trends in mean climate and its variability can be predicted, and that appropriate adaptation and mitigation strategies can be defined for implementation. Parties to the UNFCCC agreed to achieve as the ultimate objective, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic inter-

Recent human influence on the carbon cycle (From IGBP / Global Change and the Earth System)



ference with the climate system. Such a level should be achieved within a time frame to allow ecosystems to adapt naturally, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Human and technological capacity is needed for the end-to-end collection, management (including data quality control), exchange, archiving and utilization of current and future observations from the atmosphere, ocean, and terrestrial domains. Increased attention is needed to recover and access past records (both instrumental and palaeoclimate reconstructions) in order to better establish the variability and long-term trends in climate. Procedures for the storage and exchange of high quality metadata will need to be implemented. This stewardship is a significant challenge since developed countries are currently barely able to keep up with the growing influx of new data from satellites and *in situ* observations, while developing countries lack the resources to meet the high costs of accessing such data. Furthermore, observing standards and guidelines for required climate variables must be adopted and supported by countries making observations. The Global Climate Observing System (GCOS) can provide the framework for this. In many cases, this may require that outside assistance be available so that countries can contribute to and make use of a global climate network.

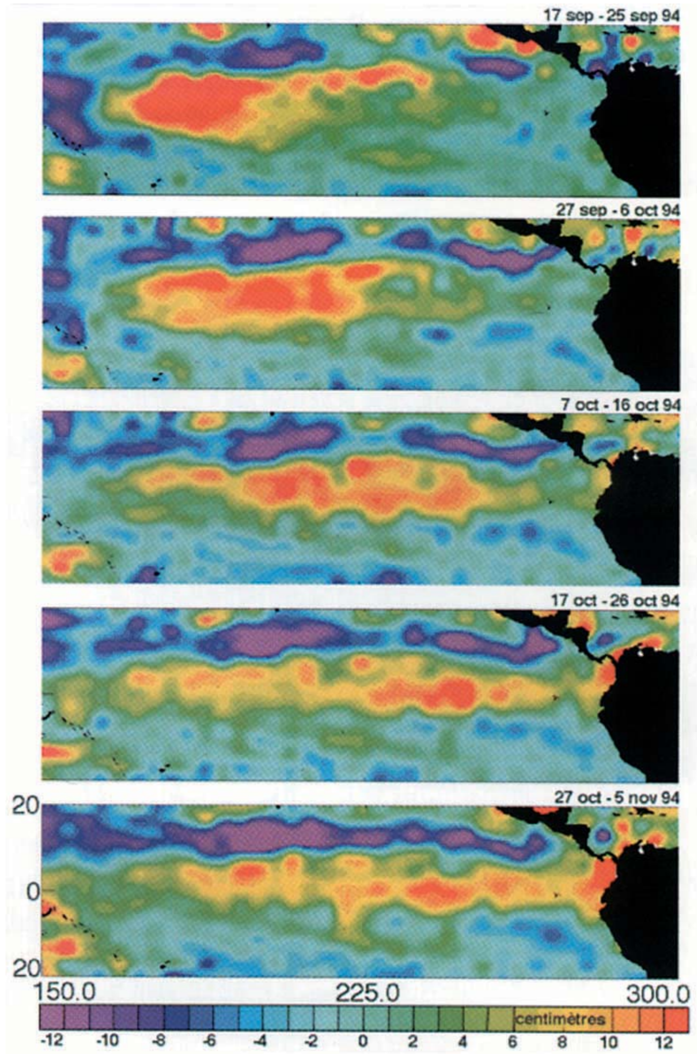


Courtesy of R. Scharroo, NOAA

Satellite altimetry measurements of sea-level rise

Example: Climate Extremes Warning System for Seasonal Forecasts

Five years from now, in June, seasonal climate forecasts predict an exceptionally strong El Niño event for the following December to February season in the Pacific, with heavy impact on regional weather patterns in parts of Latin America. A timely and tailored forecast is broadly disseminated and provides the opportunity to plan adequate mitigation measures in all affected regions and with respect to various societal areas for the coming months: in the agriculture sector, farmers in Northwestern Peru, Southern Ecuador and Uruguay are advised to expect an increased likelihood of heavy rainfalls and prepare for reducing possible flood damage, thereby improving national food security; Northeast Brazilian farmers are advised to plant drought-resistant or fast-ripening crops to adapt to forecasts of increased chances of drought conditions; livestock farmers will time their slaughtering, transportation and marketing schedules based on information that includes likely seasonal rainfall scenarios; countermeasures against possible floods, which can lead to prolonged food shortages by ruining stocks and fertile topsoils, will be taken, saving lives and property in flood-prone areas. For the regional health sector, surveillance by early warning systems within the GEOSS helps to combat diseases, such as malaria, affected by exceptional climatic conditions. The El Niño forecast has been enabled by substantial enhancement since 2005, through the coordinated efforts by GEOSS, of satellite and composite *in situ* observing networks (e.g. ships, drifting buoys) over previously data-sparse areas. Improved data exchange, capacity building and computer technology in the preceding five years will have improved our understanding of regional atmospheric patterns, their predictability, and the information dissemination to potentially affected countries where specific regional and local response measures are to implemented.



Courtesy of NASA/CNES

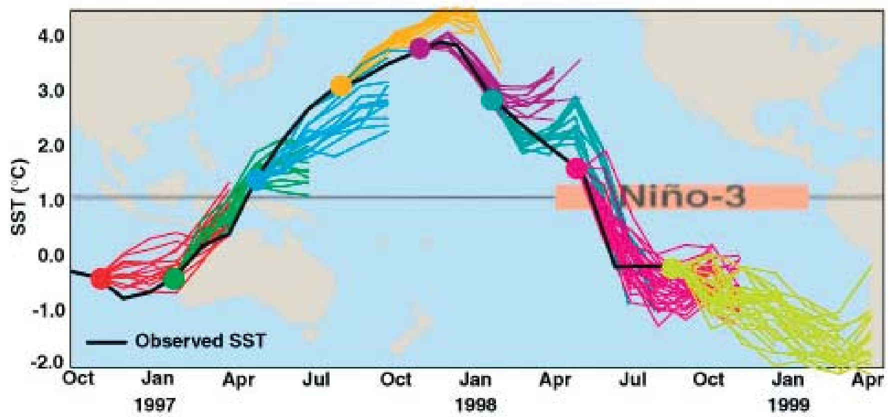
Satellite altimetry and temperature measurements provide unprecedented warning of El Niño's arrival

4.4.2 Vision and How GEOSS Will Help

The vision is to establish a climate observation system of systems that will allow us to improve our understanding of the Earth's climate system and the ability to predict climate change, and to mitigate and adapt to climate change and variability. This will enable economic and societal development in a sustainable way, with minimum perturbations on the climate system.

GEOSS can be highly effective by promoting completion of partially implemented observing systems, by facilitating access to data, by developing and implementing new observing systems, and by providing integrated climate products. It can support compliance of existing and new observing systems with the GCOS Climate Monitoring Principles (WMO, 2003; UNFCCC, 1999, 2003) and WMO data reporting guidelines. Note that these principles have wide applicability outside the climate domain, as indicated by their adoption by CEOS. GEOSS supports the phased 5 to 10 year *Implementation Plan for the Global Observing Systems for Climate in Support of the UNFCCC*, GCOS-92 (GCOS, 2004), hereinafter the "GCOS Implementation Plan." GEOSS support will be through implementation of the climate requirements for a "system of systems" involving five observing systems (WMO/GOS, WMO/GAW, WHYCOS, GOOS, and GTOS) in the atmospheric, oceanic and terrestrial

Predicted (at 3 monthly intervals) and observed variations in Sea Surface Temperature for the El Niño in 1997/98



Courtesy of ECMWF/CLIVAR

domains, including data access facilities for supporting interoperable use of large volumes of data from inhomogeneous information sources. At the same time, GEOSS can make use of the technical commissions of WMO, the achievements of the World Climate Programme (WCP) and the scientific guidance provided by the World Climate Research Programme (WCRP). This will be especially through the WCRP's ten-year strategy, *"Coordinated Observation and Prediction of the Earth System (COPES),"* and through the IGOS P Theme Reports on atmospheric chemistry, carbon-cycle, water cycle, and ocean, geohazards, and others under development.

Adapting to climate change, mitigating its impact, and assessing climate variability, will benefit from GEOSS through improvements in the provision of services to other socio-economic areas, as many of them are linked to climate variability and change. GEOSS can improve the observational basis by working to ensure the sustained operation of essential networks and systems, including the continuity of satellite systems, and by developing its activities in close contact with the scientific community, in order to take advantage of new observation techniques. GEOSS will promote data assimilation and modelling for the integration of *in situ* and satellite data, for algorithm development, validation, and the creation of integrated products that improve understanding of the climate system. GEOSS can also facilitate better telecommunications networks to exchange the data sets in an operational mode. It is important to include metadata to ensure reliable data interpretation, to activate data exchange, and to archive the increasing volume of data from very heterogeneous sources. GEOSS will support such data centre functions that systematically meet user requirements.

Because all countries contribute to factors affecting climate variability and human-induced change and are affected by them in different ways, an understanding of these phenomena and mitigation and adaptation to changes should be tailored to the specific priorities of those countries by considering their national circumstances and geographic locality, as well as to broader regional and global considerations. For example, small island countries and coastal communities may focus on the socio-economic impacts of sea-level rise, whereas inland countries and communities, such as in the African Sahel, may consider the impacts of desertification a higher priority. Once the priorities and impacts are recognized, the necessary capabilities to assess, predict, mitigate and adapt to these priority issues at both the local and national level should be established. In turn, the contribution of their knowledge to the international community will provide a more comprehensive global understanding of the Earth's climate. A capacity building commitment will require that national institutions or organizations augment operational responsibility for making the observations and for their distribution, analysis, and archiving. To do this, sustained sources of funding are needed. Countries with underdeveloped infrastructure or capacity could focus first on the collection of essential *in situ* observations, both historical and future data sets, which provide valuable data for local applications and also contribute to the cross-calibration of satellite sensors. Higher priority observations, infrastructure, and even sustained operational activities, where national capacity is insufficient, could in some cases be supported by relevant funding mechanisms with appropriate international coordination (such as the GCOS Cooperation Mechanism).

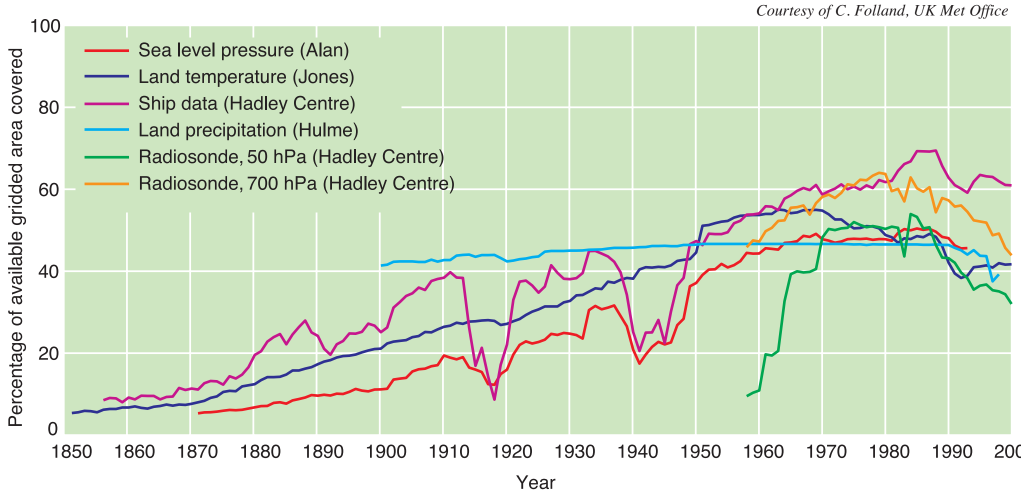
4.4.3 Existing Situation and Gaps

The IPCC Third Assessment Report (IPCC, 2001) highlighted scientific uncertainties that need additional research as well as new observational data. The Essential Climate Variables (ECVs) required for climate monitoring are identified in the GCOS *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC,* GCOS-82 (GCOS, 2003), hereinafter "GCOS Second Adequacy Report," and in the IGOS-P Theme Reports. Research activities aimed at improving our capability to predict climate variability and change are coordinated by the WCRP

and include observation, modelling, data assimilation, re-analysis and process studies programmes. The WMO World Climate Data and Monitoring Programme (WCDMP) coordinates data and monitoring activities, including the development of climate indices.

The observational networks, especially the terrestrial and ocean networks, are incomplete and are still to be fully implemented. The Global Terrestrial Networks (e.g. for glaciers, for hydrology, and for permafrost) should be fully implemented, gaps in the measurement networks that they have highlighted should be filled, and data should be provided to the designated international data centres. The ocean networks lack global and full depth coverage and commitment to sustained operation. There is a need to complete the deployment and subsequent maintenance of the global Argo float array and the global tropical moored buoy array, and to enhance these platforms with measurement capabilities for physical and chemical parameters presently only provided by research ships. The atmospheric networks are not operating with the required global coverage and quality, and both the GCOS Surface Network (GSN) and the GCOS Upper Air Network (GUAN) stations still need to be fully implemented. Surface-based atmospheric composition monitoring is currently mainly served by a sparse surface network for the long-lived gases and an inhomogeneous ozone sonde network.

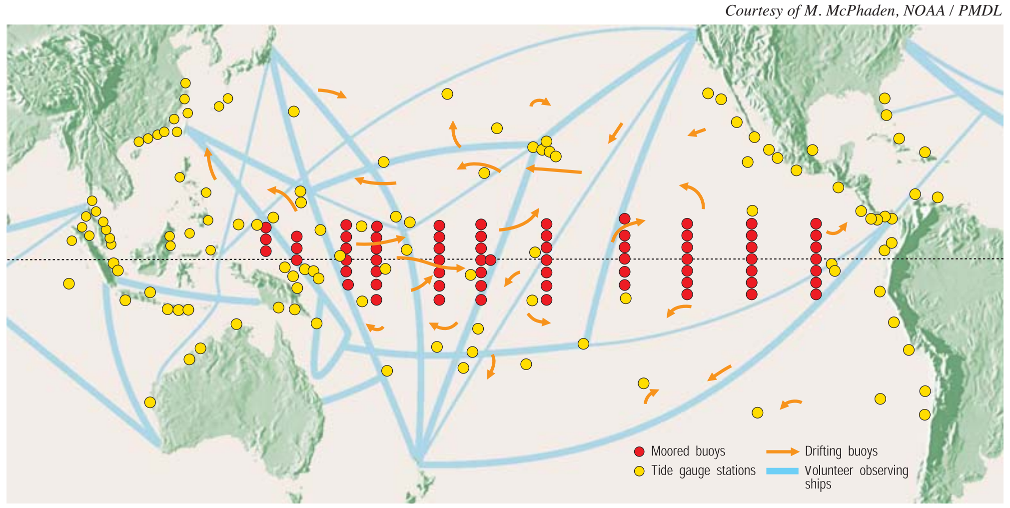
Courtesy of C. Folland, UK Met Office



The number of meteorological observing sites on land and at sea over the last 150 years. For many key elements, the area covered by observations has decreased since the 1980s

Space-based observations are an essential part of the global observing systems for climate for all three domains. Their contributions, though already substantial, and in many cases impossible to replicate with *in situ* approaches, have not realized their full potential because the mission design parameters have not considered the needs of long-term climate monitoring requirements. Ensuring the continuity of space-based observations is critical. Many of the Earth Observation missions, relevant for the climate variables, are either for research and development purposes, most of which by their very nature have a limited time horizon, or are implemented in support of weather services where the primary requirements are not as demanding on the observational quality with respect to continuity and homogeneity. It is important to note the need for a stable geodetic reference frame for ground-truth observations at reference sites and/or observatories for calibration and verification of satellite products. Adherence by countries and their agencies to the GCOS Climate Monitoring Principles for global climate observations is required.

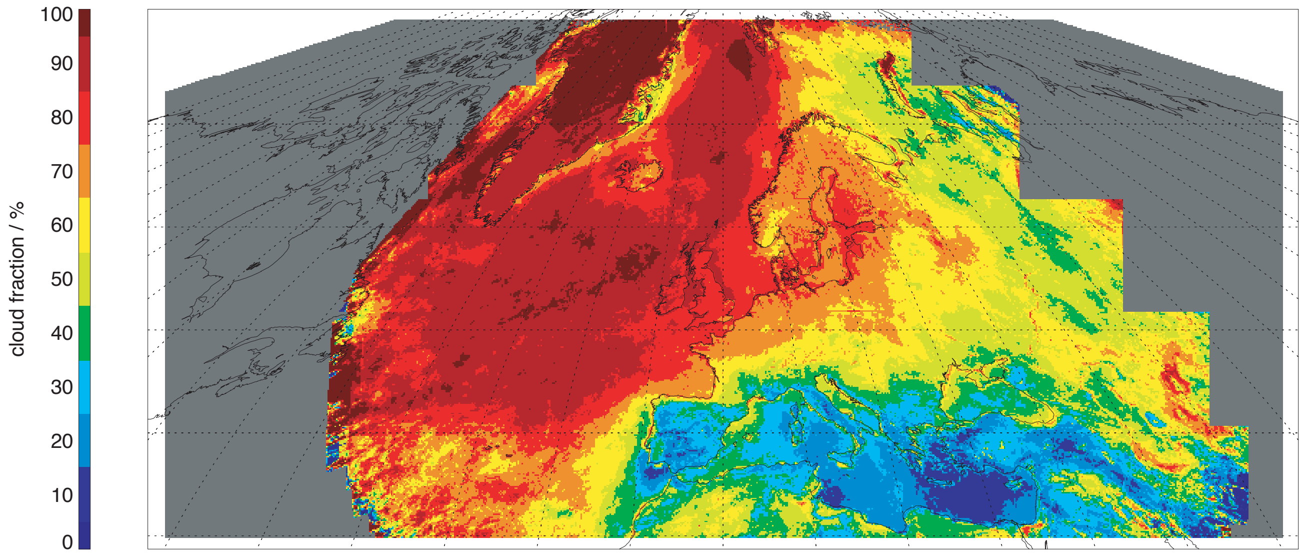
Courtesy of M. McPhaden, NOAA / PMDL



The Tropical Ocean Global Atmosphere (TOGA) project developed a comprehensive array of moored buoys, drifting buoys, tide gauges and shipboard measurements for the Pacific Ocean

Global climate products are commonly generated by blending data from different sources, such as *in situ* and space-based observations, through data assimilation and modelling. It is essential that additional analysis centres be identified and existing centres continue to regularly generate these products for the atmospheric, oceanic and terrestrial domains. Data-assimilation and re-analysis systems need to be extended, particularly for the oceanic and terrestrial domains, in order to generate comprehensive and internally consistent descriptions of the state of the climate system.

Many countries, especially the least-developed ones and small-island developing states, as well as some countries with economies in transition, are not in a position to participate fully in global observing systems for climate. Problems include a lack of trained personnel, expensive consumables, inadequate telecommunications, and an absence of equipment. There is also limited capacity for them to draw benefits from the observations currently being taken. In many countries, some historical data, including metadata, are still only available in non-digital formats, and thus cannot be easily used. The implementation of GEOSS should rectify these weaknesses and help all systems upgrade their observational and data management capacities to the necessary level.



Mean cloud fraction (%) for June 2004 derived by the EUMETSAT Satellite Application Facility on Climate Monitoring, using Meteosat data

There are many observations of the climate system being made that remain unavailable to users beyond the groups making those observations. Better interoperability standards for data and mechanisms to disseminate the data sets are needed. Countries need to ensure that their observations and associated metadata for climate variables, including historical observations, are available in a timely manner at international data centres[14] for application to climate analyses.

[14] *The term "international data centre" covers the ICSU World Data Centers, as well as other centres that support Earth Observation systems by providing the storage of data and by making it available to the users. It is implicit that these centres will adhere to their relevant data policies, apply the relevant procedures in their operations, and implement cataloguing, auditing and reporting procedures on the availability of data.*

4.4.4 Targets

2 Year Targets 4.4 Climate

Working with the climate community, GEOSS will:

Support GSN and GUAN networks, Global Atmosphere Watch (GAW) observatories, initial Global Ocean Observing System (GOOS), river discharge, lake levels, soil moisture, permafrost, snow cover and glacier observing networks, which are recommended in the GCOS Implementation Plan.

Support implementation of actions called for in GCOS Implementation Plan and the relevant IGOS-P Theme Reports.

Improve the reporting of observations to international data and analysis centres in terms of data volumes, quality and timeliness.

Improve the capability of international data centres for data archiving and distribution of data and products.

Establish a strong collaboration mechanism between observational organizations and research communities, and users of climate information, to further refine the observations, analyses and products required.

Identify the needs and solutions necessary to implement the global observing systems for climate in all regions and countries based on the recommendation of GCOS Implementation Plan and specific regional action plans.

Initiate an intergovernmental mechanism in the terrestrial domain to prepare and issue regulatory and guidance information on observational procedures and data management as, for example, also asked for in decision 9/CP.9 (UNFCCC, 2003).

Support JCOMM to coordinate the implementation of and prepare regulatory and guidance information for an operational *in situ* ocean observing system.

Emphasize to satellite agencies the importance of satellites for long-term climate monitoring, and advocate that all Earth observing satellite systems adhere to the GCOS Climate Monitoring Principles (WMO, 2003) and commit to the suite of instrumentation called for in the GCOS Implementation Plan and in the relevant IGOS-P Theme Reports.

Focus on research programmes to support the development of observational capabilities for ECVs such as tropospheric ozone, cloud and aerosol properties and their vertical profiles, CO_2 and other greenhouse gases, soil moisture and groundwater, above-ground biomass, permafrost, snow cover and glaciers, and ocean salinity, carbon and nutrients and their vertical profiles.

Coordinate climate sectors and broad user groups to clarify and specify requirements for socio-economic benefit areas (disaster prevention, health, energy, water resources, ecosystem, agriculture, and biodiversity) for climate products and information.

Enforce palaeoclimate research to improve knowledge about historical and current climate change, by combining natural science data and socio-economic information.

Promote the improvement of emission databases for aerosols, greenhouse gases and their precursors.

6 Year Targets 4.4 Climate

Working with the climate community, GEOSS will:

Enhance the collaboration mechanism between observation organizations and research communities with users of climate information to make maximum use of the observations, analyses and products.

Support implementation of actions called for in the GCOS Implementation Plan and the relevant IGOS-P Theme Reports.

Promote the establishment of data archive centres for all ECVs.

Promote institutional commitments to provide integrated global analyses of all ECVs.

Develop data integration facilities for exchanging data, products and information between climate sectors and socio-economic benefit areas.

Emphasize detection of current and historical climate changes and their impacts linked with other societal benefit areas such as disaster, health, water, ecosystem and agriculture by combining the natural scientific data and socio-economic information and enforcing paleoclimate research approaches.

Develop and operate new *in situ* and/or space-based observation instruments for the observation of ECV such as cloud and aerosol properties and their vertical profiles, ocean salinity, ocean carbon and nutrients, soil moisture and ground water, CO_2 and other greenhouse gasses.

10 Year Targets 4.4 Climate

Working with the climate community, GEOSS will:

Provide support to the development of a long-term strategy, which encompasses progress in observation, data assimilation and modelling.

Support implementation of actions called for in the GCOS Implementation Plan and the relevant IGOS-P Theme Reports.

Promote new and extended re-analysis programmes for the oceanic, terrestrial and atmospheric domains.

Contribute to major advances in the monitoring and predictability of climate on seasonal, interannual and decadal time scales, including the occurrence of extreme events.

Establish an evaluation mechanism for climate product applicability to socio-economic benefits.

Support climate sectors to implement tailored approaches to respond to socio-economic requirements.

Promote implementation of an integrated observing system for atmospheric composition monitoring in support of climate policy through an optimal combination of ground-based networks, low Earth orbit and geostationary satellites and models.

4.4.5 Table of Observation Requirements

Table 4.4.5 includes the ECVs identified in the GCOS Second Adequacy Report. Each box shows the observational situation for that application. An empty box indicates that a variable is assumed not to be relevant for this application.

Legend for Table 4.4.5

0 -	Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
1 -	Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
2 -	Not yet widely available or not yet globally monitored, but could be within two years.
3 -	Only locally available or experimental; could be available in six years.
4 -	Still in research phase; could be available in ten years.

Please see Table 4.4.5 on the following page.

Climate
Table 4.4.5

Observational Requirement		Understanding	Assessing	Predicting	Adapting to	Mitigating
Atmosphere domain, Surface measurement						
1	Air temperature	1	1	1	1	1
2	Precipitation	2	2	2	2	2
3	Air pressure	1	1	1	1	
4	Surface radiation budget	3	3	3		
5	Wind speed and direction	1	1	1	1	
6	Water vapour	1	1	1	1	
Atmosphere domain, Upper air measurement						
7	Earth radiation budget (including solar irradiance)	1	1			
8	Upper-air temperature (including MSU radiances)	1	1	1	1	
9	Wind speed and direction	1	1	1	1	
10	Water vapour	3	3	3	3	
11	Cloud properties	3	3	3	3	
Atmosphere domain, Composition						
12	Carbon Dioxide	2	2	2	2	2
13	Methane	2	2	2	2	2
14	Ozone (tropospheric)	2	2	2	2	2
15	Other long-lived greenhouse gases	2	2	2	2	2
16	Aerosol properties	3	3	3	3	3
Oceanic domain, Surface measurement						
17	Sea-surface temperature	1	1	1	1	1
18	Sea-surface salinity	3	3	3	3	
19	Sea level	1	1	1	1	1
20	Sea state	2	2	2	2	

Climate
Table 4.4.5

Observational Requirement		Understanding	Assessing	Predicting	Adapting to	Mitigating
Oceanic domain, Surface measurement *(continued)*						
21	Sea ice	3	3	3	3	
22	Current	2	2	2	2	
23	Ocean color (for biological activity)	1	1	1	1	
24	Carbon dioxide partial pressure	3	3	3	3	3
Ocean domain, Sub-surface measurement						
25	Temperature	2	2	2	2	
26	Salinity	3	3	3	3	
27	Current	3	3	3	3	
28	Nutrients	3	3	3	3	
29	Carbon	3	3	3	3	
30	Ocean tracers	3	3	3	3	
31	Phytoplankton	3	3	3	3	
Terrestrial domain						
32	River discharge	2	2	3	1	1
33	Water use	2	3	3	3	
34	Ground water	4	4	4	4	4
35	Lake levels	3	3	3	3	
36	Snow cover	1	1	3	1	
37	Glaciers and ice caps	2	2	2	2	
38	Permafrost and seasonally-frozen ground	3	3	3	3	
39	Albedo	1	1	3		4
40	Land cover (including vegetation type)	2	3	4	3	3
41	Fraction of absorbed photosynthetically active radiation (FAPAR)	1	3	3		1

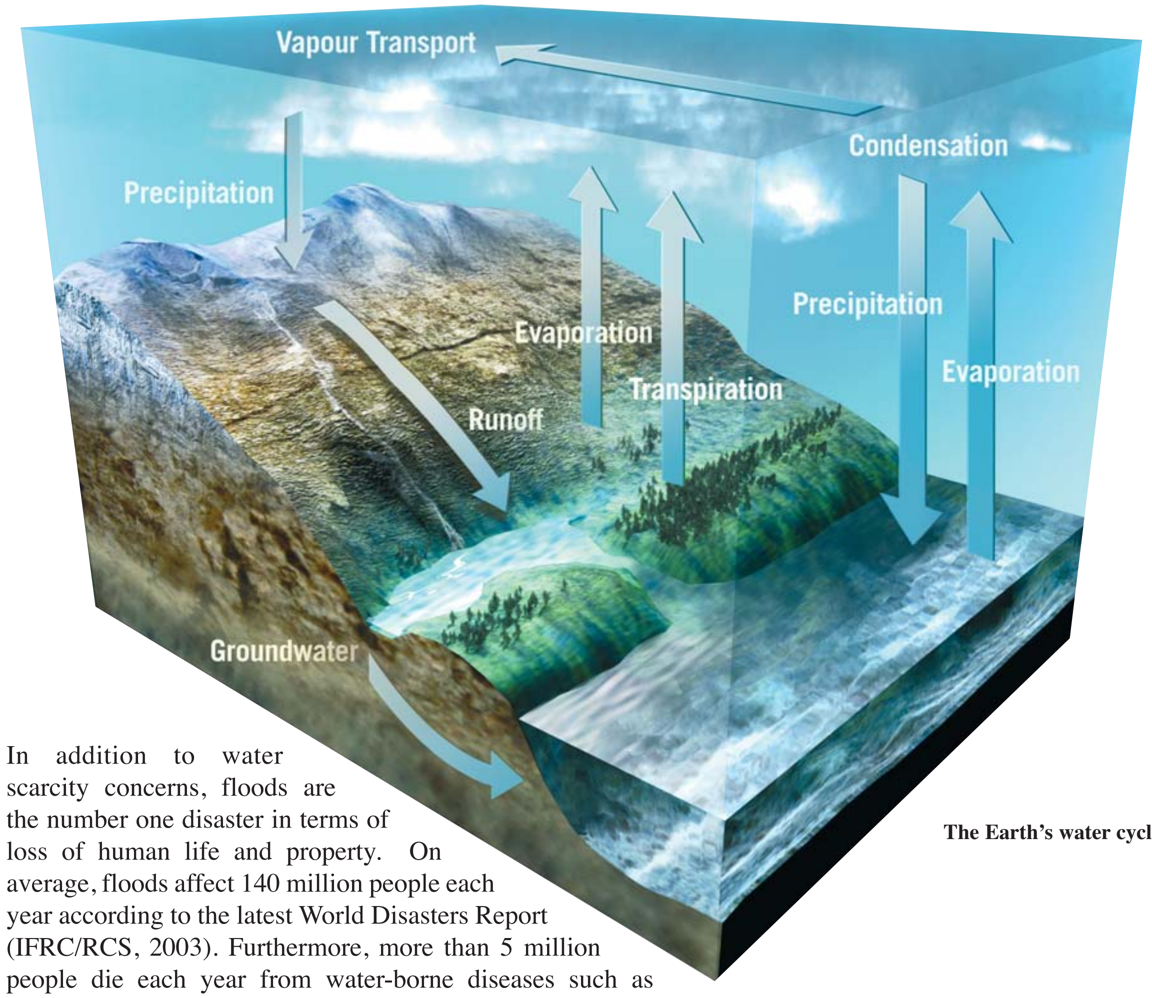
Climate Table 4.4.5 **Observational Requirement**	Understanding	Assessing	Predicting	Adapting to	Mitigating
Terrestrial domain *(continued)*					
42 Leaf Area Index (LAI)	1	1	2		
43 Biomass	3	4	3		3
44 Fire disturbance	1	1	1		1

4.5 Improving water resource management through better understanding of the water cycle

4.5.1 Statement of Need

Reliable supplies of fresh water are an essential ingredient for human prosperity and health, as well as ecosystem functioning. Water is an important, geo-socio-economic issue at local, national and global scales and changes in water resources are a part of the history of civilization. Both socially and economically, the impacts of water deficits and surpluses are large. In 1995, the World Bank reported that 80 countries, with 40% of the World's population, faced water scarcity, with this percentage projected to increase as the population grows.

In developing countries, water shortages are a major contribution to poverty and human misery. Food security, well being, and ultimately economic and political stability depend upon the ability to provide reliable supplies of clean water. Rapid population growth and development pressures impose additional stresses on scarce resources. Drought turns such vulnerable situations into a crisis. Enhanced and timely information pertaining to water resources has the potential for increasing the development capability of many of these countries. As a result, there are increasing human, institutional, and infrastructure needs for access to and use of water cycle data in water resource management.



The Earth's water cycle

In addition to water scarcity concerns, floods are the number one disaster in terms of loss of human life and property. On average, floods affect 140 million people each year according to the latest World Disasters Report (IFRC/RCS, 2003). Furthermore, more than 5 million people die each year from water-borne diseases such as malaria and cholera.

The global water cycle – the transport and distribution of large amounts of water, associated with its constant phase changes between the solid, liquid and gaseous states – is therefore one of the most important features of the Earth system, but one which cannot be described without linkage to the energy cycle on a global scale.

Local and regional water cycle variations are correlated between different areas and seasons, because of the effects of atmospheric and ocean circulations and the variations in water storage, such as in snow and soil moisture. Even when a more localized water-related event is addressed, we need to consider its connections with other areas or regions in the context of the global water cycle variation.

Courtesy of Geospace / SPOT Image

Major river catchment basins and land-cover distribution in Africa

Today, humans actively manage over 30% of the World's runoff in the inhabited regions of the globe (Postel et al. 1996). Management of the World's rivers and groundwater has resulted in profound changes in the dynamics of the terrestrial water cycle. Water development has had major impacts on the quality of the World's surface and groundwater and has degraded extensive areas of aquatic and terrestrial habitat. However, a water cycle measurement capability is inadequate for monitoring long-term changes in the global water system and their feedback into the climate system. Furthermore, the quality aspects of surface and groundwater remain largely unknown in many parts of the World. In those ungauged or information-poor basins, the lack of data is the major constraint on the development of water resources and improvement of water management.

To enhance prediction of the global water cycle variation based on improved understanding of hydrological processes and its close linkage with the energy cycle and its sustained monitoring capability is a key contribution to mitigation of water-related damages and sustainable human development. Improved monitoring and forecast information, whether of national or global origin, if used intelligently, can provide large benefits in terms of reduced human suffering, improved economic productivity, and the protection of life and property. In many cases, the combination of space-based data and high-resolution *in situ* data provides a powerful tool for effectively addressing water management issues, especially in ungauged basins. Information on water quantity and quality and their variation is urgently needed to underpin national policies and management strategies, as well as UN conventions on climate and sustainable development, and the achievement of the Millennium Goals.

Example: A Future Warning System for Preventing a Drought Tragedy

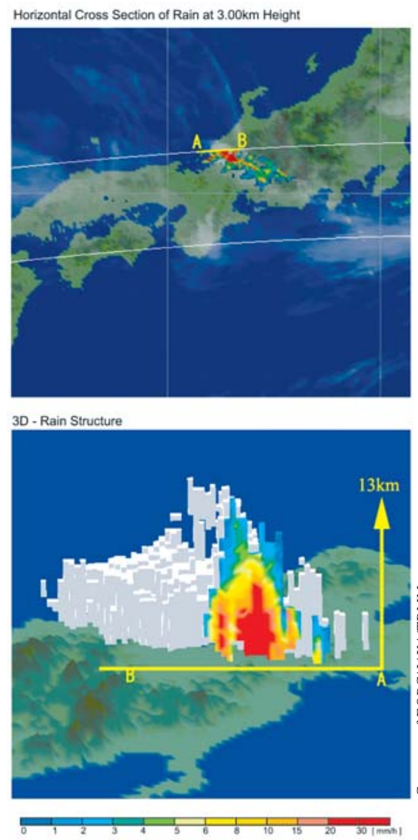
In May 2010, the Central African Famine Relief Agency received word from the African Centre for Seasonal Climate Predictions and climate observations that the monsoon would be very weak and rainfall amounts would be only 20% of the climatological average. International organizations had been monitoring conditions in Chad and other central African countries and recognized the poor states of crops from vegetation observations and the record-low river and reservoir levels throughout central Africa. They were quite prepared for the aid request that came from the Central Africa Famine Relief Agency asking for phased drought relief over the next three weeks. Fortunately with their long-range predictions they had known that drought conditions were a possibility and had begun to stockpile food and other necessary staples. Relief workers had already volunteered and were ready to work out of a temporary base that had been set up in Chad. Information was distributed to the people about the building drought conditions. Through the local drought relief centres, local conditions were monitored to ensure that no members of society were missed and that crisis hotspots were identified. The national health agencies were also alerted and they imposed regulations on industries that were polluting local waters and began to bring in supplies of fresh water from Zambia and the Congo in anticipation of the demand. Although there was some hardship the drought did not result in the direct loss of any lives. Furthermore, people followed law and order as they obtained their supplies in an orderly way and ensured that their families and neighbours had sufficient food. This was in contrast to 2004 when a large number of people died as a result of less intense droughts that had caught central Africa and the World by surprise, and was acted upon by international programmes and the developed World only after the media began to report deaths from starvation and widespread anarchy and looting in society.

4.5.2 Vision and How GEOSS Will Help

The vision for water cycle research and water resources management foresees observational systems, data assimilation, prediction systems and decision support capabilities being integrated into a system of systems that supports integrated water management. It will also enable closure of the water budget on regional and global scales to the point where effective management is possible across the globe. GEO Members and Participating Organizations will work with the research communities to realize this vision.

GEOSS will provide a process for the continuous evolution of the water cycle observing system. It will do this by inventorying and evaluating existing plans and new water cycle data needs, and the ability of observing systems to meet those needs. It will develop action plans to address the needs and ensure that countries and programmes take steps to meet those needs. There will be support for research and development activities related to the generation and evaluation of new data products. Finally, GEOSS will act as a conduit between the capabilities of national observing programmes, international scientific programmes and global conventions and policies, and will develop action plans to build capacities in developing countries.

GEO will contribute by working with the user communities to define the needs to be met by agencies planning water cycle observations. It will offer a framework for joint planning of expert systems for decision support where water information is an input



Courtesy of EORC/JAXA/TRMM

TRMM images of heavy rainfall in Fukui, Japan, on 17 July 2004, showing both horizontal and vertical distributions

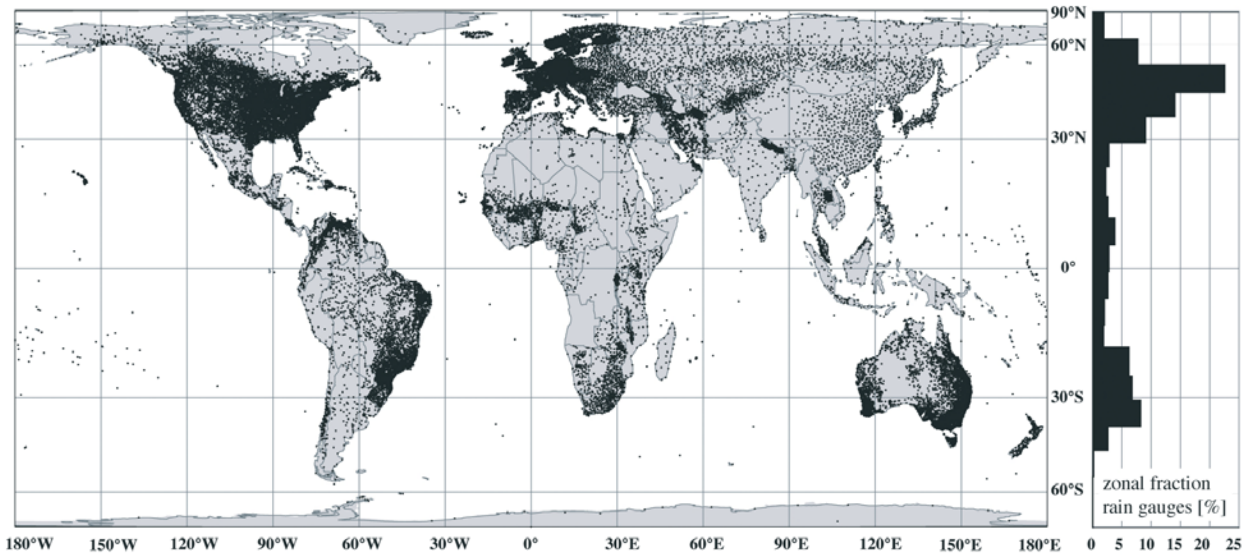
(e.g. hydrologic prediction services) or is dependent on inputs from all other societal benefit areas. It will also coordinate the development of a capacity building plan for the use of Earth Observation data (satellite, surface and subsurface data) for water management in developing countries.

On the operational side GEOSS will facilitate the development of new applications of Earth Observation data in water quality and groundwater monitoring, oversee the development of plans to increase the accuracy and space and time resolution of satellite data relevant to water budgets, and facilitate the maintenance and enhancement of *in situ* hydrometeorological observations and international coordination of planning and operating national *in situ* monitoring networks, including common standards.

GEOSS will also be active in promoting the integration and use of *in situ* data with remotely sensed data to produce new products, in order to provide the data needed to develop indicators that will be useful in advising the international conventions, and managers concerned with integrated water management at a local level. This will involve facilitating access to water resource databases needed to develop expert systems in support of integrated water management decisions.

4.5.3 Existing Situation and Gaps

Critical observations for closing water and energy budgets, detecting extreme events, and monitoring water environment are missing, including soil moisture, evaporation, surface wind speed, precipitable water over land, short-term heavy rainfall, and water quality, although missions that will be launched over the next decade will start to address these needs. However, the sensor capability for these missions is not adequate to fully meet the requirements of many user communities. GCOS is taking steps towards addressing the needs for soil moisture through the development of a reference network (IGWCO, 2004, GCOS Implementation Plan, 2004).



Rain gauges deliver the most reliable data on precipitation amounts reaching the Earth's surface, but only represent the nearby environment of the station. This map shows the distribution of stations for precipitation data acquired by the GPCC from the national networks of WMO member countries (about 40,000 stations)

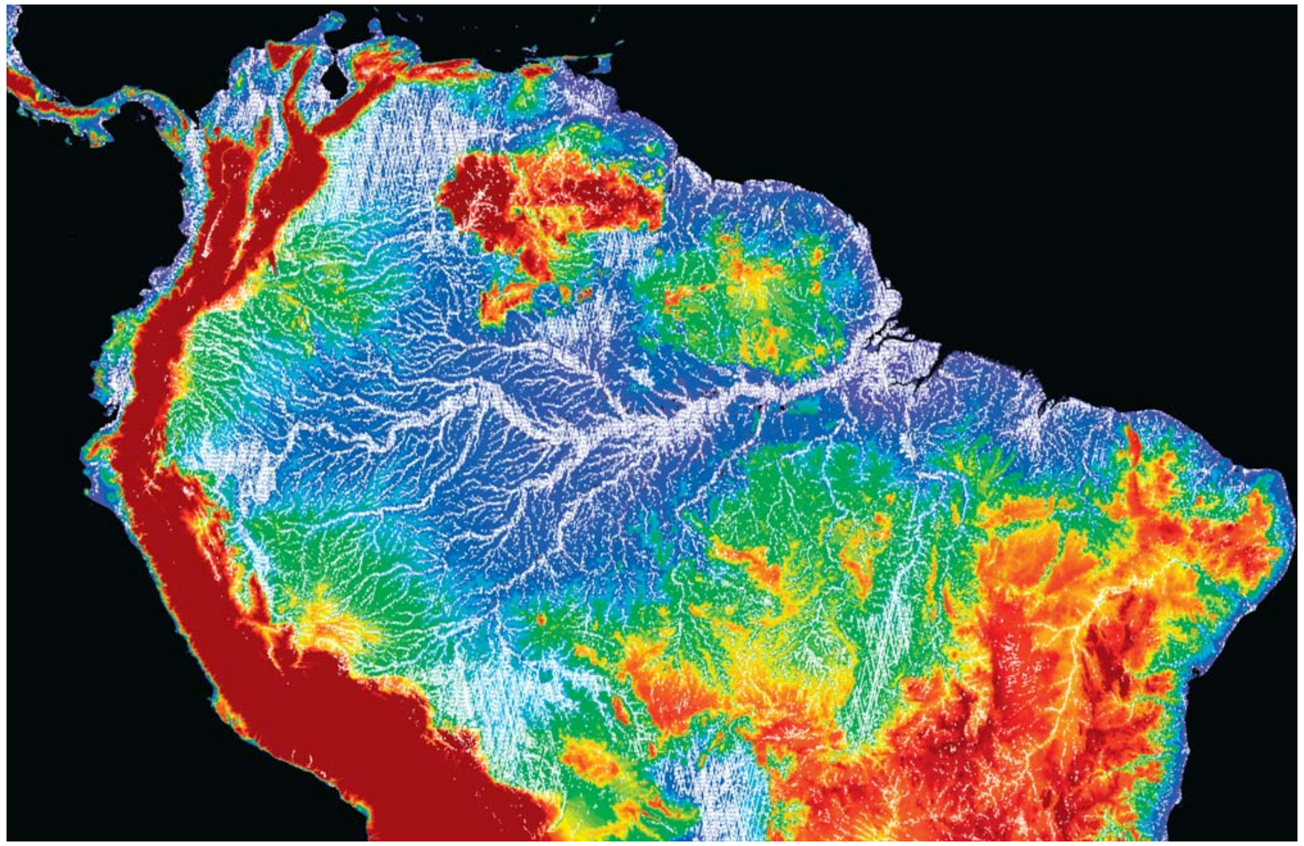
Space agencies should fully implement planned space missions and are encouraged to continue new sensor development based on user needs. To the degree possible, space agencies should give priority to the development of effective sensors and missions for precipitation, surface and subsurface water stores - including snow water equivalence, water stored in natural and man-made reservoirs, and groundwater. One of the most

The hottest air mass in the World from May to August is generated over the Tibetan Plateau and affects the seasonal and inter-annual variation of the Asian monsoon. The very active water cycle over the Tibetan Plateau, sometimes associated with cumulonimbus clouds, plays an important role in the atmospheric heating process and then in the Asian monsoon variability

critical components of the Earth system is global precipitation. Current rain gauge and weather radar techniques only cover in the order of 25% of the Earth's surface, since the majority of the planet is covered with water or is inaccessible. The challenge of global measurement of the amount, intensity, and frequency of precipitation and its extremes currently requires the use of space-based remote sensing, coordinated ground calibration and validation efforts, and an integrated data processing system for data dissemination. In the next decade considerable effort will be needed to develop space-based missions to measure the water levels of medium to large rivers (i.e. 100 m wide) and the topographic heights of fresh water in the form of lakes and wetlands. Moreover, the systematic global monitoring of base flow, soil moisture in the vadose zone, and snow water equivalent and their rates of change may remain unfulfilled, preventing closure of water budgets at any scale.

As far as *in situ* data are concerned, hydrological networks have been allowed to decline in many countries. For example, only a few dedicated organizations have high-quality data extending back 50 years. Furthermore, many countries have long-term paper and tape data archives that are at risk of being destroyed and need to be rescued and stored on modern media. Therefore, GEOSS must maintain flexibility for its data and information system network and ensure that the various existing high quality global and regional data sets needed to augment the global data sets are effectively merged into the network. Well-archived data contributes to new data set generation combined with new algorithms and models. The requirements for socio-economic data to support the demand side of water management have not been fully defined, nor have the options for acquiring these data been explored.

Long-term global data sets and products covering precipitation, water vapour, clouds, snow cover, and glaciers are essential for assessing trends. Given the tendency of networks to change over time and for satellites to drift or be moved, there is a need for routine reanalysis of such data products for use in determining trends in water cycle variables. Products to support many water quality applications are not available. This is particularly problematic for health, where threats must be monitored on a global basis, and for water quality programmes that need to target vulnerable areas where *in situ* monitoring would be most beneficial. Many of these vulnerable areas are located in poorer economies as well as developed countries. In the former areas, unfortunately, water-monitoring systems are often fragmented or non-existent.



The Amazon River Basin observed with the Radar Altimeter on ERS-1

A comprehensive, coupled, land-atmosphere-ocean data assimilation capability is needed to optimize the use of advanced data systems. The process and budgeting for the transfer of systems from a research environment to operations needs to be strengthened. Currently, although data archives exist for special collections, there is insufficient integration capacity for global observing systems. This situation is aggravated by incompatible data management plans among the individual components. A special challenge is the development of assimilation methodologies to integrate satellite and *in situ* observations, and the development of high-performance distributed data management and archiving systems with harmonized access nodes to use data from largely different sources for studies of the global water cycle. A prototype data integration system is being demonstrated by the CEOP (Coordinated Enhanced Observing Period). An overall plan for *in situ* and satellite water cycle observational systems is needed so that data can be readily exchanged, standards can be set, and data quality can be monitored. Elements of such planning do occur at present within the IGOS-P Water Cycle Theme. Also, a strong application plan is necessary for GEOSS to demonstrate its practical use. For this it is important to provide the methodology to translate the GEOSS data into the information needed, e.g. translating remote-sensing data into local discharges for ungauged basins. Demonstration programmes are especially important in countries that suffer from lack of data or have little expertise in data assembly and interpretation.

National policies regarding copyright laws and the sale of data have led to problems with the free and open distribution of hydrologic data. Although WMO and UNESCO have established international policies and practices for free and unrestricted exchange of hydrological data, there are some practical problems in implementing these policies and there is room for improvement in the flow of hydrological data.

Many developing countries lack the basic capabilities needed to access, interpret, and apply water cycle information available from satellite systems. While hardware and software capabilities are quickly improving for much of the developed World, countries with economies in transition are increasingly burdened with outdated hardware and expensive software that requires high levels of expertise to use it effectively. Social and economic differences preclude the application of a single "one size fits all" solution to every situation. Trained technicians, programmers, and analysts are needed in the disadvantaged countries to tailor new techniques to specific regional water management applications, and for the longer term, to train a new cadre of software engineers who can generate and customize the needed software systems from the ground up. Supporting Integrated Water Resources Management (IWRM) in developing countries demands flexibility and the capacity to respond to their special situations, actions, policies and infrastructure needs. Moreover, there is an urgent need for continuing dialogue between the providers of advanced data systems and the associated data system specialists in the developing countries to have strategies tailored to each country's water needs. A plan for building the technological capacity of developing countries based on operational and experimental satellites as well as on surface/subsurface observation and monitoring techniques, and advanced data assimilation capabilities should be a GEOSS priority to assist in the improvement of water management practices. These plans should include hardware and software for receiving and processing satellite data as well as for the acquisition and processing of *in situ* data and its integration with satellite and other space-borne data (airborne geophysics). Within the framework of development aid policies, the financing of the recurring costs related to maintaining the necessary national expert personnel and covering the operational costs need to be addressed.

A plan for building the technological capacity of developing countries based on both operational and experimental satellites and advanced data assimilation capabilities, should be a GEOSS priority to assist in the improvement of water management practices. These plans should include hardware and software for receiving and processing satellite and appropriate *in situ* data. Training modules should be provided and a commitment made to enable personnel from the developing countries to use and maintain this infrastructure.

Many countries, especially developing countries, have difficulty in maintaining adequate hydrometeorological networks, and consequently there are gaps in the global database. In addition, where the needed capabilities exist, there are often no quality assurance and control standards applied to the instruments, and data reduction methods and procedures. Without an effective *in situ* system, meaningful data validation is jeopardized or in some cases even out of reach. Building the capacities of those countries for effective *in situ* measurements will contribute greatly to the success of the GEO process.

4.5.4 Targets

2 Year Targets 4.5 Water

Working with the water-cycle and water-resource management community, GEOSS will:

Facilitate, with countries, WMO and UNESCO, improvements in existing *in situ* observation systems through coordination and optimization of existing *in situ* networks at global, regional and national level.

Produce a plan for a network of sophisticated, integrated *in situ* observation sites, to support process studies and algorithm and model development.

Facilitate international data sharing and exchange agreements for water data with countries, WMO, and UNESCO, and monitor and routinely report compliance with the policy.

Produce an implementation plan for a broad global water cycle data integration system that combines *in situ* and satellite and numerical model outputs and disseminates usable information for decision-making.

Facilitate, with space agencies and research communities, more accurate, frequent (3-hourly), global, high spatial resolution, and microphysically detailed measurements of precipitation through a global constellation of satellites carrying passive microwave radiometers in complementary orbits.

Advocate that IGOS-P should take the lead in development of integrated precipitation and soil moisture products and new products including indicators.

Facilitate, with space agencies and research communities, studies to evaluate the contribution of space-based observations to the determination of surface water quality and mapping of critical aquatic habitats.

Produce an evaluation of the resolution and accuracy requirements for applying satellite altimetry to the measurement of streamflow and surface water storage.

Facilitate establishment of an international coordination function for *in situ* water cycle observation and data integration and dissemination.

Produce a framework for developing ensemble-based hydrological predictions and improve the ability of users to exploit the information.

Advocate and globalize ongoing activities that promote the use of Earth observation for both monitoring the state of, and improving implementation of, water resources management in developing countries, particularly in concert with the activities pursued by the CEOS WSSD Follow-up Programme.

Organise workshops and special studies for documenting the cultural barriers to technology transfer and procedures in order to identify and avoid these obstacles.

Advocate eliminating barriers to the free and open exchange of data and software to enable full access by water managers in developing countries.

6 Year Targets 4.5 Water

Working with the water-cycle and water-resource management community, GEOSS will:

Produce a number of new products for precipitation, soil moisture, evaporation, evapotranspiration and other water cycle variables, by *in situ* observations and the planned space missions.

Provide validation of the accuracy of new water cycle data products, involving “virtual water” with respect to food production and its transportation.

Advocate continuous sensor development with improvement of accuracy and higher spatial-temporal resolutions, and with special attention to snow water equivalent and streamflow.

Facilitate international and fully networked operational data exchange capabilities.

Facilitate testing of a fully integrated prototype data system, with data assimilation, analysis and visualization capabilities for the water cycle.

Advocate a study of the water resource variables required to support an expert system in water management and provide prototyping on an operational system for assimilating routine water cycle observations for improved monitoring and management of water resources.

Advocate a system for the routine collection of water level data for use in validating satellite data and for monitoring surface water storage.

Advocate precision gravity field missions for global water storage monitoring.

Produce a plan for institutionalizing surface water and energy flux measurements.

Facilitate the establishment of coordinated *in situ* observation networks with high (and low) elevation sites along mountain transects.

Produce an experiment using the global network of sophistically and temporally integrated *in situ* observation sites for water cycle observations.

Produce integrated water cycle data sets (including predictions) on a continental scale, such as the Asian monsoon region or any large river watershed.

Produce an evaluation of the data and product requirements for use in applications to water-related health issues with a view to developing a specialized observing system in support of health.

Produce a plan for monitoring drinking water quality, along with efforts to extend water and sanitation services, especially in developing countries.

Facilitate, with space agencies and research communities, the development of effective sensors and missions for precipitation (GPM), surface and subsurface water stores – including snow water equivalence, water stored in natural and man-made reservoirs, and groundwater.

Facilitate, with numerical weather prediction agencies, space agencies and international research programmes, the reanalysis of products for use in determining trends in water cycle variables.

Produce a plan for capacity building to support water management, including hardware and software for receiving and processing satellite and appropriate *in situ* data, and training modules for the developing countries.

10 Year Targets 4.5 Water

Working with the water-cycle and water-resource management community, GEOSS will:

Produce a characterization of the long-term water cycle budget based on a hierarchy of spatial and temporal scales.

Facilitate, with countries and research communities, operationalization of the global network of sophisticated and temporally integrated *in situ* observation sites.

Produce operational, fully integrated data systems by evaluating and improving prototype systems.

Facilitate provision of data and information, including quantity and quality for both surface and groundwater, to a prototype water cycle expert decision support system.

Facilitate improved simulation and prediction capabilities for precipitation, water cycling and water cycle acceleration in weather and climate models.

Produce a system for monitoring changes in the water cycle, including clouds and precipitation, by using the integrated data system.

Produce integrated information for documentation and understanding of the relationship between known climate indices, particularly ENSO, AO, PDO and MJO, and flood and drought frequency and precipitation type and intensity.

Produce appropriate indicators of "watershed health" routinely from satellite data, surface and subsurface data, and data assimilation capabilities.

Facilitate development of plans for more effective transfer into operations of technologies that have been proven in the research environment.

Facilitate the development of a plan for building the technological capacity of developing countries based on both operational and experimental satellites, and advanced data assimilation capabilities.

4.5.5 Table of Observation Requirements

Legend for Table 4.5.5

- **0 -** Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
- **1 -** Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
- **2 -** Not yet widely available or not yet globally monitored, but could be within two years.
- **3 -** Only locally available or experimental; could be available in six years.
- **4 -** Still in research phase; could be available in ten years.

Water
Table 4.5.5

	Observational Requirement	Water Cycle Research	Resource Management		Impacts of Humans on Water Cycle	Global Biogeochemistry	Ecosystem and Water Quality Assessment	Land Use Planning	Production of Food	Weather Prediction	Heavy Rainfall and Flood Prediction	Drought Prediction	Climate Prediction	Human Health	Fisheries and Habitat Management	Telecommunication/ Navigation
			Short-term Water	Long-term Water												
Water Flux Information																
1	Surface Liquid Precip. (rainfall)	3	3		3	3	3		3	3	3	3	3	3		3
2	Surface Solid Precip. (snow)	3	4							3	3		3			
3	Atmospheric Precipitation	3								3	3	3				2
4	Evaporation	3	3	4	2	4	3		3	3		3	3			
5	Transpiration	3	3	4	2	4	3		3	3		3	3			
6	Streamflow	4	4	4	4	4	3		4		4	4		3	4	4
Water Storage Information																
7	Soil Moisture (surface)	4		3					3	2		3	3			
8	Soil Moisture (vadose zone)	4		3				3	4			4	4			
9	Groundwater Storage	4	4	4	4			1				4	4			
10	Groundwater Level	4	4	4	4			1				4	4			
11	Lake and River Extent	3	3	4	3				3		3	3				
12	Lake and River Level	3	3	4	3				3		3	3		3		
13	Reservoir Extent	3	3	4	3				3			3				
14	Reservoir Level	3	3	4	3				3			3				
15	Snow Cover	2	2	2						2	2	2	2			2
16	Snow Water Equivalent	3	3	3			3		3		3	3	3			3
17	Ground Ice	3		3			4		3	3	3					
18	Permafrost/ Frozen Soil	4		4						4			4			4

Water
Table 4.5.5

Observational Requirement

No.	Observational Requirement	Water Cycle Research	Resource Management: Short-term Water	Resource Management: Long-term Water	Impacts of Humans on Water Cycle	Global Biogeochemistry	Ecosystem and Water Quality Assessment	Land Use Planning	Production of Food	Weather Prediction	Heavy Rainfall and Flood Prediction	Drought Prediction	Climate Prediction	Human Health	Fisheries and Habitat Management	Telecommunication/ Navigation
19	Glaciers, Ice Caps, Ice Sheets	2		2												
20	Clouds	3								2	2		3			
21	Wind Speed	2								2	2		2			
22	Wind Direction	2								2	2		2			
23	Air Temperature	2								2	2		2			
24	Water Vapor	2	2	2					2	2	2		2			
25	Atmospheric Pressure	2							2	2	2		2			
Radiation and Energy Budget Information																
26	Downward Shortwave Radiation	2	2	2					2			2	2			
27	Downward Longwave Radiation	2	2	2					2			2	2			
28	Albedo	0	0	0					0			0	0			
29	Emissivity	0	0	0					0			0	0			
30	Surface Temperature	1	1	1					1			1	1			
31	Fractional Veg. Coverage	1	1	1			1		1			1	1			
32	Roughness	4	4	4			4		4			4	4			
33	Sensible Heat Flux	3	3	3			3		3			3	3			
34	Latent Heat Flux	3	3	3			3		3			3	3			
35	Soil Heat Flux	3	3	3			3		3			3	3			
Other Bio-geo-physical Information																
36	Topography/ Geography	1	1	1	1	1		1			1				2	
37	Vegetation Type	2		2	2	2	2	2	2			2				
38	Vegetation Rooting Depth	4		4	4		4	4	4			4				
39	Vegetation Height	3		3	3		3	3	3			3				
40	Land Use and its Change	1		1	1			1	1			2			2	
41	Soil Type	3	3	3				3	3			3				
Other Bio-geo-chemical Information																
42	Sea Surface Salinity	3		3		3				3		3	3		3	
43	Sea Level	2		2									2			
44	Sea Surface Temperature	2	2	2						2	2	2	2			
45	Water Chemistry (quality, isotopic ratio, etc.)	3			3	4	4								4	
46	Nutrient Cycling				3	3									3	
Anthropogenic & Socio-economic information																
47	Irrigated Area	4	4	4	4		4		4			4		4		
48	Irrigation Amount	4	4	4	4		4		4			4		4		
49	Industrial Water Use		4	4	4									4		
50	Drinking Water	1	1		1									1		
51	Population Density		1	1	1			1						1		
52	Water Demand for Nature Conservation	4		4	4		4							3		
53	Ecosystem Water Demand	4		4	4		4							3		

Water Table 4.5.5 **Observational Requirement**		Water Cycle Research	Resource Management: Short-term Water	Resource Management: Long-term Water	Impacts of Humans on Water Cycle	Global Biogeochemistry	Ecosystem and Water Quality Assessment	Land Use Planning	Production of Food	Weather Prediction	Heavy Rainfall and Flood Prediction	Drought Prediction	Climate Prediction	Human Health	Fisheries and Habitat Management	Telecommunication/ Navigation
54	Water Pollutant Area					3	3							3		

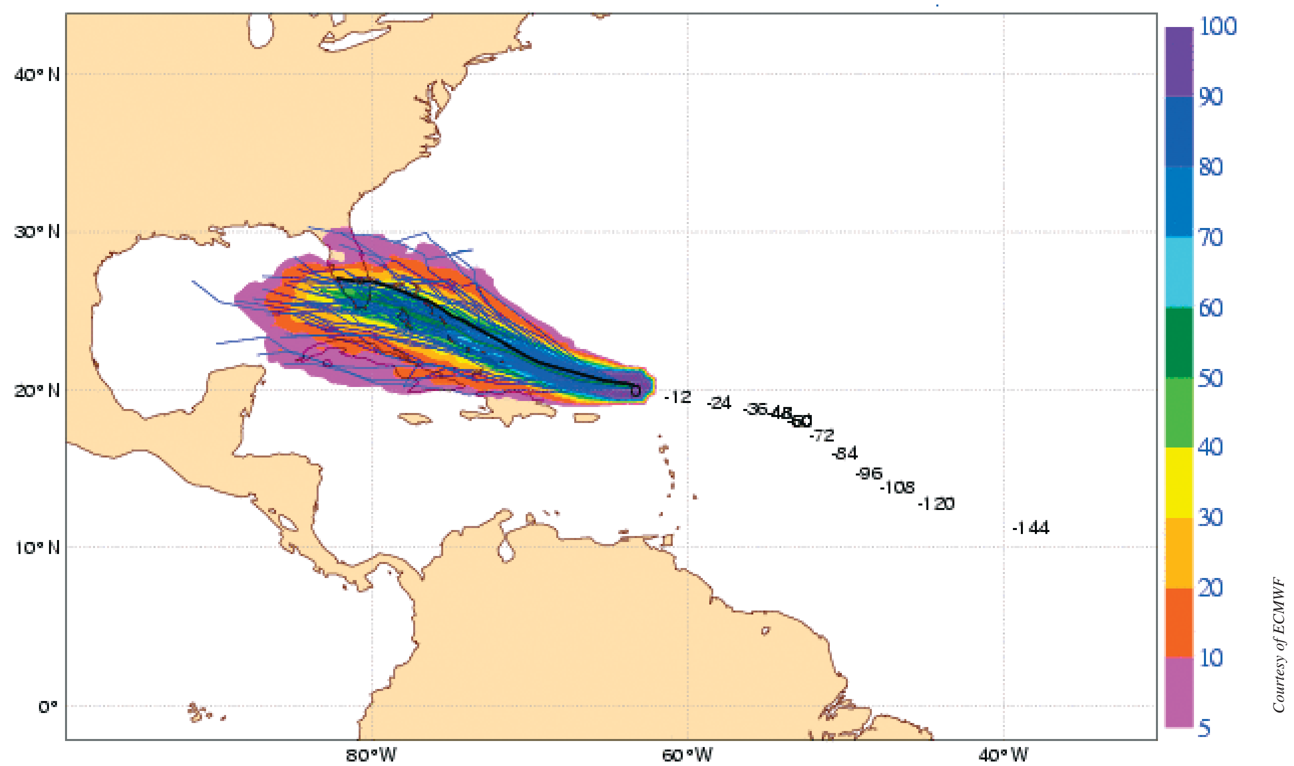
4.6 Improving weather information, forecasting and warning

4.6.1 Statement of Need

Severe weather events – hurricanes, tornadoes, flash floods, freak waves, lightning strikes, blizzards, and poor air quality episodes – impact every person and nation on the face of the Earth. This is why national meteorological services were established by some countries as early as the 1850's, leading to the current set of meteorological systems. Each year, tens of thousands of lives are needlessly lost and many billions of dollars spent needlessly because of society's inability to reliably forecast, and warn citizens and the appropriate decision makers, about impending weather hazards.

Worldwide social and economic sectors, including agriculture, energy distribution, construction, transportation, aviation, finance, tourism and recreation, public health, ecosystems and biodiversity are directly affected by temperature, precipitation, and other general weather conditions. These industries need improved and extended-lead-time weather forecasts to improve productivity and cut costs. Successful scientific research is rapidly providing the foundation for producing more accurate weather forecasts and warnings.

Achievable improvements in Earth observations (the crucial front-end of weather forecasting and warning) are needed to improve timeliness, data quality, and long-term continuity of observations in order to reduce analysis and model initialization error, increase forecast accuracy, extend warning lead times, and maintain the climate record. The depiction of critical phenomena and processes to enable more accurate and extended lead-time warnings and forecasts will be enhanced by increased coverage and resolution of observations, as well as targeted observations for numerical weather prediction. New observations will not just improve existing capabilities, but will also enable new forecast products such as air quality. Finally, rapid dissemination of weather information will provide more timely data access to people and decision-makers.

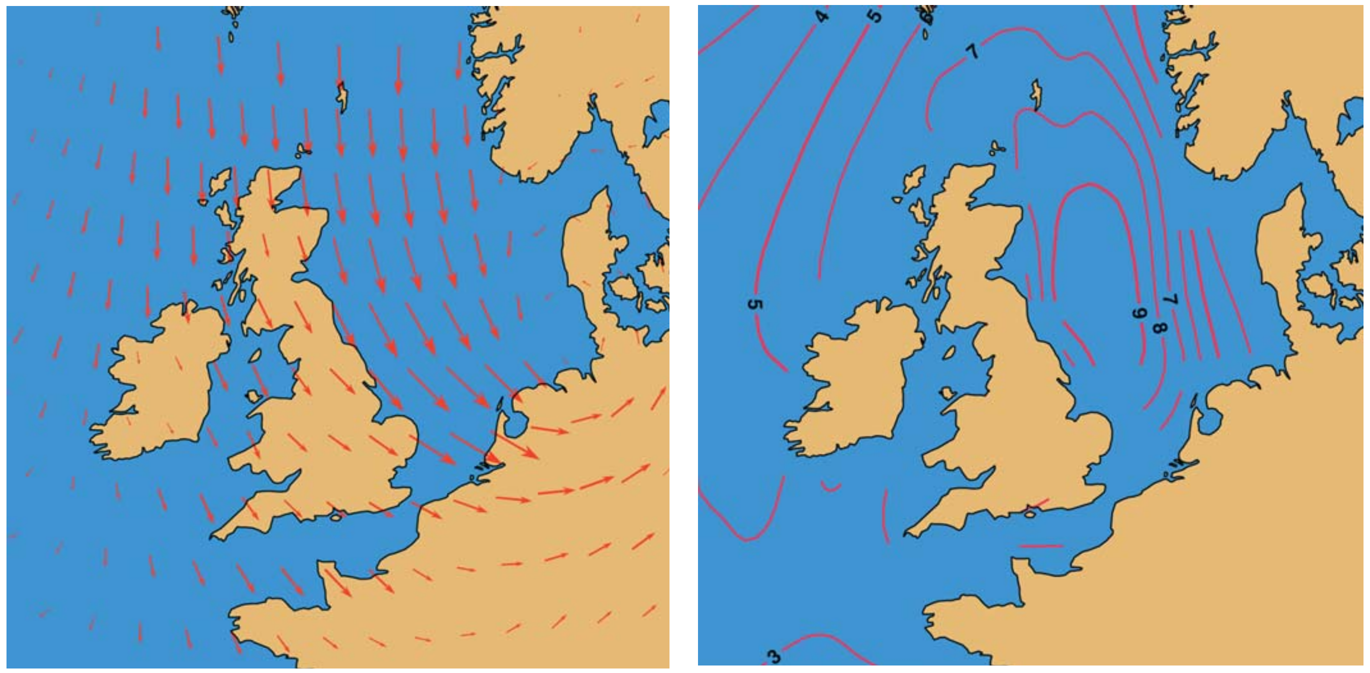


The ECMWF 5-day strike probability forecast for Hurricane Frances on 31 August 2004

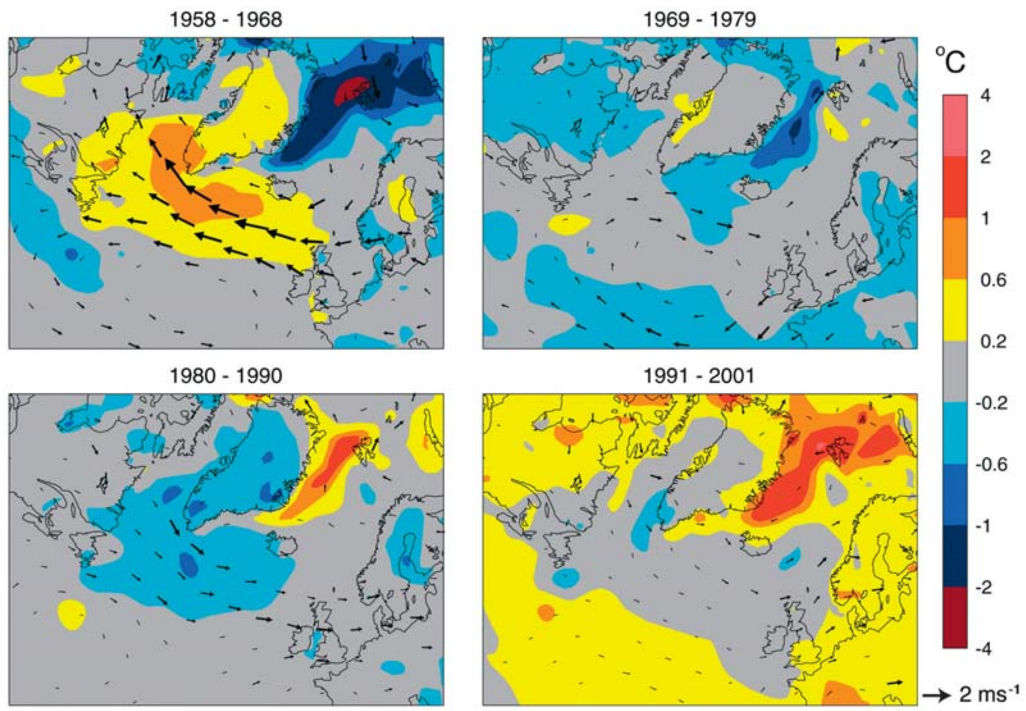
Improvements in the above will lead to better forecasts and warning accuracy for 30-minute, high-impact events, e.g. tornadoes, 1- to 12-hour short-term severe weather forecasts, 5-15 high impact weather forecasts, and medium range to seasonal forecasts relevant to monsoons and El Niño.

In summary, weather impacts every societal benefit area in this plan. In particular, better forecasting not only improves the weather information, but in doing so also produces derivative contributions to the other areas, creating an interdisciplinary approach to addressing societal needs-improving information quality for all and reducing development costs.

Courtesy of T. Hollingsworth, ECMWF



These two figures from the ECMWF ERA-40 data reanalysis show the wind and ocean-surface wave heights on 1 February 1953, at the peak of the storm and floods that caused more that 2200 deaths in the Netherlands and UK



Courtesy of T. Hollingsworth, ECMWF / ERA-40

Modern numerical weather prediction systems provide gridded global fields, essential for studies of weather predictability on time scales of days to weeks, and short-range climate predictability on time scales of seasons to decades. Depicted are the North Atlantic anomalies in temperature (at 2 m elevation) and wind (at about 1.5 km elevation) for the periods 1958-68, 1969-79, 1980-1990 and 1991-2001

Example: Future Global Interactive Forecasting System

A decade from now, forecasters at the major numerical weather prediction centres identify a global weather system that is likely to cause significant loss of life and property in Bangladesh and India. The interactive global forecasting protocol is triggered, and the Lead Forecast Centre takes responsibility for producing the global forecast product for the area. This Lead Forecast Centre role rotates between the designated WMO Global Forecasting Centres every six months.

The Centre estimates the computing, modelling, data assimilation and real time data needed. On this occasion a hybrid ensemble-deterministic forecast is completed at the Centre based upon a three model ensemble forecast combined with a single high resolution deterministic forecast model, which are run at four of the participating centres. Additional computational resources are also requested from the Grid to conduct the critical global weather forecasts.

The model identifies the need for special data from the North Pacific, the North Atlantic and over Africa. In the Pacific Ocean, three polar orbiting satellites are identified with the ability to provide targeted high spatial and temporal resolution atmospheric and oceanic measurements over a 1000 km^2 area. In the Atlantic, targeted atmospheric profiles are requested from weather and ocean reconnaissance aircraft, whilst in Africa, the automated sounding and profiler systems are activated to provide data to the data assimilation systems feeding the forecast models.

The forecast indicates potentially devastating flooding throughout a very large area of Bangladesh and Northeast India. A societal and economic response model is thus initiated by the forecast to assess the consequences of the flooding and the best response from local governments and the international community to minimize the loss of life and property. Timely action is then taken to evacuate or shelter people, to minimize the spread of water-borne diseases, and to protect specific structures identified as being at risk.

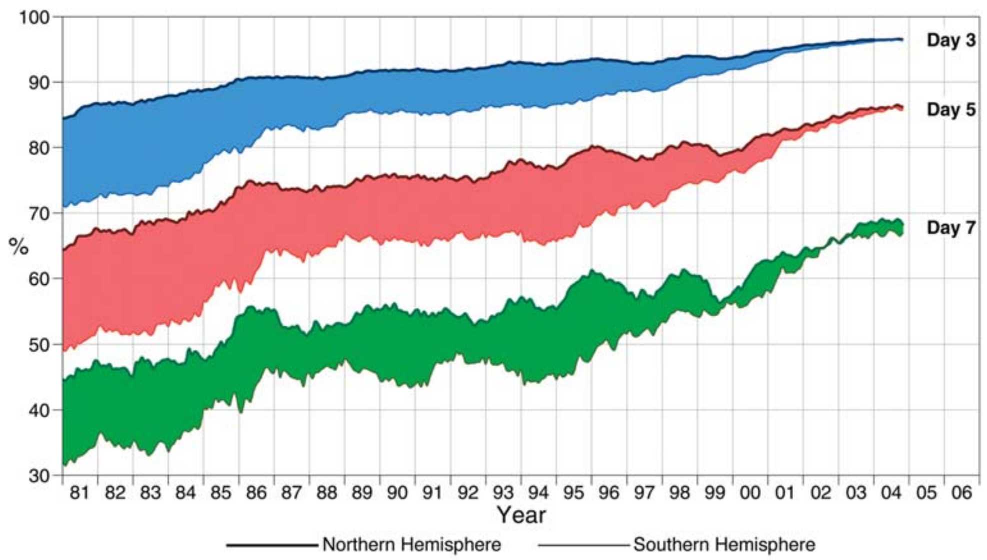
This unprecedented level of cooperation in global weather forecasting depends upon the success of the GEOSS and access to new targeted sensing systems capable of measuring the environment where and when required.

4.6.2 Vision and How GEOSS Will Help

The vision as expressed by WMO is that every country will have the weather information needed to virtually eliminate loss of life and to reduce property damage due to severe weather events. The aim is to have a society in which weather forecasts are fully used in decision support systems to improve economic efficiency and productivity, as well as environmental protection, through improved longer-range predictions available in probabilistic terms.

In developing countries for which there are limited or no operational weather capabilities, the vision is to enable them to efficiently and effectively exploit existing weather observations and develop information services. This will include partnering with developed countries for access to high-cost weather data and prediction services, partnering with neighbouring countries to develop and deliver regional warnings, and local education and training for use of warnings by decision makers and the public.

There should be an end-to-end weather information system that provides decision makers around the World with timely, reliable and actionable information prior to, during and after the event for relief support. This system will have improved *in situ* and space-based observations of critical parameters, coordinated and exchanged globally. These will provide input to improved numerical prediction models, with advanced physics capabilities, providing accurate (in location and time) forecasts of severe weather events to new or strengthened regional and local warning centres, allowing rapid and tailored notification to local authorities responsible for protecting people and property.



The improvement in 3, 5 and 7-day weather-forecasting skills over the last two decades

GEOSS will contribute to improving weather information in three ways. Firstly, GEOSS will contribute to providing a timely, comprehensive, and accurate initial state for forecast models, which is crucial to making more specific short-range forecasts. This will result in more timely, and accurate weather information being available to decision-makers for appropriate action. Secondly, GEOSS will provide comprehensive observations necessary to extend the range of useful products, which when acted upon will effectively reduce the adverse impact of weather on a larger number of global inhabitants and regions. Thirdly, GEOSS will help GEO Members and Participating Organizations to more efficiently address the end-to-end weather information services needs, resulting in greater service for less cost.

More specifically, models will be able to exploit improved observations to produce weather forecasts of sufficient quality that many disciplines, which are currently structured to cope with weather as it occurs, will transition to operations that anticipate threats and take action days in advance. For example, energy generation decisions made 4-6 days in advance of heat waves and cold snaps based on accurate weather forecasts can save millions of dollars. Accurate forecasts of excessive temperature and humidity will allow health officials to anticipate and adequately staff for heat-stress-related emergencies. Similarly, accurate weather forecasts will allow: proactive measures for agriculture to protect crops; ecological monitoring teams to evolve beyond tracking to predicting biological invasions; and disaster teams to proactively respond, minimizing the impact of potentially catastrophic environmental events threatening life and property.

4.6.3 Existing Situation and Gaps

4.6.3.1 Overview

The WMO World Weather Watch Programme sets out and coordinates the provision of observations through national agencies. The Programme requirements for the weather observations cover the observing component (space-based and *in situ*), and data dissemination. It also harmonizes certain global products and model centres. The maintenance of the requirements is a key task for the WMO and is achieved through a rolling review process. The WMO Space Programme coordinates space-based observations for all WMO Programmes from both operational and research satellites. Interaction with the space agencies is achieved through a high level working group on policy issues and the Co-ordination Group for Meteorological Satellites (CGMS) for technical issues.

In situ observations are primarily undertaken at a national level, but there have been some significant developments in Europe on improved coordination through the European Meteorological Network (EUMETNET). EUCOS (the EUMETNET Composite Observing System) is an initiative to establish a cost sharing mechanism for all *in situ* data and targeted observations. There has been a rapid expansion in data from aircraft (AMDAR) and upper air data from commercial shipping (ASAP) are envisaged to meet evolving user requirements. These integrated elements are managed at a European level, so providing efficiency opportunities for the individual national meteorological services. GEOSS could provide a mechanism to expand this coordinated effort.

WMO, through its Expert Team on Observational Data Requirements and Redesign of the Global Observing System (GOS), has developed a vision for the GOS of 2015, which includes an observation component (with both space-based and *in situ* systems), and a data management component. This vision document provides a prioritized list of critical atmospheric parameters that are not adequately measured by current or planned observing systems.

Exploiting existing weather information is a particular problem for developing countries, which often lack communication mechanisms to properly receive and act on that information. Additionally, there is a shortfall in education and training processes, and the resources needed to sustain the development and use of existing weather information capabilities in those developing countries.

There are four sub-categories of gaps in weather information that can be addressed by GEOSS:

4.6.3.2 Observational Gaps

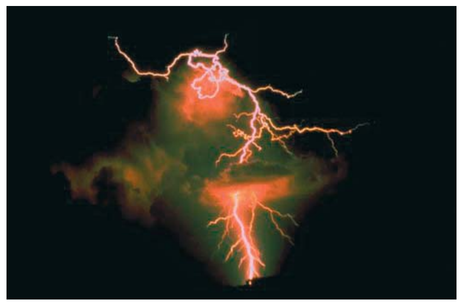
As previously stated, lack of complete global observational coverage of the atmosphere, land and oceans (e.g. inadequate resolution and quality) inhibits development and exploitation of extended range products. Table 4.6.5 illustrates the critical atmospheric parameters that are not adequately measured by current or planned observing systems.

Expansion of observing capacity is needed to detect precursor environmental conditions as the foundation for improving all weather and climate services, as called for in the plan for the WMO World Weather Watch. Highest priority should be given to filling gaps in the *in situ* and space-based observation capacity that limit data assimilation and predictive capabilities. Additionally, emphasis is needed on open global sharing of data. Next, these data must be exploited through better research, advanced data assimilation and predictive models, building telecommunications infrastructure capacity, and transforming weather predictions into formats understandable to decision makers and the public.

As an example, the WMO GOS 2015 vision document sets out a set of prioritized recommendations for specific issues on parameters to be addressed by the satellite and *in situ* systems for numerical weather prediction. Other needs have been delineated for other aspects of weather. In order of priority, they are:

- Wind and humidity profiles at all vertical levels.
- Temperature profiles with adequate vertical resolution in cloudy areas.
- Precipitation.
- Soil moisture.
- Surface pressure.
- Snow equivalent water content.

For satellites, the priority covers the need for improved calibration of all data. In the geostationary orbit there is a need for improved Imagers and Sounders. There is also a need to improve the timeliness and temporal coverage of data delivery from low Earth orbit. Improving the observations of sea-surface winds, altimetry and Earth radiation are the key observational needs from low Earth orbit. More research is also needed into Doppler technology, precipitation observation capability and radio occultation techniques.



With respect to *in situ* observations, there is a need for improved data distribution and coding, the development of AMDAR and ground-based GPS. Improving the network of observations in the oceans, polar areas, and tropical land areas, as well as developing new observing technologies, are also seen as priorities. Specifically for polar areas, there is a major gap in the provision for atmospheric wind profiles. Improved effectiveness of *in situ* data observations (including aircraft) could also be developed by GEOSS. The expansion of the Thorpex initiative should be considered.

4.6.3.3 Gaps in Modelling

Despite the progress made, scientific modelling techniques (data assimilation, NWP, and statistical post processing) still limit the accuracy and reliability of weather forecasts and warnings, and data are needed to validate the models. NWP models still have gaps in the following categories of data that increase uncertainty and reduce model accuracy: vertical profiles of moisture flux; coverage of tropical land areas and ocean areas; measurements of clouds, precipitation, and ozone; rigorous calibration of remotely sensed radiances; and enhanced data initialization and assimilation capabilities to facilitate full use of the expanded remotely sensed and *in situ* observations.

4.6.3.4 Gaps in Information Technologies

Telecommunication and computer processing gaps limit observation exchange, scientific collaboration, and dissemination of critical information to decision-makers and the general public. Also, full implementation of new observing system technologies is challenging due in part to a lack of structure to facilitate transition of research technologies to operational use in all components of the end-to-end weather information services system.

4.6.3.5 Gaps in Research, Education and Training

With improvements in all facets of producing and delivering weather information, parallel improvements in education and training processes are necessary to ensure full user exploitation of that information worldwide. Research and Development activities are necessary, related to new archive, access and data processing (including numerical modelling) capabilities, to ensure sustained weather information for the long-term.

4.6.4 Targets

2 Year Targets 4.6 Weather

Working with the weather community, GEOSS will:

Facilitate investment in the critical data gaps (atmospheric wind and humidity profiles, ocean evaporation and precipitation, soil moisture, precipitation) and improve predictive models to augment the quality of forecasts of severe events and general weather conditions.

Advocate support for plans to assist developing countries to utilize the forecasts in order to reduce impacts on life and property.

Facilitate, with WMO, education and training of developing country personnel in the effective use of currently available weather information.

Advocate support for existing weather capacity building programmes and initiatives, understanding their status and regional distribution.

Advocate support for the WMO plans to establish the feasibility of expanding EUCOS to other regions.

6 Year Targets	4.6 Weather

Working with the weather community, GEOSS will:

Advocate support for WMO coordinated activities to improve data observations and models to produce reliable forecasts of severe weather. These are forecasts that include reliability/probability estimates, as well as a range of possible outcomes, and interact with local authorities to improve usage and provide tailored services through newly established regional and local warning centres.

Advocate support for WMO plans in developing countries to support the establishment of new regional centres, to allow reliable warnings of impending severe events.

Advocate support for WMO plans to establish better coordinated regional *in situ* observation networks on the basis of the EUCOS model.

10 Year Targets	4.6 Weather

Working with the weather community, GEOSS will:

Facilitate continuous education, evaluation and improvements in developing countries, especially to allow sustained operations of the newly established regional centres.

Advocate and facilitate the establishment of new observing systems to cover specific observations set out in this Reference Document.

4.6.5 Table of Observation Requirements

Legend for Table 4.6.5

0 - Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.

1 - Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.

2 - Not yet widely available or not yet globally monitored, but could be within two years.

3 - Only locally available or experimental; could be available in six years.

4 - Still in research phase; could be available in ten years.

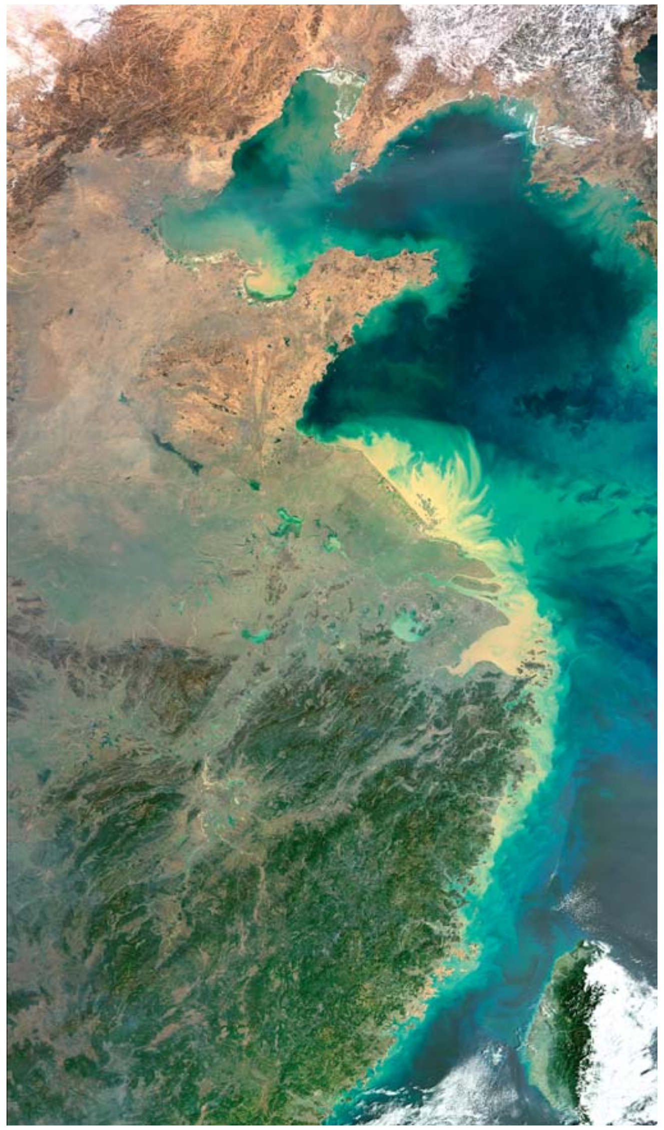
Weather
Table 4.6.5

	Observational Requirement	Warnings and Nowcasts **0-1 day**	Short-range Forecasts **1-3 days**	Medium-range Forecasts **3-5 days**	Long-range Forecasts **5-15 days**
1	Aerosol profile	4	4	4	4
2	Air pressure over land and sea surface	1	1	1	2
3	Air specific humidity (at surface)	1	2	3	3
4	Air temperature (at surface)	1	1	1	2
5	Atmospheric stability index	1	1	2	4
6	Atmospheric temperature profile	1	1	2	4
7	Cloud base height	2	3	3	4
8	Cloud cover	1	1	1	1
9	Cloud drop size (at cloud top)	4	4	4	4
10	Cloud ice profile	2	3	4	4
11	Cloud imagery	1			
12	Cloud top height	1	2	3	4
13	Cloud top temperature	1	2	3	4
14	Cloud type	1	3	4	4
15	Cloud water profile	2	3	4	4
16	Dominant wave period and direction	2	2	3	3
17	Fire area and temperature	2	3	4	4
18	Height of the top of the Planetary Boundary Layer	2	3	4	4
19	Height of tropopause	2	3	4	4
20	Land surface temperature	1	1	2	3
21	Leaf Area Index (LAI)	4	4	4	4
22	Long-wave Earth surface emissivity	1	2	3	4
23	Normalized Differential Vegetation Index (NDVI)	2	3	4	4
24	Ocean currents (vector)	3	3	4	4
25	Outgoing long-wave radiation at TOA	2	2	3	4
26	Outgoing short-wave radiation at TOA	2	2	3	4
27	Ozone profile	3	3	4	4
28	Precipitation index (daily cumulative)	2	3	4	4
29	Precipitation rate (liquid and solid) at the surface	2	3	4	4
30	Sea surface bulk temperature	1	1	2	3
31	Sea-ice cover	1	1	2	3
32	Sea-ice surface temperature	4	4	4	4
33	Sea-ice thickness	3	4	4	4
34	Significant wave height	1	2	3	4
35	Snow cover	1	3	4	4
36	Snow water equivalent	3	3	4	4
37	Soil moisture	2	3	3	4
38	Specific humidity profile	2	3	4	4
39	Temperature of tropopause	2	3	4	4
40	Wind profile (horizontal and vertical components)	3	4	4	4
41	Wind speed over land and sea surface (horizontal)	2	2	3	4

4.7 Improving the management and protection of terrestrial, coastal and marine ecosystems

4.7.1 Statement of Need

Ecosystems are the basis and necessary condition for all life on Earth. *Ecosystem services* are the benefits that people derive from ecosystems, such as food, water, fibre and timber, energy, climate, flood and pest regulation, nutrient cycling and soil fertility, detoxification of waste, coastal and marine protection. *Ecosystem condition,* also referred to as *health,* is the capacity of the ecosystems to sustainably supply services, even in the presence of mild disturbance and stress. Ecosystems, beyond their utilitarian values, also have intrinsic value. *Ecosystem extent* is the actual (as opposed to potential) area and location of a particular ecosystem type.



Envisat MERIS image showing river-discharge and sediment loading in the East China Sea

The purpose of observations within the Ecosystems societal benefit area of GEOSS is to describe accurately and to assess the present conditions and trends of ecosystem services, as well as the pressures and impacts upon them, for policy making and natural resource management to promote sustainability, as illustrated in Figure 4.1. To this end, it is essential to improve the basic knowledge of the temporal and spatial variation in the ecosystems in question. This requires sustained and comprehensive observations. Ecosystem observations will also help assess ecosystem resilience, i.e. the capacity of ecosystems to resist changes due to internal and external pressures (e.g. habitat fragmentation and alien invasive species) and the pace at which they would be able to recover to conditions similar to the original ones after those pressures have been removed.

Ecosystems are the basis of all natural resource industries agriculture, forestry, pastoralism, and wild-harvest fisheries,[15] to name a few prominent examples. A key outcome of GEOSS is to support these industries in understanding the resource production potential and its limits.

The capacity of ecosystems to support diverse and abundant life and to supply ecosystem services is under pressure worldwide. Levels of resource extraction are unsustainable in many instances; i.e. they exceed the rate at which the resources are replenished. Examples include over-fishing, over-grazing and over-logging. Habitat degradation and loss, including deforestation, desertification, and destruction of wetland, riparian, coastal and marine habitats is widespread.

The byproducts of human activities may have a negative impact on ecosystem condition, through the processes of eutrophication, nitrogen and sulphur deposition, aquatic, soil, and air pollution, and greenhouse gas induced climate change. Changes in the natural disturbance regime, through fires, pest and disease outbreaks, major storms, earthquakes and climate variability alter ecosystem composition and function. Depletion of the ecosystem composition and connectivity through these processes leads to the over-abundance of particular species, facilitating the invasion by alien species and undesirable genomes that can result in naturally-occurring species becoming endangered.

Given that ecosystem services are essential for human existence, their total economic value is incalculably large. Nevertheless, various partial analyses of the marginal net costs and benefits resulting from loss of particular ecosystem services at various scales indicate that the economic impacts run into millions, and in some cases billions, of dollars, and significantly affect the well-being of hundreds of millions of people.

[15] Note that fisheries appear both in 4.7 Ecosystems and in 4.8 Agriculture. This is for two reasons: fish are currently harvested from both wild populations (4.7) and farmed populations (aquaculture) (4.8); secondly, the main body maintaining international fisheries statistics is FAO.

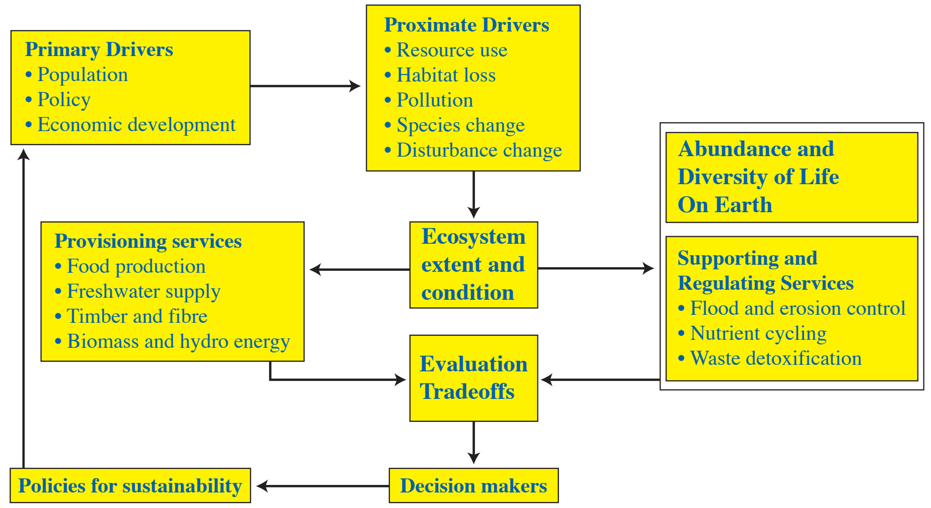


Figure 4.1. In order to support decisions relating to sustainability, decision makers, scientists and natural resource managers need information on ecosystem services, as impacted by ecosystem extent and condition and trend, which are in turn affected by direct and indirect drivers

Many international agreements and conventions, as well as national laws, call for actions in ecosystem management and sustainable utilization of resources, including specifications for terrestrial, coastal and marine ecosystems monitoring, to detect rapidly and provide timely predictions of their changes (e.g. the Johannesburg Declaration on Sustainable Development; the Convention on Combat Desertification; the Convention on Biological Diversity; the UN Framework Convention on Climate Change; the RamSAR Convention on Wetlands, the UN Forum on Forests; and the Marine Conventions).

GEOSS takes note of the trend within Multilateral Environmental Agreements towards an 'ecosystem approach', i.e. an integrated approach taking into account the total impact on human activities, and focused at an appropriate scale for effective decision-making. The observations need to be consistent with the data needs for such an approach.

The key users of improved observations of ecosystems will be decision-makers in the field of natural resource management at the global, regional and national levels. At the global scale, particular beneficiaries will be those charged with implementing Multilateral Environmental Agreements. Environmental government agencies and NGOs at the international and national scales, such as IUCN and WWF, are also important users.

Satellite imagery of active fires in the Tete and Nampula Provinces of Mozambique

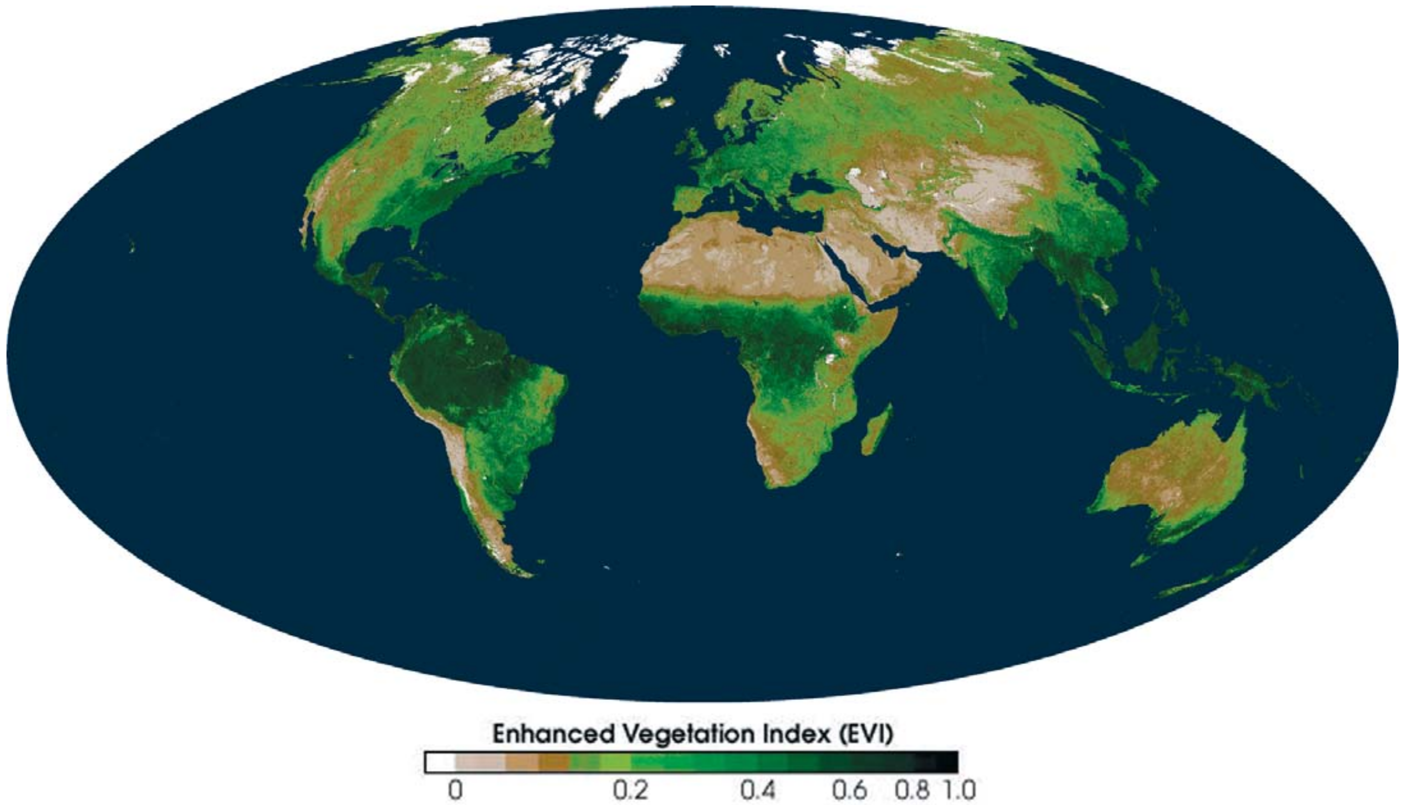
Example: Early Warning of Toxic Algal Blooms

In recent years, the economic losses caused by harmful algal blooms in the China Sea, which is bordered by several countries, have exceeded US$ 1.2 billion. To mitigate the damage to coastal and marine ecosystems and to reduce the economic losses, approaches to monitor and to predict the occurrence of the blooms are being developed. The observational products from GEOSS such as Sea Surface Temperature (SST), sea surface chlorophyll, suspended sediment and ocean colour could be used in monitoring the state of the coastal ocean, and in conjunction with an ocean ecosystem model, to predict the time of occurrence and spatial coverage and intensity of algal blooms. Complementary in situ data would provide additional detail on the nature of the blooms, and on their level of toxicity. A warning system would inform the fishing industry, transportation industry and recreation agencies of the risks.

4.7.2 Vision and How GEOSS Will Help

The vision is to develop, on a global basis, standardized and integrated methodologies, observations and products that allow the repeated mapping of ecosystem extent and the quantification of ecosystem condition, for the purposes of detecting and predicting changes in ecosystem function, identifying locations under threat of degradation, and identifying uses that are unsustainable.

Courtesy of MODIS Land Group



Satellite measurements can be used to quantify the concentrations of green-leaf vegetation around the World, allowing scientists to monitor major fluctuations and understand how they affect, and are affected by, regional climate trends

Ecosystem properties are currently widely observed, but not consistently, systematically or in an integrated way, and the data are not widely shared. Many ecosystem processes are transnational and require an integrated, global approach to avoid, contain and mitigate problems related to ecosystem management. GEOSS can be the mechanism to help the integration, harmonization, and coordination of the efforts and outcomes of current research and monitoring programmes related to marine, coastal, inland aquatic and terrestrial ecosystems at the international level.

GEOSS can also serve as an instrument for scaling up local and regional observations to the global scale, in order to address issues with global implications, or those that are ubiquitous in nature. To this purpose, GEOSS must be built from regional networks or national institutions working on ecosystem monitoring.

Increasing worldwide concerns regarding ecosystems argue for improved monitoring. As yet, no system for sustained, long-term monitoring of ecosystem processes is in place at the global scale. The products derived from integration of remotely sensed and *in situ* observations through GEOSS will contribute to closing this gap. GEOSS will improve the capacity to monitor the status and variability of ecosystems and the pressures on them and thus contribute to sustainable management of living resources. It will also contribute to monitoring the pressure on terrestrial, coastal, marine and freshwater ecosystems and the assessment of their ability to support sustainable development. Thirdly, it will be of value in acquiring and integrating information on the biological causes and feedback mechanisms implicated in global change and climate variability.

Boom-mounted microwave sounders mounted on a truck can quickly measure soil moisture

4.7.3 Existing Situation and Gaps

There are elements of existing global observing systems that can contribute to the needs identified above, and much detailed planning for needed observation systems has been done. Specifically, the IGOS-P Oceans, Carbon, Land and Coastal Theme Reports describe most of the observational requirements relating to ecosystems. The IGOS-P specifications are themselves based on observations made by space agencies represented in the Committee on Earth Observation Satellites (CEOS) and *in situ* observations made by governmental agencies in individual countries (including environmental agencies, forestry, fisheries, and ocean departments; and research organizations), coordinated by the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS) and the Global Geodetic Observing System (GGOS). Key organizations, initiatives, projects and programs include LOICZ, GLOBEC, SOLAS, IMBER, GeoHab, IOCCP, IAG, UNEP Biodiversity Program, UNESCO, and the FAO Forest Resource Assessment. This societal benefit area has close links to those of Climate, Water, and Biodiversity, so organizations and observations involved in those areas are often also relevant here.

Global maps of land cover (from which ecosystem extent can be inferred) have been prepared by a number of organizations. The conceptual equivalent for oceans (large marine ecosystems, or alternately the biogeochemical provinces) has been mapped. High-resolution global products of leaf area, ocean colour, and net primary production exist in the research domain. Observation-based maps of nitrogen deposition exist for limited regions, some making use of hyperspectral information from airborne or space-based remote sensing. At the global scale, nitrogen deposition maps are model-based and incompletely validated. The GOFC/GOLD panel of GTOS has an operational fire observation system. Metadata on several thousand existing terrestrial, freshwater, coastal, and cryosphere observation sites around the World are maintained in the GTOS TEMS database.

Detailed observation plans exist in the following subtopics:

- Coastal ecosystems (IGOS-P Coastal Theme, GTOS and GOOS coastal observation panels, OOI/IOOS networks).
- Land cover, including global fire mapping products, cultivated area, and forest area (IGOS-P Land Theme, GTOS GOFC/GOLD, FAO Global Land Cover Network (GLCN)).
- Carbon cycle observations (IGOS-P Integrated Global Carbon Observation (IGCO) Theme, incorporating the GTOS Terrestrial Carbon Observations on land, GCOS components for the atmosphere and the GOOS International Ocean Carbon Coordination Project (IOCCP) for the oceans).
- Freshwater ecosystems are partly covered by the IGOS-P Global Water Cycle Observation Theme (IGWCO).

Nonetheless there are significant gaps. As yet there is no universally agreed classification scheme for ecosystems, although there are strong efforts in this direction by, among others, the FAO Land Cover Classification System. Neither are there reliable maps of the geology, soil, and sediment properties that control many ecosystem processes, such as soil depth, geochemistry, carbon content, particle size distribution and pollution status, at a resolution appropriate to ecosystem processes, and with global coverage, although there are efforts underway by FAO and the International Soil Science Society SoTER project to address this need.

The observation and estimation of the lateral flow of material (carbon, nitrogen and other elements) in traded products, river discharge, ocean currents and air masses are poor. In addition there is no assured continuity of moderate to high-resolution satellite data for ecosystem mapping and key variable observations, specifically of land cover, ocean colour and temperature. The time scale of ecosystem dynamics makes long-term monitoring of ecosystem processes highly desirable.

There is not a sufficient and representative *in situ* observational network for complementing and validating satellite data. Nor do adequate observation systems exist for: soil moisture; land-ocean-atmosphere exchanges of water, energy and carbon and nitrogen; biomass and standing stocks of carbon, nitrogen and other elements; canopy properties and their temporal dynamics; and routine *in situ* chemical and biological measurements of the aquatic environment, including primary and secondary production and biomass in lakes and oceans. There is a need to develop and improve data assimilation, data fusion, historical data mining, models and remote sensing algorithms in the ecosystems field, and to generate operational products relating to ecosystem disturbance regimes, such as harvesting, fire, drought, pest and disease outbreaks, major storms, and large-scale climate anomalies (e.g. *El Niño-La Niña* events, see Section 4.4).

Flux tower for in-situ carbon-dioxide measurements

4.7.4 Targets

2 Year Targets 4.7 Ecosystems

Working with the ecosystem management community, GEOSS will:

Facilitate the harmonization of methods for observing the GEOSS set of ecosystem variables.

Facilitate the full implementation of a global carbon observing system, in accordance with the specifications detailed in the IGOS-P IGCO Theme Report, which incorporates the Terrestrial Carbon Observation plan of GTOS, and carbon-related components of GOOS and GCOS.

Facilitate a globally agreed, robust and implementable (operational) classification scheme for ecosystems.

Advocate the operational continuity of moderate to high-resolution Earth-observing satellites for land cover and ocean colour.

Facilitate efforts to eliminate regional disparity in observing capacity. For example, two thirds of the World's oceans are in the Southern Hemisphere, whereas most of the advanced oceanographic centres are in the Northern Hemisphere. Stations for observing ecological variables on land are much more closely spaced in temperate countries than in the tropical belt.

Facilitate the networking of institutions making observations relating to ecosystems.

Advocate the development of tools to scale up from a limited number of *in situ* ecosystem observations made at local scales, to arrive at a large-scale, comprehensive picture of ecosystems.

Advocate the continued rescue, acquisition, digitisation and making accessible of historical information relating to ecosystems.

Facilitate the validation of existing tools such as synthetic aperture radar and hyperspectral imagers for the measurement of ecosystem properties.

Advocate the development of new sensors and platforms, and facilitate their use for routine observations in the field on an operational basis. For example, airborne sensor technologies such as LIDAR are ready to move out of the research domain. Molecular tools are now being developed to study the microbial ecology of marine systems. *In situ*, self-contained, flow cytometers for classification of phyto-plankton and bacteria (the "cytobuoys") and underwater laser imaging and scanning techniques that can be used for recording marine life underwater and for detecting terrestrial ecosystem structures, are in advanced stages of development. New sensors are also on the horizon for measurement of the chemical properties of the ocean and terrestrial ecosystems.

6 Year Targets 4.7 Ecosystems

Working with the ecosystem management community, GEOSS will:

Facilitate the execution of a global (terrestrial, inland water, coastal, and oceanic) ecosystem mapping initiative at a resolution of 500 m, using a standardized classification and the tools validated above, and integrated with the Global Spatial Data Initiative.

Facilitate the implementation of a global nitrogen observing system.

Facilitate the coordination and expansion of a network of land, ocean and coastal reference stations for monitoring ecosystem properties such as carbon, nitrogen, phosphorus, and iron fluxes, including change detection.

Facilitate the establishment of a global, sufficient and representative *in situ* and airborne network for validating and enhancing space-based observations of ecosystem properties in both terrestrial and aquatic ecosystems, based on existing national and regional integrated environmental monitoring networks, and coordinated with and linked to the network described above.

Produce or facilitate the production of baseline maps for the globe, with adequate resolution and known uncertainty, of selected ecosystem properties such as: leaf area phenology, phytoplankton bloom dynamics; primary production, and net carbon exchange; energy and water exchange; productivity at higher trophic levels (e.g. grazing, fisheries production), and ancillary data such as topography, land use, geology and soils.

10 Year Targets 4.7 Ecosystems

Working with the ecosystem management community, GEOSS will:

Facilitate the production of spatially-resolved information on ecosystem change, condition and trend, in relation to their capacity to deliver sustainable ecosystem services in sufficient quantities to meet societal needs; i.e. maps of ecosystem health, risk and vulnerability with sufficient resolution to support national and global decision-making.

Facilitate monitoring of urban ecosystems.

4.7.5 Observation Requirements Table

Legend for Table 4.7.5	
0 -	Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
1 -	Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
2 -	Not yet widely available or not yet globally monitored, but could be within two years.
3 -	Only locally available or experimental; could be available in six years.
4 -	Still in research phase; could be available in ten years.

Please see Table 4.7.5 on the following page.

Ecosystems
Table 4.7.5

Observational Requirement		Land, River, Coast & Ocean Management	Agriculture, Fisheries, Forestry	Carbon Cycle
Ecosystem extent and composition				
1	Extent and location of ecosystem and habitat types	1	1	1
2	Fragmentation of ecosystems	2	2	2
3	Community composition (including benthos)	2	2	2
Ecosystem structure and function				
4	Leaf Area Index or greenness	1	1	1
5	Ocean, freshwater water color and chlorophyll content	1	1	1
6	Canopy architecture: height, cover	2	2	2
7	Biomass per unit area	2	2	2
8	Carbon fluxes: NPP, NEE and Respiration	3	3	3
9	Water fluxes: evaporation	2	2	2
Climatic drivers of ecosystem function				
10	Max and min temperature (at or near surface)	1	1	
11	Near-surface winds	2	2	
12	Humidity (near surface)	1	1	
13	Precipitation	1	1	
14	Ocean currents and waves	2	2	
15	Solar radiation (net, and PAR)	2	2	2
16	Sea-level rise	1	1	1
Soil, sediment and medium drivers of function				
17	Soil type (texture, depth)	3	3	3
18	Nutrient supply: nitrogen, phosphorus, micronutrients	3	3	3
19	Water and soil salinity	2	2	2
20	Soil moisture	3	3	3
21	Optical properties of water	2	2	2
22	Soil, sediment and water column organic matter content	2	2	2

Ecosystems
Table 4.7.5

Observational Requirement		Land, River, Coast & Ocean Management	Agriculture, Fisheries, Forestry	Carbon Cycle
Human drivers of ecosystem function				
23	Human population density and growth rate, urban and rural	1	1	
24	Harvest intensity (on land and oceans)		1	1
25	Nitrogen deposition	3		3
26	Extent of coastal and lake eutrophic zones	2		
Disturbance regime				
27	Burned area	1	1	1
28	Pest and disease outbreaks	3		
29	River discharge pattern	2		

Note: many ecosystem services are listed under other benefit areas, and would be part of the ecosystem benefit area as well. These include water yield, food and forest production, climate regulation, flood amelioration, and extent of desertification.

4.8 Supporting sustainable agriculture and combating desertification

4.8.1 Statement of Need

There are approximately 800 million people in the World who are chronically exposed to hunger or malnutrition. Moreover, most of these people are found in developing countries in Asia (62%), Africa (22%), Latin America and the Caribbean (7%) and the Near East and northern Africa (4%). The 1996 World Food Summit (WFS) agreed that the number of hungry people should be reduced by half by the year 2015. This objective to reduce hunger is reflected in the Millennium Development Goals (MDG), the first of which calls for eradicating poverty and hunger and establishes specific targets to be met consistent with the WFS.

The conditions for achieving short-term food security over 1-5 years vary by region. For example, in China and India, the conditions for achieving food security are relatively good in so far as both the countries and the region have been experiencing favourable economic growth over a number of years. This is despite the fact that they contribute the largest numbers in terms of population to Asia's food-insecure.

In the African sub-continent, where processes of desertification, highly variable climatic conditions and civil unrest have limited the achievement of sustainable increases in food production, there remain significant constraints to achieving the targets set for reducing the number of hungry and food-insecure. This is despite the fact that unused land of a good quality for agriculture is available in many countries. Nonetheless, there is emerging evidence that desertification is a major issue due to misuse of land.

The maintenance, enhancement and reliability of agriculture, rangeland, fisheries (including aquaculture)[16] and forest production are essential if the World is to cope with a global population that will require approximately 700 million additional tons of cereal production to meet projected population growth by the year 2020. In this context, the issue of desertification in marginal lands is important and the assessment of drought is critical.

Although GEOSS is primarily global in scope, the specific issues identified in this section have direct benefit to agriculture planners, policy makers and technicians who can derive useful information for applications at regional and national levels.

Primary among the potential beneficiaries are small farmers and land managers in lower income countries. These persons generally lack almost all of the essential information that many take for granted, including weather and climate information, market and pricing data, crop forecasts. It is by no means unrealistic to envisage a World in the not too distant future in which the use of Earth Observation and communication technologies will bridge the divide that separates these underprivileged persons from the economic and social benefits that can be obtained through access to appropriate information.

A second group of beneficiaries of a GEOSS will be agriculture development experts of countries and international organizations who run operational systems for the production, distribution and consumption of food and other products. Improved data and information flow will provide immediate benefits for early warning systems to detect crop yield shortfalls and pest outbreaks, for response farming, and for ensuring the proper use of inputs and management of biophysical resources.

A third community of beneficiaries includes scientists and researchers who seek to understand better the potential impacts of global change on agriculture and food systems through data assimilation, modelling and food systems analysis. Important among these are forward-looking studies (e.g. Agriculture Towards 2015-2030) aimed at assessing future food needs in relation to the available biophysical resources and population projections, to ensure that the necessary resources are invested in a timely manner to meet future food needs. Internationally coordinated research efforts, such as Global Environmental Change and Food Systems (GECAFS), which examine links between food production, climate change and biodiversity loss, will also be important users of the new and improved data and information.

[16] *See footnote concerning fisheries in Section 4.7.*

A fourth community of beneficiaries is those national policy makers who are involved in efforts to ensure that coordinated actions are taken to respond to global environmental change. These include, in particular, a variety of multi-lateral environmental agreements such as the Convention to combat desertification, as well as the Millennium Development Goals.

Example: Helping Poor Farmers With High Technology

Example 1

A World in which there are reliable estimates of the numbers of people who live in the drylands of the World (i.e. sub-humid zones with less than 120 days of growing period) that are subject to desertification, climate variability and land degradation. First order estimates, obtained in 2003 through the allocation of global population density data to individual 1 km map pixels, revealed that approximately 620 million persons inhabit these zones. However, a systematic effort to map all available socio-economic data in agriculture at the pixel level would have an excellent cost/benefit ratio and allow for strategic analysis and decision making based on human needs. It would be possible to identify highly vulnerable populations, to match income with production, to identify market and pricing opportunities, which can help in strategic decision making to combat desertification and conserve biodiversity.

Example 2

A World in which high resolution satellite imagery is validated in near real-time and combined with local information and provided to poor, low income farmers on a daily basis through wireless communication technologies such as rural radio. Market and price information, local weather forecasts, and crop information would be provided directly to farmers in food-insecure countries. Radar imagery proves particularly useful as cloud cover is prevalent in the crop growth season.

4.8.2 Vision and How GEOSS Will Help

The vision is to have a truly global poverty and food monitoring, land use mapping and information service that will enable sustainable development within countries and allow international organizations to plan their activities. This involves developing effective national and regional capacity to use Earth Observation data in local, national and regional agriculture, rangelands, forestry, and fishery sectors. It requires comprehensive socio-economic data that is disaggregated and geo-referenced at a pixel level suitable for describing agricultural production.

One element of such a system will be operational and validated on drought early warning systems that reach to the level of the individual farmer in food-insecure regions in Africa, Asia and Latin America. A second will be an on-time monitoring and information system for events such as fire, forest conversion, forest concession management, crop yield, land degradation and desertification. A third is the need for periodic large-scale integrated assessments of land and water resources at a high resolution that supports sustainable agriculture (e.g. irrigated land, land degradation and desertification, aquaculture expansion, land fragmentation). Underpinning this is a need for a set of comprehensive and validated global products for land cover and land use.

A first step is the need to work with international organizations and governments to establish a harmonized land cover classification system that can be widely adopted, and in parallel assist developing countries to access and manage geospatial data.

Completion of the ongoing global assessment of irrigated land is essential, and the early development of a World soil and terrain database at resolution of 1:1 million or better is needed. Other key aspects are: the assessment in drylands of land degradation; a systematic farm systems mapping exercise at 1:500,000 resolution; fishing fleet monitoring as an input

to ensuring sustainable use of resources; and high-resolution (5-40 m) monitoring of selected environmental problem locations in agriculture, rangelands, forestry, freshwater and fisheries.

GEOSS will contribute to the integration of all the parameters required to meet the vision. Four main categories of products or data sets are needed:

- Land resources, e.g. land cover and use, land degradation, crop production, physical and chemical soil characteristics, forestry assessment, fire.
- Freshwater resources, e.g. total irrigated area, fluxes in small water bodies, and groundwater resources, aquaculture.
- Ocean and coastal resources, e.g. aquaculture, shellfish, fish.
- Socio-economic conditions, e.g. population distribution, production intensity, food provision, and the location of cultural heritage sites.

Foremost in importance among the products needed for sustainable agriculture are those related to land cover, land use, and the associated socio-economic data. However, biological factors such as pollinators, wild relatives of domestic species, invasive species and pests are significant influences on agriculture, forestry, and fisheries. All of this information must have known accuracies and be geospatially referenced, in order that it can be integrated with data from other sources.

GEOSS can work to ensure the continuity of existing space-based and *in situ* terrestrial and marine observation systems and support the ongoing assimilation of these data with *in situ* data for the generation of products that are relevant for monitoring and assessing food security, crop production and land quality.

GEOSS also needs to work with the institutions that run programmes to facilitate access to and use of Earth Observation products in order to ensure an "end-to-end" system whereby the farmers and land managers receive sufficient information. This involves the provision of "change" products that demonstrate the response of agriculture, forestry and fishery systems to different management and environmental factors. GEOSS can also improve the ongoing dialogue between data and product providers and the local, national and regional bodies to ensure that relevant data and information gets into the hands of persons who make decisions about agriculture, forestry and fisheries policy.

4.8.3 Existing Situation and Gaps

FAO is a key player in establishing the link between the GEOSS data and product suppliers and the users of agricultural information. FAO has a well-established and structured mechanism for interacting with farmers, national agencies and international organizations. It has also started to develop direct cross-links to work on ecosystems and biodiversity. WMO has links with farmers, etc., primarily through the National Weather Services for weather related issues.

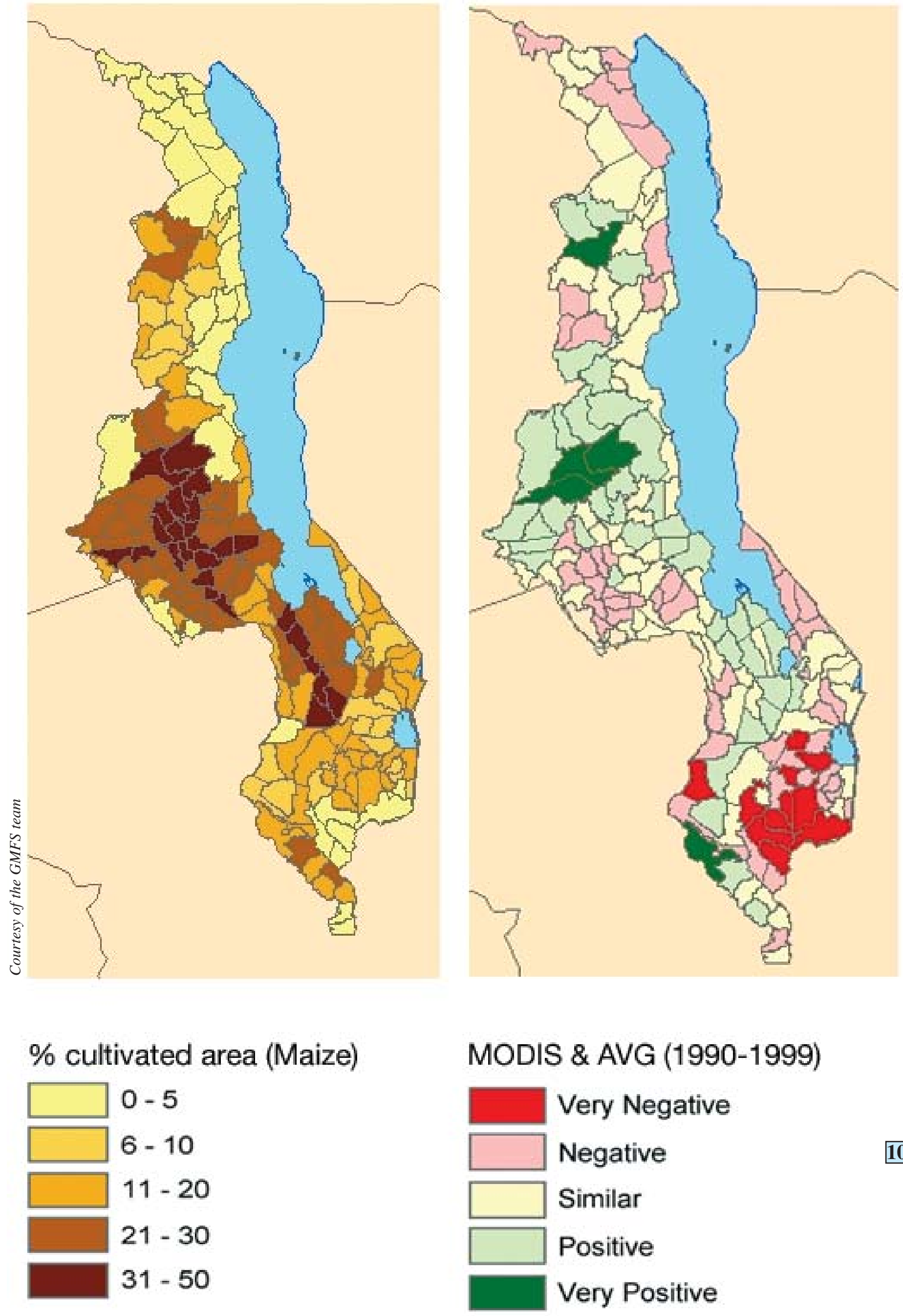
During the past ten years, the ability to access data and information has consistently improved, but there remains a great weakness in the availability of trained personnel and dedicated financial resources to maintain technology and personnel needed to ensure archiving, access and use. As a consequence, most developing countries use only a small fraction of the Earth Observation data that is available and relevant to sustainable agriculture.

A key point for improving the capacity of developing countries to use Earth observation data lies with regional and national bodies that are already involved in the use of these tools for drought or pest early warning systems or for monitoring significant natural resources such as forests. For example, the Southern Africa Development Committee (SADC) has developed significant Earth observation infrastructure capacity during the past 20 years and would be able to extend that capacity with relative ease, including the development of relevant policy products.

The drought-monitoring centre for the Greater Horn of Africa can be a point for building upon existing capacity and familiarity with Earth observations. In all cases, it is essential that emphasis be given to improving the science/policy dialogue among the interest groups.

The existing class of observational systems can supply the majority of needs. The main efforts need to be directed toward improved product development – with validation – and ensuring continuity of data sources. One key gap is to ensure the continuity of funds for the high (5 m) and medium (30-40 m) resolution satellite systems such as Landsat and Spot, IRS and radar sensors such as those on Envisat and Radarsat.

Integration of data collection, management and assimilation are also areas that can be improved considerably. There is a need to strengthen the links between *in situ* networks and satellite programmes for the purposes of validating products such as those relating to land cover, land use, crop production, cultivated area, forest area, and protected sites for natural or cultural heritages. Some of these require links with socio-economic data sets. There is scope to facilitate large-scale data assimilation exercises for agriculture related data and information and building capacity in the agriculture community to undertake such exercises on a regular basis. The Global Ocean Data Assimilation Experiment (GODAE) is an example that could be applied to the agriculture, forestry and fishery sectors.



Estimated cultivated area of maize in Malawi and trend analysis with respect to previous years (growing season 2003-2004), generated from MODIS and MERIS data under the ESA GMFS project

There is a need for all relevant agencies to build an end-to-end process of data collection, analysis, product generation and decision making. This should include strengthening the capacity of developing regions to take up the existing flow of Earth Observation data and to generate relevant products. To support this, there is a need for international standards for registering and exchanging geospatial data and information. Once established, these facilities can provide long-term support to the re-analysis of data archives relating to land cover, vegetative cover and other types to generate "change" products that facilitate understanding of the effects of global forces on sustainable agriculture.

Capacity building would be aided by the implementation of prototype projects at a multi-national level among developing countries. These could involve the use of precision agriculture technologies to assess water stress, plant disease and other factors using high-resolution satellite and *in situ* data on high-value crops. AFRICOVER and the Global Land Cover Network (GLCN) are good examples of capacity building activities.

4.8.4 Targets

2 Year Targets 4.8 Agriculture

Working with the agriculture community, GEOSS will:

Facilitate - with relevant users at regional, national and local level - definition of user needs for agriculture, rangelands, forestry and fisheries in terms of Earth Observation data and information, as well as mechanisms to keep users informed.

Advocate and facilitate existing initiatives that regularly provide updates of land cover data at 1:1,000,000 scale; use agreed ISO standard to initiate land cover mapping activities at 1:500,000.

Facilitate regional training in land cover classification and the assimilation of existing data sets in Africa, Asia and Latin America.

Facilitate the use of agriculture, forestry, and fishery production statistics to be exploited at pixel level.

Advocate the adoption and use of geostationary satellite data (e.g. Meteosat Second Generation) in food-insecure regions.

Facilitate establishment of a basis for the continuity of high resolution optical and radar satellite observing networks (5-30 m).

Facilitate production of a map of the World's irrigated agriculture areas, and the establishment of a monitoring programme among users.

Advocate the development of on-time monitoring and information systems for significant and extreme events such as fire, forest conversion, and forest concession management.

Facilitate the development of courses to demonstrate the usage of Earth observation data and products in developing countries.

6 Year Targets 4.8 Agriculture

Working with the agriculture community, GEOSS will:

Advocate the development and improvement of the analytical tools and methods for agriculture risk assessment, and establish common standards and formats.

Advocate support for the completion of the World soil and terrain database (SoTer) at a resolution of 1:1 million.

Advocate support for the completion of land degradation and desertification assessment in drylands (LADA).

Facilitate provision of regularly validated global land cover product at 1:500,000.

Facilitate the role of satellite data in monitoring and maintaining a global farming systems database.

Facilitate the establishment of operational linkage of Earth Observation data to geospatially referenced production and use statistics. This should cover crop agriculture, livestock, forestry and freshwater fisheries.

Facilitate the continuity of high-resolution imagery for monitoring logging concessions in areas with high biodiversity concentrations.

Advocate operational on-time monitoring and information systems introduced for significant and extreme events such as crop yield and crop water stress.

10 Year Targets 4.8 Agriculture

Working with the agriculture community, GEOSS will:

Facilitate, with identified partners, the development of a fully integrated *in situ* and spaced-based observation service for on-time drought early warning systems in food-insecure regions.

Facilitate, with identified partners, the production of a comprehensive and validated global products suite production capability for land cover in higher resolution (e.g. 1:250,000) and land use in moderate resolution (e.g. 1:500,000).

Facilitate the creation of global databases and assessments of irrigated land, water availability for agriculture, land degradation, forest conversion, and aquaculture expansion. Define process for data supply for updates.

Facilitate conversion of all statistics and associated sub-national socio-economic data and environmental information to pixel format with known accuracies for cross linkage with satellite data.

Facilitate on-time monitoring and information systems for significant and extreme events such as areas of land degradation and desertification.

Produce an assessment of the effectiveness of delivery of GEOSS capacity building activities in the agriculture, forestry, and fishery sectors.

4.8.5 Table of Observation Requirements

Legend for Table 4.8.5

0 -	Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
1 -	Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
2 -	Not yet widely available or not yet globally monitored, but could be within two years.
3 -	Only locally available or experimental; could be available in six years.
4 -	Still in research phase; could be available in ten years.

Please see Table 4.8.5 on the following page.

Agriculture
Table 4.8.5

Observational Requirement		Food Security	Fisheries	Timber, Fuel & Fiber	Agricultural Economy & Trade	Grazing Systems
Land						
1	Crop production (yield, by crop type)	1		1	1	
2	Livestock number, type and offtake	1			1	1
3	Land cover and change: cultivated area, forest area, rangeland area	1		1	1	
4	Within-season crop condition: greenness and water stress	1		1	1	1
5	Topography (Digital elevation model)	1		1		1
6	Fuelwood supply	2		1	2	
7	Drought risk	1		1	1	1
8	Active fire, burned area and fire risk	2		1		2
9	Soil type (depth, texture, stoniness, fertility, acidity)	3		3		3
10	Land quality and land quality change (degradation)	3		3		3
11	Nutrient status and balance	3		3	3	
12	Area affected by salinisation, water erosion, wind erosion	3		3		3
Marine & Coastal						
13	Fishery production, by resource type	1			1	
14	Fishing effort: vessels and activity		2		2	
15	Fishery areas, marine protected areas		1			
16	Sea surface temperature		1			
17	Ocean color and chlorophyll content		1			
Freshwater						
18	Aquaculture area and production	1	1		1	
19	Fishing effort: vessels, activity		3		3	
20	Water availability and quality for irrigation and pastoralism	2		2	2	
21	Irrigated area and quantity of water used for irrigation	1			2	
22	Wetland area	3	3			
Socio-economic						
23	Farming systems	3			3	3
24	Land use and land use change	3		3	3	3
25	Distance to market and transport infrastructure			2	2	2
26	Agricultural income				1	
27	Food aid shipments	2			2	
28	Access to food (availability, infrastructure, income, physiology)	3		1	3	
29	Population density (rural and urban)	1		1	1	1
30	Production intensity (actual/potential)	2		2	2	2
31	Agricultural and forestry machinery			1	2	
32	Fertilizer and pesticide use				2	

4.9 Understanding, monitoring and conserving biodiversity

4.9.1 Statement of Need

Biodiversity is the *variety* of life on Earth. It can be thought of as having three major levels of organization (the genetic level, the species level, and the ecosystem level), within each of which there are three aspects of diversity: composition; structure and function (Fig. 4.2).

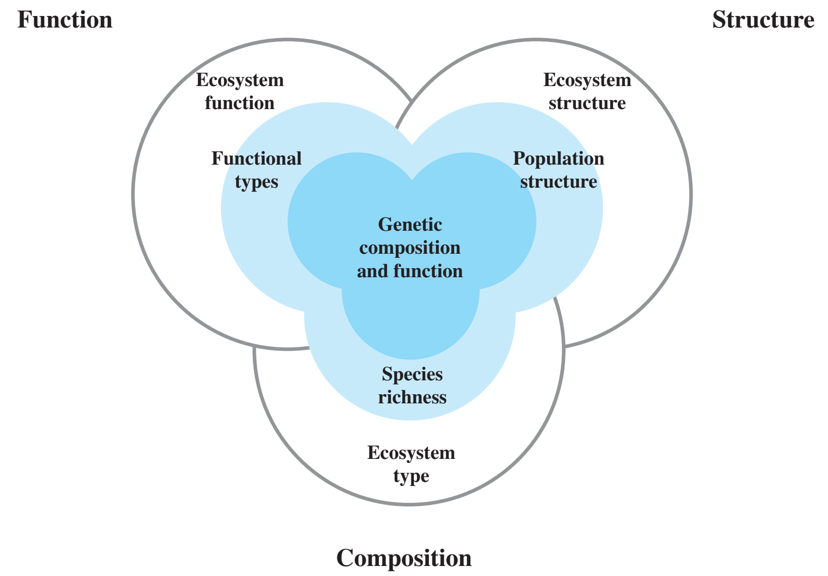


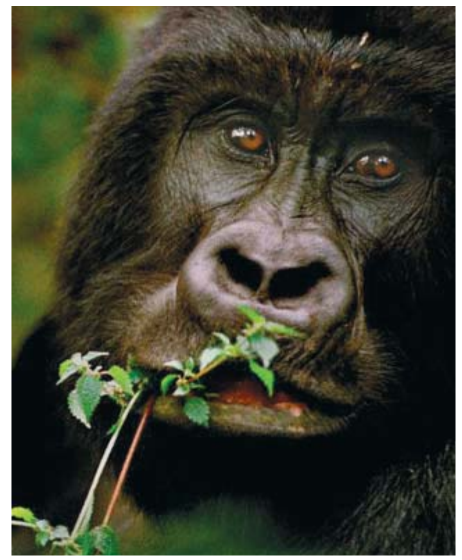
Figure 4.2. A conceptual diagram illustrating the multiple levels and aspects of biodiversity. Simplified from Noss (1990).

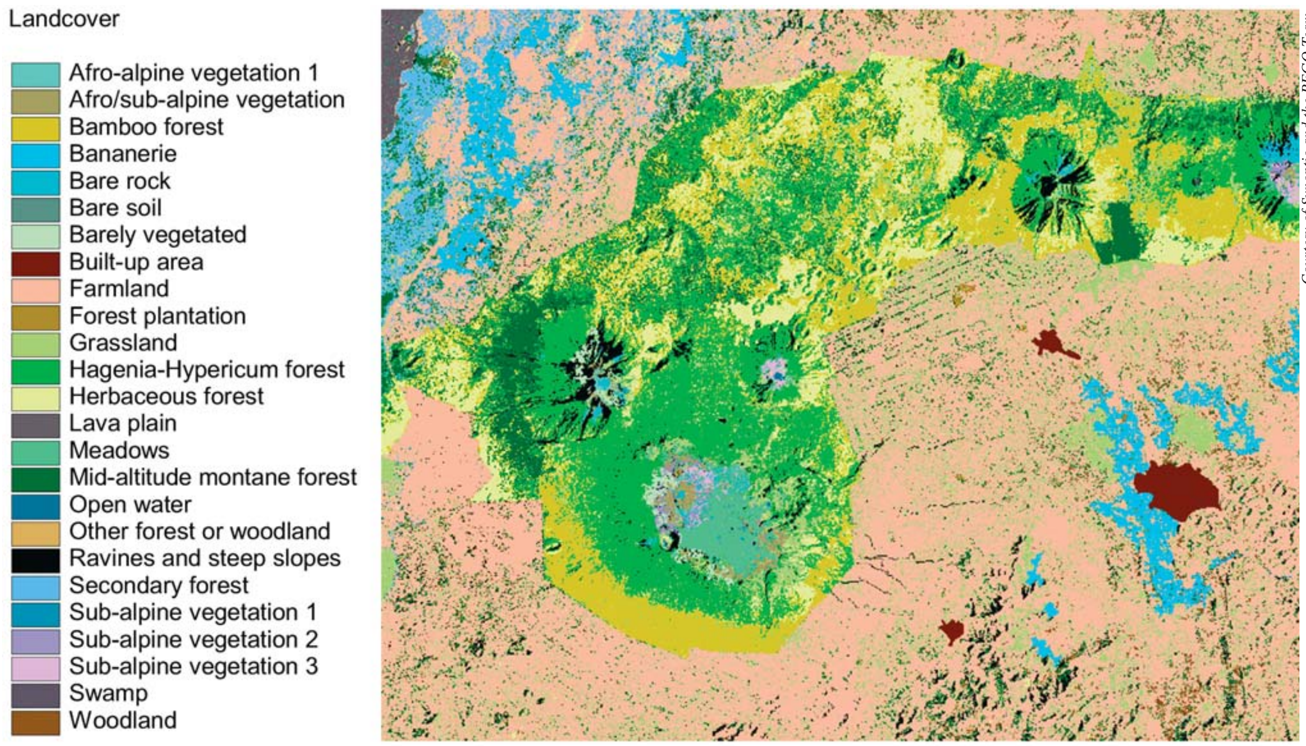
Biodiversity is necessary for the sustained delivery of the goods and services essential for human well being, as well as for the maintenance of life on Earth in general. Examples of ecosystem services (a term that includes goods) that fundamentally depend on the existence of adequate biodiversity include food, fibre, the control of pests and diseases and the discovery of novel natural products, such as pharmaceuticals. These are 'utilitarian' values for biodiversity. Biodiversity also has 'intrinsic' value; in other words a value independent of human use.

If we are to understand biodiversity and its loss, build global, regional and national baselines, make rational management decisions and assess the success of conservation measures, many sources of biodiversity observations must be pooled. Most biodiversity observations are, and will continue to be, made *in situ*. The sampling strategy must cover all major ecosystems and taxonomic groups, and must address the ecosystem, population, and genetic levels of biological organization.

Although we have learned much about biodiversity, less than a fifth of all species are described. Thus we still do not know exactly what we are losing. The ecological importance and potential uses of most species are unknown, so we can not accurately predict the consequences of further loss. To answer key environmental, agricultural and health questions, biodiversity scientists are obliged to base their predictive models on incomplete data. A coherent global system of observations would greatly improve the capacity for analysis and prediction.

Biodiversity is currently being lost across the globe at a rate unprecedented in human times. Recognizing the threat this poses to human societies, the countries of the World have agreed, in several international treaties and conventions, to protect aspects of biodiversity. These binding agreements include the Convention on Biological Diversity (CBD), the Convention on Migratory Species of Wild Animals (CMS) the Ramsar Convention on Wetlands, the World Heritage Convention, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the





Courtesy of Synoptic and the BEGO Team

Land cover map of the Volcanoes National Park on the border between the Democratic Republic of Congo, Uganda and Rwanda, generated from a Landsat-7 image acquired in 2003 and Envisat ASAR data in the context of the ESA BEGO project for conservation of the gorilla habitat in Central Africa

Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (CCD), among others. The CBD is the overarching multilateral agreement relating to biodiversity. It has the monitoring of biodiversity as an explicit objective (articles 7 and 12). In 2002 the Parties to the CBD set a target of significantly reducing the rate of loss of biodiversity by 2010, which was subsequently endorsed by the WSSD. Currently no observation system exists in support of this objective.

Integrated biodiversity data are needed for local, national and international policy makers to develop science-based policy, establish priorities in biodiversity action plans and to implement legislation, especially in the context of international conventions. They will also help researchers in their understanding of biodiversity drivers, pressures, processes, and interactions. Conservation management is aided by a better understanding of biodiversity. Knowledge of biodiversity is also important for businesses as they work to develop sustainable growth plans. A significant part of the knowledge and understanding of biodiversity is traditional knowledge, held in particular by indigenous peoples. Additional users and beneficiaries of biodiversity information include Non Governmental Organizations, indigenous and local communities, public interest and advocacy groups, as well as the public media.

Example: Minimizing Damage to Biodiversity from an Oil Spill

On 1 November 2008, an oil tanker founders in seas off Acropora, a small island state. Satellite images collected by a GEOSS-linked agency show the oil slick as it approaches a protected marine area. Long-term monitoring data, collected for many years by Acroporan agencies participating in GEOSS and from GEOSS contributors are analyzed, using modelling tools. The data shows that this area contains endangered species of coral, mollusks, and fish that are slowly recovering after having been at the edge of extinction. Officials in the Acroporan Ministry of the Environment, Tourism and Transport, who have been trained in the use of modelling and the available data and resources, immediately consult GEOSS databases and discover that most of the World's records of many other marine species were collected in or near the protected area. Further analysis of the data shows that five of these species are now probably only found within the protected area and two just outside it. Within three days of the accident, the international effort to contain the oil slick focuses on limiting any damage to the protected area and the key areas outside it. Booms are placed to enclose the protected area and skimmers remove much of the oil from the sea surface. Dispersants are prepared, but prove not to be necessary thanks to the rapid reaction of the World community and the use of biodiversity data for decision making.

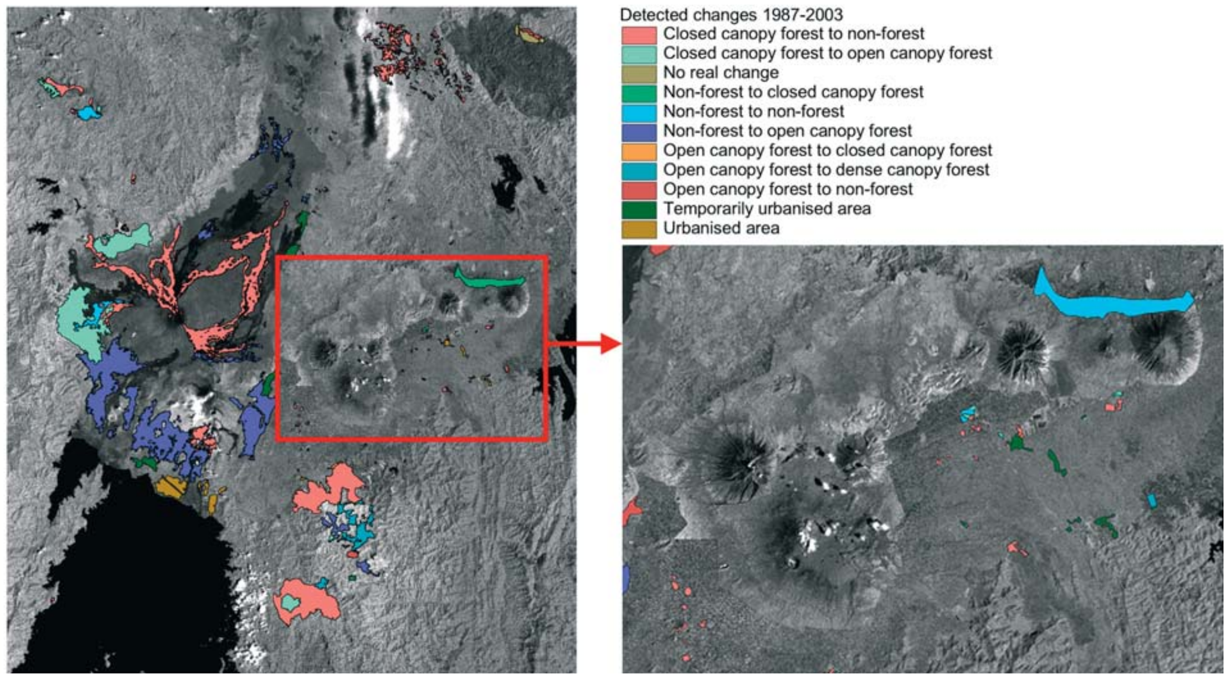
4.9.2 Vision and How GEOSS Will Help

The vision is to develop a high quality, timely, and comprehensive global biodiversity observation system that fulfills the data needs of the multilateral environmental agreements, governments, natural resource planners, scientific researchers and civil society, and integrates with ecological, agriculture, health, disaster, and climate monitoring policy.

A GEOSS biodiversity observation system would create a mechanism to integrate biodiversity data with other observations more effectively, leverage investments in local and national research and observation projects and networks for global analysis and modelling. It will build on existing efforts in order to collectively provide essential data and models for monitoring and reporting in the framework of the biodiversity-related conventions, and provide new information and tools for biodiversity research.

4.9.3 Existing Situation and Gaps

There are a number of existing observational organizations that are already providing support and information on biodiversity.



Land cover map of the Volcanoes National Park on the border between the Democratic Republic of Congo, Uganda and Rwanda, showing changes that occurred in the area between 1987 and 2003, generated from multitemporal Landsat-5 and 7 images, JERS-1 SAR data and Envisat ASAR imagery

The Global Biodiversity Information Facility (GBIF) offers a coordinated list of known species and collections, linking many taxon- or region-specific databases. The Worldwide Fund for Nature (WWF) has a global map of ecosystems ('ecoregions') at a coarse scale. Distribution maps for birds, mammals, and reptiles are available from a variety of research and conservation agencies. The WWF Living Planet Index (LPI) is an indicator of the state of the Earth's natural ecosystems, based on the area of the World's natural forest cover, and global populations of freshwater and marine species. The UNEP World Conservation Monitoring Centre (WCMC) maintains databases of protected areas, endangered species, conservation processes and maps of ecosystems and habitats of particular importance, such as mangrove forests. The United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MAB) programme coordinates the International Network of Biodiversity Monitoring (IBMN), which monitors forest biodiversity. The UNESCO Biosphere Reserve Integrated Monitoring (BRIM) initiative promotes the monitoring of abiotic, biodiversity, and social changes in the World Network of Biosphere Reserves. The IUCN Species Survival Commission operates a network of over 7000 volunteer experts in over 120 specialist groups worldwide. Notably, it produces the IUCN Red List of Threatened Species, and is developing the Species Information System in support of this effort. Wetlands International operates the International Waterbird Census (IWC), a site-based scheme for monitoring waterbird numbers. GCRMN, the Global Coral Reef Monitoring Network, promotes coral reef monitoring. The Census of Marine Life (CoML) is a biodiversity research network that makes its global geo-referenced information on marine species available through the web-based Ocean Biogeographic Information System (OBIS). The state of global diversity has been assessed by Global Biodiversity Assessment, the Pilot Analysis of Global Ecosystems (PAGE) and the Millennium Ecosystem Assessment.

GBIF is a global effort to provide interoperability between biodiversity databases. It has developed protocols and mechanisms for data standards and data sharing. It has started its work with specimen-level data, and intends to integrate species, geospatial, genetic, and ecological data also. GBIF and GEOSS must develop common interoperability protocols and tools, and extend them to other biodiversity-related observation systems.

GOOS and GTOS (in coordination with DIVERSITAS, a programme on diversity co-sponsored by the International Council for Science (ICSU), UNESCO, International Union of Biological Sciences (IUBS), International Union of Microbiological Sciences (IUMS), and the Scientific Committee on Problems of the Environment (SCOPE)) integrate existing marine and terrestrial observing systems to observe, model, analyze and predict marine and ocean variables, including living resources. The International Biodiversity Observation Year (IBOY) has established an observation baseline in some areas, and taxonomic groups.

The Global Marine Assessment (GMA) works with the Intergovernmental Oceanographic Commission (IOC) and GOOS to test ocean sampling methods, whilst the Smithsonian Tropical Research Institute Center for Tropical Forest Science facilitates a network of long-term standardized Forest Dynamics Plots in tropical sites. The Global Invasive Species Programme (GISP) focuses on information exchange on invasive species. It does not collect field data.

FAO's State of the World's Plant Genetic Resources for Food and Agriculture is based on 158 Country Reports. UNEP's Global Environment Outlook is based on information from a network of multidisciplinary Collaborating Centers and more specialized Associated Centers.

Monitoring projects are under development or ongoing in several countries to provide statistically reliable estimates of species status and trends. For instance, DIVERSITAS Western Pacific and Asia (DIWPA) has promoted studies in its region.

Together, the above agencies and their activities provide a non-homogenous set of requirements and information on biodiversity and GEOSS would need to develop the appropriate links. The following significant gaps need to be addressed:

Some taxa have not received the attention merited by their numerical contribution to biodiversity. There are few global assessments of less charismatic groups (such as lichens or marine worms, whereas studies of microbial diversity are still in their infancy). Many observations of biodiversity are from easily accessible areas and hence are not regionally or globally representative. Observations are mostly recent and lacking a long time-series. Most of the vitally important historical and baseline data are not yet digitized and in some cases need to be rescued. Observations in of different components of biodiversity are uncoordinated. Genetic data are largely absent.

Comprehensive descriptions and listings of the fauna and flora exist for many countries, but are often not updated effectively. The global distributions and conservation status of most organisms are not known. Gazetteers and geographic information systems for the mapping and spatial analysis of species distributions frequently lack necessary observational data. Terrestrial and marine research facilities that can collect comparable and long-term biodiversity data are not well distributed across the ecosystems of the World, nor adequately coordinated, equipped or funded. Collections in museums, botanical gardens, seed banks, zoos, aquaria, and culture collections universally need increased funding to prevent loss of specimens and human expertise and to leverage the investment in these invaluable, irreplaceable resources.

4.9.4 Targets

2 Year Targets 4.9 Biodiversity

Working with the biodiversity community, GEOSS will:

Facilitate the interoperability of the multi-institutional biodiversity observation network through GBIF and ensure that it links to data sets of ecological and other related observation systems.

Develop a biodiversity observation strategy that is spatially and topically prioritized, based on analysis of existing information, identifying unique or highly diverse ecosystems and those supporting migratory, endemic or globally threatened species, those whose biodiversity is of socio-economic importance, and which can support the 2010 CBD target.

Facilitate the capture of ten million new biodiversity observations per year, the agreement to data collection protocols by networks of permanent sites, and the launch of initiatives on three key issues.

Advocate additional support to permit data system integration sharing by data providers, particularly the research and collections institutions.

Produce an analysis of the gaps and needs in capacity building initiatives within the biodiversity observation system, including for microbial biodiversity.

Produce a strategy for capturing the outputs of citizen-based biodiversity monitoring systems.

6 Year Targets 4.9 Biodiversity

Working with the biodiversity community, GEOSS will:

Produce timely data and information for local, national, regional and international policy makers, scientists and natural resource managers through the distributed observation network.

Facilitate the establishment of monitoring systems for policy-interest and endangered species, allowing frequently-repeated globally-coordinated assessment of trends and distributions of species of special conservation merit, including domesticated animals, cultivated plants, and fish species and their wild relatives and species of medicinal or economic value.

Facilitate the operational deployment of a system to provide near-real-time data on detection, establishment and spread of problematic invasive organisms.

Facilitate the systematic monitoring of biodiversity in all ecosystems using statistically valid methods.

Facilitate the full operationality and integration of citizen-based biodiversity observation systems.

Facilitate the addition of twelve million new spatially and temporally explicit observation records yearly.

Facilitate the delivery of capacity building programmes on data use and interpretation.

10 Year Targets 4.9 Biodiversity

Working with the biodiversity community, GEOSS will:

Ensure the integration of the distributed biodiversity observation network with sectoral, crisis, health and policy systems. Ensure that it is routinely used to solve problems, guide policy and management and generate opportunities for sustainable development.

Facilitate the addition of fifteen million new spatially and temporally explicit observation records yearly, and the wide accessibility of systems to analyze and model trends in abundance and distribution.

Ensure the optimization of the observational network, including where necessary facilitating the development of new sites, facilities, technologies and networks, based on an analysis of the observations collected in the first decade.

4.9.5 Table of Observation Requirements

Legend for Table 4.9.5

- **0 -** Monitored with acceptable accuracy, spatial and temporal resolution; timeliness and in all countries worldwide.
- **1 -** Monitored with marginally acceptable accuracy, spatial and temporal resolution; timeliness or not in all countries worldwide.
- **2 -** Not yet widely available or not yet globally monitored, but could be within two years.
- **3 -** Only locally available or experimental; could be available in six years.
- **4 -** Still in research phase; could be available in ten years.

Biodiversity
Table 4.9.5

	Observational Requirement	Conservation	Invasive Species	Migratory Species	Natural Resources & Services
Ecosystem Level					
1	Location and area of ecosystem types (forest, coral reefs, etc.)	1	1	1	1
2	Condition of ecosystem types	3			3
3	Community composition (survey species lists)	3			3
4	Fisheries trophic index (marine and freshwater)				2
5	Species interactions	4			4
Population / Organism Level					
6	Geographic distribution of species	3	3	2	1
7	Population number or abundance of selected species	3	3	2	2
8	Threatened and extinct species lists	1	1	1	1
9	Diversity of organisms used in medicine	4			3
10	Extent, intensity and cost of alien species invasion	3	3		2
Gene Level					
11	Number of land races/cultivars/breeds in production systems				2
12	Genetic heterogeneity within populations of selected species	4			3

4.10 Common observations and data utilization

Analysis of user requirements in the nine societal benefit areas indicates that there are significant synergies between them in terms of underlying needs for Earth observations and data utilization. Addressing these common requirements can provide for prioritized and efficient implementation of GEOSS.

4.10.1 Observation Commonalities

4.10.1.1 Space-based Observation

Considerable effort has been expended on studying user requirements and reflecting them in the planning and coordination of satellite missions, but the current situation does not satisfy all requirements for each benefit area. All-weather observation data and climate-related observations, as well as high temporal/spatial resolution data, are basic observation data and can be used across virtually all societal benefit areas. SAR sensors, passive microwave observations, high-resolution optical observation systems and geostationary observation systems should be considered key observing systems.

The following highlights requirements for space-based observation from specific societal benefit areas:

- Addressing disaster requirements includes the need for high spatial resolution and all-weather capability through technology such as optical and SAR satellites, as well as high temporal resolution observation from geostationary orbit for disaster monitoring of floods, volcanic eruptions, forest fires, and other hazards.
- Facilitating the availability of wide-area health parameters derived from satellite data, e.g. sanitation, transport, energy, communications, traffic management systems, and housing.
- For improved climate observations, it is strongly recommended that satellite operators in GEOSS adhere to the GCOS Implementation Plan.
- Improving agriculture ecosystem monitoring through observations requires high to medium resolution observation from space for land cover classification, and the widespread adoption and use of geostationary observations in food-insecure areas.

4.10.1.2 In situ Observation

The baseline *in situ* observation networks are declining and authority over data and information, especially in the terrestrial domain, is often scattered regionally and sectorally, resulting in highly fragmented management approaches, and these trends need to be reversed. The first step is to track the performance of observational networks and identify and fix problems. The second step is to improve existing observation networks, including where necessary the availability of the qualified human resources needed, the development of new sites, facilities, technology, and networks. Adherence by countries and agencies to the recommendations in the GCOS Implementation Plan is important. There is a need to complete and strengthen the ocean *in situ* observing system, particularly Argo floats. Elimination of regional disparity in observing capacity, such as the imbalance in advanced oceanographic observation sites between the Northern and Southern Hemispheres, needs to be tackled. More coordinated investment of resources is necessary to achieve the maximum effect.

4.10.1.3 Convergence of Observation

It is essential for GEOSS to encourage the establishment of global, efficient and representative networks of integrated *in situ* observation sites, relying on existing national and regional environmental monitoring networks. These *in situ* networks will also support satellite data validation, process studies and algorithm and model development. GEOSS will promote the convergence of observations, integrating *in situ* and satellite data to obtain improved products.

4.10.2 Data Utilization Commonalities

4.10.2.1 User Involvement

To maintain the effectiveness of GEOSS, it is essential to regularly review and assess the needs and requirements for Earth Observation data, products and services. GEOSS should focus not only on global users, but also on local and national users contributing to global observations.

4.10.2.2 Continuity of Observations

Continuity of observations, while adhering to the GCOS Climate Monitoring Principles included in the GCOS Implementation Plan, is the underlying key to understanding, assessing, predicting, mitigating and adapting to climate variability and change. Societal benefits in the Water area could be served by development of a plan to institutionalize surface flux measurements.

Continuity of SAR sensor data, including L-band, C-band, and X-band, for interferometry and global positioning capability, is required to meet the needs of the Disaster societal benefits area. The Agriculture area needs continuity of a high to moderate resolution satellite network for monitoring selected locations of rapid change in agriculture, rangelands, forestry, freshwater and fisheries. The Ecosystems societal benefit area also needs high- to moderate-resolution satellite observation continuity for land-cover and ocean-colour monitoring.

4.10.2.3 Products

There are several commonly required and used products among the nine societal benefit areas, (Disasters, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture and Biodiversity) and several of these address the need for data assimilation, modelling and re-analysis. All areas require topography (including bathymetry) and land cover products. Several societal benefit areas demonstrate the need for a data assimilation tool to scale up from limited *in situ* observations made at local scales to arrive at a large-scale, comprehensive global picture. GEOSS will promote data assimilation and modelling, integrating *in situ* data and satellite data to produce global integrated products. Re-analysis of historical data using updated techniques can produce consistent long-term data records. The timeliness of data exchange and product generation is crucial to proper performance tracking of the observing systems, and for the assimilation of data into forecasting models and decision making.

4.10.2.4 Linkages Among Data Sets

To respond to the needs of each societal benefit area, integration of Earth Observation data with socio-economic data will produce useful information for application in socio-economic areas. For example, improving understanding of human health through Earth Observation requires the development of human health indicators based upon environmental measurements. Similarly, agriculture requirements include linking Earth Observation data to geospatially referenced production and use-statistics for crop agriculture, livestock, forestry and freshwater fisheries. Geographic framework data,

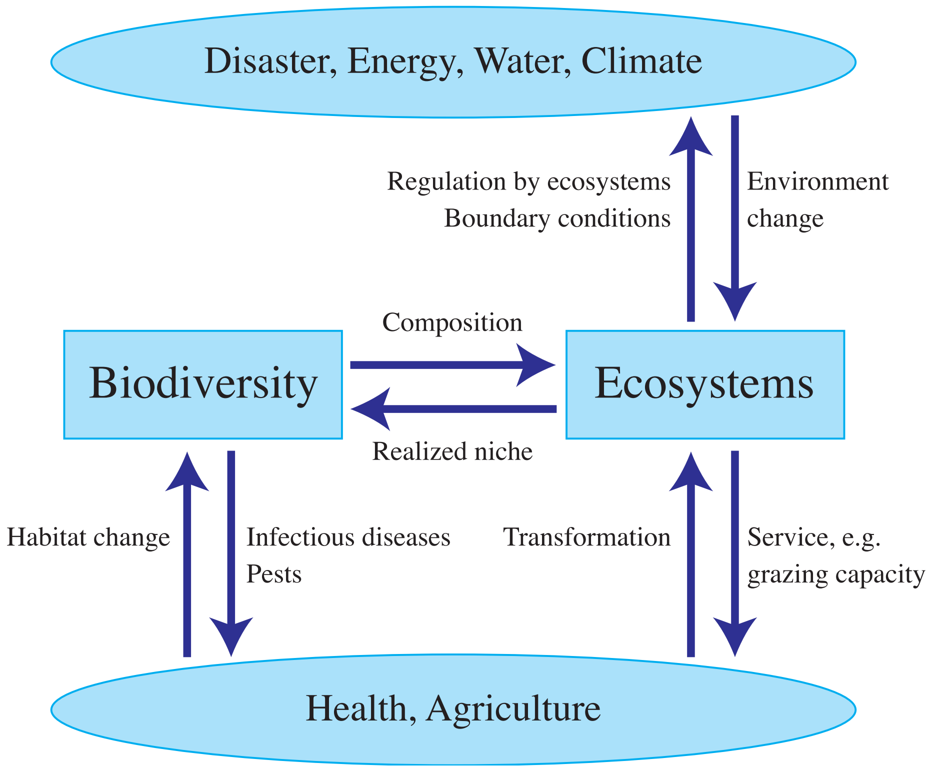


Figure 4.3. A simplified schematic of the links between Ecosystems, Biodiversity, and other societal benefit areas

such as roads, rivers, cities and administrative boundaries, are indispensable as a basis for integrating Earth Observation data with socio-economic data.

It is essential to consider the impact or linkage among the different societal benefit areas; for example, climate change impacts on other areas, such as Disasters, Health, Water, Ecosystems and Agriculture (an example is illustrated in Figure 4.3) Thus, it is necessary to emphasize the detection of climate changes and their impacts on these other societal benefit areas by combining scientific data and socio-economic information. Indicators of water quality and environmental factors affecting human health are examples of such an application.

There is a very high level of information interdependency between the societal benefit areas (Table 4.10.3). This is a strong validation of the advantages of creating an integrated GEOSS.

In addition, different users have a variety of data exchange needs, including:

- real-time data, e.g. for disaster management
- near-real-time data, food security statistics
- data that may be delayed by months, e.g. land cover data.

Appropriate data access needs to be provided for each user, and a proper end-to-end system needs to be designed to support specific user requirements for data, products and services.

4.10.3 Common Approaches to Connecting Systems

GEOSS is designed to provide many ways to connect its various components to serve specific needs. GEOSS will provide opportunities for interconnection between various societal benefit areas. GEOSS should provide ways to help share implementation experiences, as well as their data product availability and requirements of contributing systems. Whenever users within one societal benefit area have a dependency on observations and data products originating from another societal benefit area, it is essential that a comprehensive set of requirements is communicated.

In the example of system interaction given in Figure 4.4, the Weather and Climate systems provide data and information that is broadly useful to systems in the other societal benefit areas. Systems in the Water and Ecosystems areas then combine their own data with outputs from Weather and Climate systems, producing integrated data sets and other derived products, which can in turn be passed on to other societal benefit areas. In this way, a comprehensive understanding of issues in areas such as Disasters, Health, Energy, Agriculture, or Biodiversity can be gained through interoperable use of data and information from the other areas. As the managers of Weather and Climate systems react to this broader market for their outputs, they become more attuned to making products that are responsive to these broader user requirements. The same process occurs in each of the other areas, as requirements flow back to the providers.

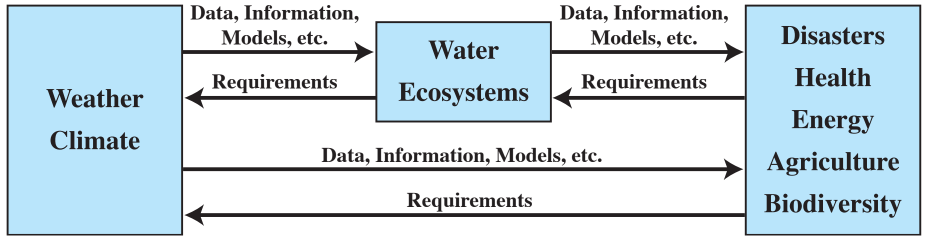


Figure 4.4. An illustrative example of how the interconnectivity made possible by GEOSS could provide users in the Water and Ecosystems societal benefit area with access to information in other societal benefit areas, and at the same time provide information to other areas

GEOSS is designed to be highly scalable: the same architectural principles that make GEOSS a "system of systems" can be applied independently to any element within GEOSS. As noted elsewhere, the current level of collaboration and interoperability varies across and within the societal benefit areas. Accordingly, both the initial stage and the evolutionary paths of each area are expected to be quite different. By adhering to the common principles of GEOSS, any progress toward convergence among any set of component elements contributes to the overall progress of GEOSS.

Table 4.10.3 An illustrative and non-exhaustive list of issues for which the societal benefit areas have a dependency on information supplied from observations typically made within the ambit of the societal benefit areas listed down the left of the table. There is a high degree of information interdependency between societal benefit areas, which often leads to a common data specification. However, the dependency is not necessarily symmetrical, so the requirements for the same general type of observations may differ when they are needed for different purposes.

Examples of Information Provided to these Societal Benefit Areas (columns); Examples of Information Provided from these Societal Benefit Areas (rows)

	Disasters	Health	Energy	Climate	Water	Weather	Ecosystems	Agriculture	Biodiversity
Disasters		Early warning of likely injury or loss of life	Risk to energy infrastructure	Volcanic eruptions Fire emissions	Risk to water infrastructure	Volcanic eruptions Fire emissions	Ecosystem disturbance Ocean pollution	Risks to crops and livestock, farming land and pastureland	Population disturbance Ocean pollution
Health	Vulnerability of exposed population				Sources of pathogens		Spreading of endemic disease Distribution of vectors		Distribution of vectors
Energy	Loss of energy services	Heating and cooling Pollutants of air, water, and by heat		Emission of greenhouse gases	Pollutants Energy for water services	Air quality	Mining of fossil fuel Fuel wood and peat	Energy for agriculture	Disturbance due to energy activities
Climate	Projections of climate change	Epidemiology of vector-born diseases Other climate sensitive diseases	Wind and solar energy potential		Expected level and variability of water balance	Climate change, anomaly identification	Climate and disturbance data, climate change	Climate data Climate change Desertification	Climate and disturbance data
Water	Risk of floods and droughts	Water borne pathogens, pollutants Availability of safe water for drinking	Hydroelectric potential	Water cycle and energy budgets		Fluxes of energy and water, surface boundary conditions	Water amount Water quality	Availability and suitability for irrigation	Water amount Water quality
Weather	Extreme weather forecasts	Extreme events Pollen allergy	Changes in demand Risk to energy infrastructure	Long-term statistics	Precipitation Evaporation		Disturbance Droughts Productivity effects Fire risk	Rainfall Frosts Temperature	Meteorological data for survival of species
Ecosystems	Vulnerability to flood and landslides Fire risk Recovery after disasters	Ecological condition for out break of disease vector Red tide Sand storms	Biomass for energy Carbon cycle	Water budget Carbon cycle Trace gases Albedo	Land cover	Land cover		Weeds Pests Diseases Rangelands Wild fisheries	Habitat distribution and fragmentation Ecosystem function
Agriculture	Food insecurity	Nutrition Food safety Vector-born diseases	Biomass fuels	Greenhouse gas emissions Land cover and Land use	Use of irrigation Water pollution Water storage	Land cover Land use	Loss of area Eutrophication Fertilizer application Chemical application		Agricultural biodiversity Distribution of GMO Trade statistics on alien organisms
Biodiversity	Locust plagues	Distribution of medical plants microbes, and disease vectors Spread of endemic diseases			Bio-indicators of water quality	Abundance and distribution of organisms Phenology	Abundance and distribution of organisms Phenology Prediction of change in distribution Invasive species	Agricultural biodiversity	
Base data	Topography, bathymetry, geographic framework data (base maps), population, well-being indicators, trade and mobility, urbanization, transportation, geology, soils, etc.								

4.10.4 Targets

2 Year Targets 4.10 Common Observations and Data Utilization

Working with all GEOSS communities across societal benefit areas, GEOSS will:

Facilitate sharing of best practices for the development of products customized for particular socio-economic benefits.

Produce practical strategic and tactical guidance on how to converge disparate systems to a higher degree of collaboration and interoperability using GEOSS principles.

Facilitate interoperability among data sets acquired by different countries and agencies, as these are not likely to be in compatible formats or easily usable form.

Facilitate the development of basic geographic framework data.

6 Year Targets 4.10 Common Observations and Data Utilization

Working with all GEOSS communities across societal benefit areas, GEOSS will:

Facilitate the joint evaluation of prototypes that connect multiple systems, and support making operational any research demonstrations of such collaboration and interoperability.

Facilitate periodic demonstrations of the overall progress toward the highest level of collaboration and interoperability achieved, as a measure of realizing the full vision of a global system of systems for Earth observations.

10 Year Targets 4.10 Common Observations and Data Utilization

Working with all GEOSS communities across societal benefit areas, GEOSS will:

Advocate optimum use of data and information available from GEOSS.

Develop a plan to sustain and evolve a system of systems beyond 10 years.

5

ARCHITECTURE OF A SYSTEM OF SYSTEMS

5 Architecture of a System of Systems

This section describes how GEOSS component strategies and systems fit together to produce a comprehensive, coordinated, and sustained system of systems that better satisfies overall requirements in the identified societal benefit areas.

GEO will employ a range of methods to advance the implementation of the Plan, tailoring them as required to address each of the various implementation issues. The methods will include: establishment of standing and specific task-oriented GEOSS structures; referring specific tasks to participating international organizations or agencies; coordinating and cooperating with national agencies; collaboration between international organizations; providing a forum for dialogue and resolution of issues at varying levels, and advocacy within and across existing systems and other mechanisms.

5.1 Functional components

Five functional components are identified in the GEOSS 10-Year Implementation Plan. User requirements are addressed in Sections 4 and 6, and performance monitoring is addressed in Section 9. The remaining three are addressed here:

- components to acquire observations based on existing local, national, regional and global systems to be augmented as required by new observing systems;

- components to process data into useful information, i.e. geo-products that are part of GEOSS, recognizing the value of modelling, integration and assimilation techniques (including re-analysis) for example, global sea-surface temperature fields – such geo-products will be prepared in those modelling centres participating in GEOSS and serve as input to the decision support systems required in response to societal needs; and

- components required to exchange and disseminate observational data and information including those for archiving. Components are understood to include data management that encompasses functions such as QA/QC (Quality Assessment/Quality Control), access to data, and archiving of data and other resources.

In common with Spatial Data Infrastructures and services-oriented information architectures, GEOSS system components are to be interfaced with each other through interoperability specifications based on open, international standards. Access to data and information resources of GEOSS will be accomplished through various service interfaces to be contained within the data exchange and dissemination component. The actual mechanisms will include many varieties of communications modes, with a primary emphasis on the Internet wherever appropriate, but ranging from very low technology approaches to highly specialized technologies.

A key consideration is that GEOSS catalogues data and services with sufficient metadata information so that users can find what they need and gain access as appropriate. The Internet is a primary medium for the mechanism to allow users to access the catalogue of available data and products, with hardcopy media to also be available as appropriate. Users searching GEOSS catalogues will find descriptions of GEO Members and Participating Organizations and the components they support, leading directly to whatever information is needed to access the specific data or service in a harmonized way, independent of the specific provider. In this sense, the interoperable GEOSS catalogues form the foundation of a more general 'clearinghouse'. GEOSS data resources can be fully described in context, and data access can be facilitated through descriptions of other useful analysis tools, user guides, data policies, and services. Many examples of such clearinghouse facilities

Spatial Data Infrastructures

GEOSS will advocate further development of the Global Spatial Data Infrastructure (GSDI) and use of existing Spatial Data Infrastructure (SDI) components as institutional and technical precedents. SDI's are concerned with data and information that is 'geospatial', i.e. referenced to locations on the Earth, at all scales. In common with GEOSS, SDI's support a components-based, services oriented architecture that provides interoperability based on open, international standards. To the extent that GEOSS adopts identical or compatible standards, GEOSS and SDI components become interoperable with each other as well. This provides a powerful synergy as GEOSS addresses types of data and information that are not always geospatial, while SDI's address types of data and information that are not always Earth observation. Examples of SDI data and information types include transportation, population, political boundaries, land ownership, socio-economic data, cultural heritage, and minerals, among many others.

GSDI "encompasses the policies, organizational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives."[17] A key operational feature of the GSDI is its Clearinghouse network, which now includes over 400 catalogues in which comprehensive metadata about available geospatial data is maintained.

Many countries and international organizations are members of GSDI or ongoing participants in the GSDI Clearinghouse. Among these are: Argentina, Australia, Barbados, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Dominican Republic, Ecuador, El Salvador, Ethiopia, European Union, Finland, France, Germany, Guatemala, Honduras, Hungary, India, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, Namibia, Netherlands, Nicaragua, Norway, Poland, Senegal, South Africa, Spain, Trinidad and Tobago, United Kingdom, United States, and Uruguay.

Among the regional and topic-specific organizations participating in GSDI are: Antarctic Geographic Data Integration Project, Association for Biodiversity Information, Committee for Earth Observation Satellites (CEOS), Consultative Group on International Agriculture (CIGAR), Environmental Information Systems Africa, European Umbrella Organisation for Geographic Information, Geographic Information for Sustainable Development (Africa), Global Disaster Information Network (GDIN), Global Map (ISCGM), Global Resource Information Database (GRID), Global Water Information Network, Infrastructure for Spatial Information in Europe (INSPIRE), Intergovernmental Panel on Climate Change (IPCC), International Geosphere-Biosphere Program (IGBP), Open Geospatial Consortium (OGC), Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP), Permanent Committee on SDI for the Americas, and World Bank Development Gateway.

Although national SDI's share a common architecture and commitment to standards-based interoperability, specific policies and operational components can vary widely. As one example, United States law (44 USC Ch 36) and policy (OMB Circular A-16) establishes the U.S. National Spatial Data Infrastructure (NSDI). The policy states that the NSDI "assures that spatial data from multiple sources (federal, state, local, and tribal governments, academia, and the private sector) are available and easily integrated to enhance the understanding of our physical and cultural world". This policy puts specific requirements on all agencies that collect, use, or disseminate geographic information to assure that the resulting data, information, or products can be readily shared and integrated among federal agencies and non-federal users. In their activities, they must require adherence to the SDI standards for data and metadata, and must make metadata available online through the GSDI Clearinghouse. The U.S. NSDI includes various interoperability standards, including Framework Data Standards, Web Mapping Service, Web Feature Service, and Geographic Markup Language, among other ISO and national standards.

[17] *Global Spatial Data Infrastructure, http://www.gsdi.org*

already exist in the realm of Earth Observation and networked information systems generally, and many of these already employ interoperable interfaces.

GEOSS will develop a set of guidelines for archiving Earth observations, which will emphasize that archive centres must have adequate funding to address data growth and be in a position not only to ensure the perpetuity of incoming data, but also to safeguard data on ageing or obsolete media.

Historical data, and in some cases contemporary data (particularly in developing countries), are frequently kept as paper records. They are often stored locally, and their existence is not well known. The rescue, digital capture, and secure storage of such data are important to strengthen and broaden the historical records for assessing trends.

GEOSS will promote the use of common mechanisms for the cataloguing of archives, including how to access them. All providers need to ensure that archived data and products provide a statement of the access conditions in terms of the mechanics and policies. There should also be a well-documented statement of the ancillary data needed to understand and use basic data sets and products.

5.2 Observations

5.2.1 Convergence of Observations

One of the goals of GEOSS is to establish a system of systems that can provide timely data and information for local, national, regional and international policy makers. For example, near-real-time observations are required to address specific disaster needs (e.g. submarine seismic and volcanic activity and tsunami propagation) and significant extreme events in Agriculture (e.g. fire). Consequently, some participating systems will need to provide real- or near-real-time monitoring, early detection, and globally integrated observations.

Topic-specific integration of global observations is required by almost all of the identified societal benefit areas, but each area has a different balance between *in situ* and satellite observations.

5.2.2 Observation Continuity

GEOSS will address Earth Observation continuity, emphasized as a fundamental requirement across the range of societal benefit areas. Continuity is needed for both basic observation networks and intensive observation focused on selected areas. Only with assured continuity can users invest confidently in applications that rely on particular data sets.

In situ observations provide the long-term historical record for most variables and serve a vital role in applications for various societal benefit areas. There is a declining trend of observations from *in situ* atmospheric networks and hydrological networks. This trend needs to be reversed and these baseline *in situ* observations must be sustained. Many *in situ* observations are provided by research programmes, which do not have guarantees for long-term funding. Argo is one such programme, which is now critical to understanding the ocean dynamics and applications in meteorology and climate. GEOSS should encourage continuity of *in situ* observations in operational services and research programmes.

The continuity of high-temporal-frequency geostationary imagery, high- to moderate-resolution optical and SAR observations over land, and other critical observations over oceans needs to be assured. Accordingly, contingency plans of observation system operators should be sensitive to how their user communities are affected by interruptions of data and services.

5.2.3 Data Sampling

Sampling problems emerge wherever Earth system processes operate at scales requiring observations beyond the boundaries of the operating agency, e.g. climate, weather, river basins, and migratory species. For instance, an atmospheric carbon dioxide observation system is required to satisfy the objectives and protocols of the UN Framework Convention on Climate Change. Improving the most sparsely sampled regions would lead to improvements in estimation of net carbon dioxide fluxes both locally, as well as in distant regions. Consequently, it is in the global interest to ensure an adequate sampling network everywhere. Clearly, coordination in such situations can minimize the duplication of effort, while also bolstering the credibility and transparency of the sampling programme. GEOSS can enhance international coordination of investments in observation systems and observation procedures as well as data exchange, processing, and archiving.

5.3 Data processing

5.3.1 Common Products

GEOSS will place a high priority on data and information products commonly required across diverse societal benefit areas. GEOSS products include current status assessments and descriptions, as well as predictive products in each of the domains of socio-economic benefit discussed in Section 4. Examples of GEOSS status assessments or descriptions include topography, land cover, vegetation status, soil moisture, extent of floods, snow cover, wind profile, precipitation, water quality, and ocean dynamics. Examples of GEOSS predictive products include outlooks, forecasts, and predictions generated by global and regional Earth system models and their associated data assimilation systems. These may be direct products in the form of weather and air-quality forecasts, as well as seasonal and climate predictions, or indirect products in the form of outputs from specialized models (hydrological models, ocean models, crop models, health models, biosphere models, etc.) driven by the predictions of the Earth system models.

To understand the interaction of societies with Earth systems, it is critically important to blend socio-economic data with Earth Observation data. Consequently, GEOSS will emphasize promoting the accessibility of socio-economic data products, including census data, economic activity, and political boundaries.

5.3.2 Modelling and Data Assimilation

GEOSS will advocate harmonized methods in the modelling and analysis techniques needed to transform data into useful information. Best practices and up-to-date scientific understanding should be shared broadly. This should include techniques for estimating and recording quality indicators and representation of uncertainties in models as well as observation data.

In applications such as climate and weather modelling, methods known as data assimilation are commonly used. These procedures transform a wide variety of *in situ*, airborne, and space-based Earth observation data into parameters that feed into numerical models of physical, chemical, and biological processes calculated over time and space. There may be benefit in a targeted effort to enhance sharing across Earth Observation areas of operational experience in data assimilation.

Reanalysis of climate data incorporating new data and techniques provides longer and more consistent data sets valuable for climate change research and prediction. Such reanalysis products have found widespread applications in studies of climate, basic atmospheric process, and ocean modelling. Reprocessing of satellite data is becoming common as algorithms are improved. Establishing continuing capabilities for reprocessing and reanalysis is essential. GEOSS will work with operational agencies, space agencies and international research programmes to develop coordinated systems of reanalysis and reprocessing of Earth Observation data in order to ensure the provision of historical data sets.

5.3.3 Data and Product Quality

GEOSS will advocate the association of quality assessments with all Earth Observation data. It is clear that observation data of known quality from calibrated sensors are essential. For instance, the ability to perform long-term "traceability" is highly dependent on complete and accurate metadata about precision and accuracy. Calibration must be addressed during product creation, and validation is required to ensure the quality of the resulting product. In addition to useful quality descriptions, greater standardization of quality control procedures may be needed. Quality control procedures should be developed and implemented. These should include provision for calibrating space-based instruments through solar and lunar observations and coordinating defined Earth sites for vicarious calibration.

5.4 Data transfer and dissemination

Collecting data from remote *in situ* sites, marine buoys, and atmospheric profilers remains a challenge in many parts of the World. This is often simply because of the remoteness of sites, and/or poor communication structures. Enabling a wider exploitation of existing capabilities will be important. Examples are the WMO network, the data capture capability and transfer capability of geostationary weather satellites, and the services based upon commercial satellites such as the EUMETSAT dissemination system (EUMETCast). In addition, the Internet, which is already important in many areas, will be an increasingly important mechanism as availability and accessibility improve, particularly in remote areas and developing countries.

GEOSS will promote data management approaches that encompass a broad perspective of the observations data life cycle, from input through processing, archiving, and dissemination. In some instances, Earth Observation systems have met the needs of an immediate user community, but lack the documentation or procedural rigour needed for the data to be broadly exchanged with other communities or to be useful for long-term applications. Data dissemination problems are encountered with restricted and charged data resources, as well as with open and free data, and with data archives as well as real-time data sources. The level of data dissemination practice must be raised to meet the needs of the many disciplines and the varying access requirements of the global Earth Observation community.

Improvements in communications management are also important, whether handled as an integral data management function or treated as an outside utility. Earth Observation systems utilize many types of communication technologies depending on the particular data, product, and timeliness needs of the user. For instance, observation collection systems may involve data exchange among satellites in orbit or floppy disks sent by mail from remote rain forest locations; disaster-warning systems may involve broadcast TV alerts and messages displayed on highways. For many Earth Observation applications, the medium of choice will be the Internet, but system designers need to think globally when choosing appropriate communications technologies. This is particularly true for developing countries.

5.5 Interoperability arrangements

Interoperability, in this context, refers to the ability of applications to operate across otherwise incompatible systems. In order for interoperability to be broad and sustainable, fewer arrangements, each accommodating many systems, are preferred over many arrangements each accommodating a few systems. Interoperability should focus on interfaces, defining only how system components interface with each other and thereby minimizing any impact on affected systems other than interfaces to the shared architecture.

Interoperability arrangements must be based on non-proprietary, open standards, and profiles must be specified when standards are not sufficiently specific. Rather than defining new specifications, GEOSS should adopt standard specifications agreed upon voluntarily and by consensus, with preference given to formal international standards such as ISO. All interface implementations should be specified in a platform-independent manner, and verified through interoperability testing and public demonstrations. In the instances cited below, the service standards are widely deployed in commercial products and are also available free as open source software implementations. GEOSS will transition to more advanced standards as they evolve in these and other relevant areas.

Open Standards and Intellectual Property Rights

GEOSS will not require any commercial or otherwise proprietary standards, following the policy that software components must have open-standards-based interfaces. An 'open standard' is a standard specification that is not restricted in its use. This is a matter separate from whether the document that expresses the specifications may be subject to Intellectual Property Rights (IPR) restrictions. (For instance, standards bodies such as ISO rely on sales revenue from standards documents to support their operations.)

A goal of GEOSS is that multiple software implementations compliant with the open standards should exist for the most commonly used components. Such software may be subject to IPR restrictions, typically expressed as a licensing agreement.

In light of its capacity building commitments, a further goal of GEOSS is that at least one of the implementations for the most commonly used components should be available to all implementers 'royalty-free' (i.e. having no requirement for recurring payment).

GEOSS also encourages the development and verification of software that has no restrictions on being copied, modified or redistributed. Such software is typically distributed in the form used by programmers ('source code'), and is therefore commonly known as 'open source'. Given the lack of restrictions on its use, open source software typically requires payments at roughly the cost of distribution.

It should be noted that distributors may disclaim responsibility to repair defects or otherwise update royalty-free or open source software, relying instead on a network of developers who contribute updated versions on a best-effort basis.

GEOSS interoperability arrangements are to be based on the view of complex systems as assemblies of components that interoperate primarily by passing structured messages over network communication services. By expressing interface interoperability specifications as standard service definitions, GEOSS system interfaces assure verifiable and scaleable interoperability, whether among components within a complex system or among discrete systems.

It should be understood that the GEOSS approach to interoperability does not require, for example, that all participating systems use the same data format. Rather, it is only necessary that all participating systems provide a precise definition of their data formats and how the data is accessed. This access mechanism is called a 'service' and a precise service definition lets other systems designers know how to get the data appropriately. This is because the interoperability specification states exactly how the service and the data must be described. (These descriptions are 'metadata'.)

GEOSS service definitions are to specify precisely the syntax and semantics of all data elements exchanged at the service interface, and fully describe how systems interact at the interface. At present, the systems interoperating in GEOSS should use any one of four open standard ways to describe service interfaces: CORBA, Common Object Request Broker Architecture; WSDL, Web Services Definition Language; ebXML, electronic business Extensible Markup Language, or UML, Unified Modelling Language.

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. The international standard ASN.1 (Abstract Syntax Notation) and the industry standard XML (Extensible Markup Language) are examples of robust and generalized data syntaxes, and these are themselves interconvertible.

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. The standard ISO/IEC 11179, Information Technology-Metadata Registries, provides guidance on representing data semantics in a common registry.

A major concern in GEOSS is the set of standards for archiving data and other resources that are acceptable to both providers and users. Communities with particular expertise in archiving, such as those data managers associated with the World Data Center programme managed by ICSU (International Council for Science), will provide advice on archival standards. Archived data should be well documented, be stored using known and published standards, and be readily transferable to a standard format for data exchange.

Many Earth Observation catalogues that require interoperability at the search service have adopted the international standard used for catalogue search (ISO 23950 Protocol for Information Search and Retrieval). This search service is interoperable with the broadest range of information resources and services, including libraries and information services worldwide as well as the Clearinghouse catalogues supported across the Global Spatial Data Infrastructure now implemented in more than 50 countries. This standard search service also has demonstrated interoperability with services registries using either an ebXML metadata model or UDDI (Universal Description, Discovery, and Integration).

Data and information resources and services in GEOSS typically include references to specific places on the Earth. Interfaces to discover and use these geospatial data and services are agreed upon through the various Spatial Data Infrastructure initiatives. These include the ISO 23950 search service interface standard, as well as a range of ISO standards covering documentation and representation, and place codes.

The standard for geospatial metadata is ISO 19115: Geographic Information – Metadata. This standard facilitates the exchange and integration of data and information by giving a standard description of the identification, extent, quality, spatial and temporal scheme, spatial reference and distribution specifics of geospatial data.

Services providing access to Earth Observation data and products often include significant requirements for assuring various aspects of security and authentication. These range from authentication of user identity for data with restricted access, to notification of copyright restrictions for data not in the public domain, and to mechanisms for assurance that data is uncorrupted. In addition to security, accommodations will be made for necessary data and information charges and fees, when appropriate.

Other standards typically are needed for the appropriate interchange of particular kinds of data. These include standards on calibration and methodology, among many others. GEOSS will promote convergence to common standards for each of these various aspects.

5.6 Collaboration mechanisms

GEOSS will provide coordination and cost-and-benefit-sharing mechanisms that address several challenges plaguing typical international efforts requiring collaboration.

Shared Infrastructure - GEOSS will promote shared infrastructures for Earth Observation, leading to cost reductions for GEO Members and Participating Organizations, and provide scientific benefits as well. For example, an oceanographic cruise to sample plankton diversity can simultaneously collect weather data, and a terrestrial network for weather observations can also measure pollution. Similarly, the incremental cost of adding another sensor to a satellite platform with spare capacity is much smaller than building, launching and operating another satellite. In general, sample co-location often yields savings. This is because the costs of single observations are often quite high (especially in remote places), but the incremental costs of additional observations at the same place are relatively small.

Multi-Use Systems - Efficiency can also be realized by designing Earth Observation systems from a multi-use perspective as envisioned in GEOSS. For instance, weather data are necessary inputs to all the societal benefit areas specified in the Framework Document. An optimal observation system for, say, weather forecasting, would not likely be optimal or even sufficient for climate, ecosystems, agriculture or health. However, a mechanism promoting coordination of user requirements can expose opportunities for synergy among users with similar observation needs.

Shared Costs and Benefits - A mechanism for cost and benefit sharing such as GEOSS can often lead to a substantial improvement in an observation network. For instance, the accuracy of weather forecasting models is limited by upper air observations in the Southern Hemisphere, and particularly over Africa and South America. In the context of many of the developing countries located there, the national benefits of making such observations do not justify the cost, given all the other demands on national resources. Cost sharing can be crucial whenever the principal benefits of a given observation accrue at a scale or location that differs from the jurisdiction of those best placed to make it.

5.7 Initially identified GEOSS systems

GEOSS will be based on existing observing, data processing, data exchange and dissemination systems, while fostering and accommodating new systems operated by GEO Members and Participating Organizations, as needs and capabilities develop. The technical commitments of a GEO Member or Participating Organization will apply only to those contributions that they have identified.

One of the initial tasks for GEOSS will be to establish and maintain an inventory of contributing systems. Annex 3 shows GEO Members and Participating Organizations that have so far provided an informal indication to contribute to the initial GEOSS with the noted systems.

5.8 Targets to enable the architecture for GEOSS

To enable implementation of the GEOSS architecture, certain actions need to be undertaken as a first priority, as follows:

2 Year Targets 5 Architecture

GEOSS will:

Advocate formal commitments of contributions by GEO Members and Participating Organizations, including agreement to adhere to GEOSS interoperability specifications.

Produce a publicly accessible, network-distributed catalogue maintained collectively under the auspices of GEOSS. The catalogue will include information on GEO Members and Participating Organizations and the components they support. The catalogue system will itself be subject to GEOSS interoperability specifications, including the standard search service and geospatial services.

Establish and maintain a process for reaching interoperability arrangements, informed by ongoing dialogue with major international programmes and consortia. That process is to be sensitive to technology and accessibility disparities among GEO Members and Participating Organizations, and must include mechanisms for upgrading arrangements.

Advocate use of existing Spatial Data Infrastructure (SDI) components as institutional and technical precedents in areas such as geodetic reference frames, common geographic data, standard protocols, and interoperable system interfaces, among other components.

Establish and maintain baseline sites for global *in situ* networks.

Develop a cost-and-benefit-sharing mechanism(s) for observations by which an optimum observation system can be realized.

Provide a framework for securing the future continuity of necessary observations and initiating new observations.

Facilitate the analysis of the current and planned systems for data transfer and dissemination by GEOSS members.

Facilitate a common understanding of future capabilities at a global level for data dissemination.

6

DATA IN THE SERVICE OF USERS

6.1 Key principles

The societal benefits of Earth Observation cannot be achieved without data sharing. The following are GEOSS data sharing principles:

- There will be full and open exchange of data, metadata, and products shared within GEOSS, while recognizing relevant international instruments and national policies and legislation.
- All shared data, metadata, and products will be made available with minimum time delay and at minimum cost.
- All shared data, metadata, and products for use in education and research will be encouraged to be made available free of charge or at no more than the cost of reproduction.

Use of data or products does not necessarily imply agreement with or endorsement of the purpose behind the gathering of such data.

6.2 Data management

Opportunities include synergies among the systems operating in the different user domains and serving the different communities of users. It is expected that there will be a large increase in the volume of Earth Observation data. In addition to distributed data archives and integration systems, data management facilities will be used for diverse and large-volume Earth Observation data from inhomogeneous information sources in cooperation with existing data centres that will keep their institutional identity and mandates. Thus, GEOSS will facilitate:

- life-cycle data management for large volume data from leading-edge storage technology
- utilization of advanced database technology that enables multi-layered visualization of various types of data
- integration of natural science data and human societal data by standard co-registration techniques for data and geographic information
- new value-added products resulting from data and information fusion of diverse and large volume Earth Observation and socio-economic data
- implementation of international information sharing capabilities through an open and accessible system using appropriate international standards
- free availability of standardized metadata through a standard Internet-based catalogue search service, supporting multidisciplinary data and information search.

The GCOS Climate Monitoring Principles are a useful guideline for Earth observing systems in general. They aim to ensure high-quality data and products. These ten basic principles were adopted by the UNFCCC through Decision 5/CP.5 in 1999, as a means of ensuring such a homogeneous climate record for the future.

GCOS Climate Monitoring Principles

Effective monitoring systems for climate should adhere to the following principles:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems should be required.
3. The results of calibration, validation, data homogeneity assessments and assessment of algorithm changes should be treated with the same data.
4. A capability to routinely assess the quality and homogeneity, including high-resolution data and related descriptive information for data on extreme events should be ensured.
5. Consideration of environmental climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Uninterrupted station operations and observing systems should be maintained.
7. A high priority should be given to additional observations in data-poor regions and regions sensitive to change.
8. Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of new system design and implementation.
9. The carefully planned conversion of research observing systems to long-term operations should be promoted.
10. Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems.

In 2003, the UNFCCC, through Decision 11/CP.9, requested the Subsidiary Body to expand these principles. The expanded principles, agreed by WMO at its Fourteenth Congress and adopted by CEOS at its Seventeenth Plenary, contain an additional 10 principles specifically relating to satellites.

6.3 User involvement and user support

GEOSS will regularly involve users in reviewing and assessing requirements for Earth Observation data, products and services. The benefits of GEOSS will be realized globally by a broad range of user communities, including managers and policy makers in the targeted societal benefit areas, scientific researchers and engineers, civil society, governmental and non-governmental organizations, and international bodies, such as those tasked with implementing multilateral environmental agreements. Engagement of users in developing countries will maximize their opportunities to derive benefits from GEOSS.

GEO will perform a coordination role to address the adequacy, efficiency, and integrative way user requirements are being met and transmit recommendations for improvements to the relevant contributing systems.

The needs of users, and the technical solutions to those needs, change with time. GEO will organize regular GEOSS User Fora among and within societal benefit areas or sub-areas, making use of user communities where they exist and catalyzing the formation of new ones where they do not. It will also create an appropriate mechanism for coordinating user requirements across societal benefit areas. The function of the User Fora will be to document and review user requirements, assess the extent to which they are being met, and make recommendations to GEO with the objective of improving the delivery of information appropriate to user needs.

GEO Participating Organizations will continue to play a key role in connecting users and Earth Observation systems. Although GEOSS focuses on global issues, involvement of local and national users is also essential, in order to address issues that have global implications.

In many cases, tools and/or manuals are needed to handle the data and products. GEOSS will encourage the development of the appropriate tools and manuals for users, and the provision of help desks in order to make GEOSS "user-friendly."

6.4 Research facilitation

GEOSS will promote more effective transition of Earth Observation technologies, proven in the research environment, into operational use. Research strategic plans should not only address continued investment in research, but should also consider how to turn a successful research system into an operational system. Research space-based observation missions, once proven successful and useful, need to be transferred into operational services through collaboration among space agencies and operational agencies. It will be necessary to evolve experimental or research-based *in situ* observations into operational services in order to provide long-term monitoring capabilities.

Because of the rapid pace of technological change, continuous and evolutionary system development is necessary to keep Earth Observation systems effective and efficient. Clearly, the science and practice of Earth Observation has a continuing need for improved sensors, sampling strategies, and networks, among many other components. New technologies often provide better coverage or precision at lower cost, and occasional breakthroughs lead to societal benefits hardly considered possible before. However, for changes to be effective in observation networks and systems, there need to be assurances that long-term consistency and homogeneity will be preserved.

GEOSS will promote coordination between observation and research, which includes WCRP, IGBP, and other international research programmes. Strong collaboration with the research community, represented by ICSU and other organizations, will further refine required analyses and products. GEOSS will provide access to the observations and data necessary for research communities, while research outcomes will have an impact on observation system planning and system design.

GEO will advocate research and development in key areas to facilitate, on an ongoing basis, improvements to Earth Observation systems, including:

- improved and new instrumentation and system design for *in situ*, airborne, and space-based observation on a long-term basis
- life-cycle data management, data integration and information fusion, data mining, network enhancement, and design optimization studies, and
- development of models, data assimilation modules, and other algorithms that are able to produce global and regional products more effectively.

GEOSS implementation will promote research efforts that are necessary for the development of tools required in all societal benefit areas. It will also encourage and facilitate the transition from research to operations of appropriate systems and techniques. This includes facilitating partnerships between operational groups and research groups.

6.5 Radio frequency protection

In order to enable the various functions of GEOSS, it is necessary that appropriate frequency allocations exist and are protected. The frequency allocations will be necessary both for telecommunications and for observing systems. In some observing systems, the required radio frequency will be determined by physics. The full set of GEOSS required radio frequency allocations must take into account national frequency plans as well as those of the International Telecommunication Union (ITU). To this end, GEOSS will:

- review allocations of radio-frequency bands and assignments of radio-frequencies to GEOSS related activities for requirements (telecommunications, instruments, sensors, etc.) and research purposes
- coordinate with GEO Members and Participating Organizations to ensure the proper notification and assignment of frequencies, and to determine their future use of the radio spectrum
- keep abreast of the activities of the Radio Communication Sector of the International Telecommunication Union (ITU-R), and in particular of the Radio Communication Study Groups
- prepare and coordinate proposals and advice to GEO Members and Participating Organizations on radio-regulation matters pertaining to GEOSS activities with a view to ITU Radio Communication Study Groups, Radio Communication Assembly, World Radio Communication Conferences and related regional and global preparatory meetings
- facilitate the coordination among GEO Members and Participating Organizations for the use of frequency bands allocated to GEOSS activities with respect to:
  (i) coordination of frequency use/assignments between countries, and
  (ii) coordination of frequency use/assignments between various radio communication services sharing the same band
- facilitate the coordination among GEO Members and Participating Organizations and other international organizations that address radio-spectrum planning, including specialized organizations (e.g. CGMS, SFCG, IUCAF) and regional telecommunication organizations (e.g. CEPT, CITEL, APT), and
- assist GEO Members and Participating Organizations, upon request, in the ITU coordination procedure of frequency assignment for radio communication systems sharing a frequency band.

6.6 Targets

The targets given below are in addition to specific targets given for each of the nine societal benefit areas in Section 4 of this document. The targets given here also relate to overarching data management issues that need to be addressed.

2-Year Targets — 6 Data in the Service of Users

GEOSS will:

Establish a mechanism for coordinating user needs within the various societal benefit areas.

Facilitate, with relevant countries and international organizations, the development and availability of data, metadata, and products commonly required across diverse societal benefit areas, including base maps and common socio-economic data.

Advocate, through appropriate representations to the International Telecommunication Union, the protection of radio frequencies critical to Earth observation.

6-Year Targets — 6 Data in the Service of Users

GEOSS will:

Facilitate data management approaches that encompass a broad perspective of the observation data life cycle, from input through data acquisition, processing, archiving, and dissemination, including analysis and visualization of large volumes and diverse types of data.

Advocate and facilitate international information sharing capabilities through appropriate technologies, including, but not limited to, Internet-based services.

10-Year Targets — 6 Data in the Service of Users

GEOSS will:

Facilitate sharing of data and products among the societal benefit areas and their use for decision-making support.

Advocate new and increased efforts to enhance data availability and usability beyond the 10-year implementation period.

7

CAPACITY BUILDING

7.1 Introduction

Capacity building is an integral part of the implementation strategy of GEO and is a cross-cutting component for the societal benefit areas identified and discussed in Section 4. Specific capacity building activities, however, need to be tailored to suit regional or local requirements on the basis of existing capacity.

The most efficient means to improve the geographic coverage of the Earth observing system is to encourage wider participation from all countries. The capacity building envisaged within this context must extend beyond training of qualified technical personnel to operate the observing instruments, to include building of a broader community that will be trained in the development, interpretation and utilization of value-added products from the observations. Capacity building initiatives must therefore target a spectrum of citizens – from the general public, to scientists, to managers, to decision-makers. This is essential to ensure that all countries benefit from GEOSS.

Many potential GEOSS components have made significant progress in developing capacity, but linkages and partnerships between these activities are critical to ensure sustainability and the most effective use of resources.

7.2 What is capacity building?

The UNCED (1992) definition of capacity building encompasses a country's human, scientific, technological, organizational, and institutional resources and capabilities. A fundamental goal of capacity building is to enhance the abilities of stakeholders to evaluate and address crucial questions related to policy choices and modes of implementation among different options for development. These choices would be based on an understanding of environmental potential and limits and of the needs perceived by the people of the country concerned.

7.3 Goals

The goals of capacity building in GEO will be to strengthen the capability of all countries, in particular developing countries, to:

1. Use Earth Observation data and products (i.e. process, integrate, model, etc.) in a sustainable, repeatable manner (both space-based and *in situ* sensors), with results or outputs that are consistent with accepted Earth observing standards.

2. Contribute *in situ* observations to global networks, and access and retrieve relevant data from global data systems useful for *in situ* applications.

3. Analyze and interpret data (both *in situ* and space-based) to derive nationally, regionally and globally relevant information and provide decision-support systems and tools useful to decision-makers.

4. Integrate Earth Observation data and information with data and information from other sources for a comprehensive and holistic view and understanding of problems in order to identify sustainable solutions.

7.4 Strategy and principles

The GEO capacity building strategy takes its lead from the emerging understanding of Best Practices derived from a study of successful and less successful approaches from the past. The GEO capacity building strategy follows the WSSD concept of a global partnership between those whose capacity needs development and those who are able to assist in the process, recognizing that activities have intertwined social, environmental, and economic impacts.

GEO capacity building activities will build on existing local, national, regional, and global initiatives to achieve the goals of the GEOSS. Capacity building across the entire continuum of GEOSS activities is crucial for sustained results, whereby each country must determine the set activities in which it is able to engage. The capacity building recommendations that are reflected in the 10-Year Implementation Plan are based on the following considerations:

1. GEO capacity building efforts are funded and sustained, to ensure the continuity and enhancement of initiatives. These initiatives must be approached as a multi-level activity – enhancing research capacities, expanding tertiary educational facilities and training, and creating highly skilled and dedicated technicians.

2. Capacity building activities must respect the needs and recommendations of, and lessons learned from, previous and existing efforts.

3. Efforts must be based on the recognition that Earth Observation and related capacity building activities have intertwined social, environmental, and economic impacts.

4. Sustainable capacity building will only be successful if local and national stakeholders are partners in the process from the onset, and if there is an ongoing and long-term political and institutional commitment. Advantage should be taken of existing experience and capability within regions.

5. Capacity building envisaged here should lead to sustained improvements in Earth observations and related activities.

6. Capacity building efforts should be directed at maintaining and strengthening existing structures and developing new infrastructure where necessary.

7. Infrastructure development in regions of poor observational coverage is to be encouraged on a priority basis to realize maximum societal benefits.

8. Capacity building efforts should aim to move individual countries from a position of awareness to a position where they take all necessary actions to continuously improve their own capacity.

9. Capacity building should address not only issues related to data collection, but also those related to data archiving, data distribution, data analyses, product creation and interpretation.

10. A variety of outputs, ranging from raw data to processed outputs will be necessary to meet the needs of various applications. These outputs will have to be tailored to meet the requirements of the applications envisaged, and adapted to the regional situations and technological capabilities and continuously improved as the demand for products increases.

7.5 Targets

The recommendations given below are in addition to specific capacity building recommendations and targets identified under Sections 4, 5, and 6. The recommendations given here relate to overarching capacity building issues that need to be addressed. They are written being cognizant of the vast array of capacity building interventions that do exist within various national, regional, and international organizations. These will need to be considered in the implementation of GEOSS.

2 Year Targets — 7 Capacity Building

GEO will:

Produce a comprehensive review and gaps analysis based on existing regional and international capacity building efforts as a first step in the implementation of GEOSS. GEO will facilitate coordination of those efforts with the objective of achieving the maximum return for the effort expended.

Produce methodologies to monitor and evaluate capacity building initiatives relating to Earth Observation systems.

Facilitate, with existing international, regional and national efforts, the maintenance and strengthening of education, training, research, and communication so that each country reaches and sustains a level of capability that enables them to participate in GEOSS, receiving maximum benefits from it according to their needs.

Facilitate, with developing countries and across all societal benefit areas, the establishment and maintenance of baseline sites for global *in situ* and remote-sensing networks that cannot always be justified on national grounds alone, in cooperation with relevant global research programs and activities to ensure that synergies in observations and understanding are achieved. Examples include the inadequacy of GCOS, GTOS, GOOS, and Global Geodetic Observing System (GGOS) sites in developing countries and the need to establish a minimum set of oceanic, terrestrial and atmospheric reference stations for long-term observations of key variables.

Develop a network of experts involved in existing local, national and global capacity building initiatives related to Earth Observation to facilitate the task of furthering capacity building, and inform the GEO Members and Participating Organizations of existing efforts in capacity building. GEO will encourage users to access this knowledge base.

Encourage, in each societal benefit area, the development of capacity building components as a requirement to any network, project, activity, or user forum that will be a component of GEOSS.

Facilitate access to data and models, particularly for developing countries.

Develop recommended priorities for new or augmented efforts in capacity building, to meet the objectives of the overall GEOSS 10-Year Implementation Plan.

6 Year Targets — 7 Capacity Building

GEO will:

Advocate funding of multinational projects to leverage the end-to-end value of observations including the establishment of necessary infrastructure.

Produce monitoring and evaluation mechanisms aimed at determining the efficacy of GEO capacity building efforts.

Facilitate education and training to provide a global base of technical expertise for GEOSS.

Develop recommended priorities for new or augmented efforts in capacity building, to meet the objectives of the GEOSS 10-Year Implementation Plan.

10 Year Targets 7 Capacity Building

Within 10 years, GEO will seek to have in place a sustained capacity building strategy that will have significantly strengthened the capability of all countries, and particularly of developing countries, to:

- Use Earth Observation data and products (e.g. process, integrate, model) following accepted standards.
- Contribute to, access, and retrieve data from global data systems and networks.
- Analyze and interpret data to enable development of decision-support tools.
- Integrate Earth Observation data and products with other data and products, for a more complete view and understanding of problems and derived solutions.
- Improve infrastructure development in areas of poor observational coverage.

Develop recommended priorities for new or augmented efforts in capacity building.

8

OUTREACH

8.1 Introduction

GEOSS outreach activities and the resulting dialogue will provide many benefits. They will: inform individuals or stakeholders to enable better decision making; inform GEOSS principals, providing for continuous improvement of the "system of systems"; and increase understanding among policy makers and the general public to ensure appropriate support for Earth Observation systems.

The overall objective of the GEOSS outreach component is, therefore, to promote and increase the general awareness of the benefits of Earth Observation, in the broadest sense possible. The key target audiences will be the present and future users, beneficiaries and sponsors of relevant systems. The Outreach Plan should be considered a flexible component. It can be adapted in response to major strategic and operational developments that might occur during the 10-year implementation period. It will also include ways to measure its success.

Decision-makers and the general public will be two target groups for Earth Observation promotion activities. In the past, material generated for these groups has been insufficient and not always "tailored" to their needs (frequently focusing on engineering/technology/science). Several examples exist where properly driven Earth Observation promotion has successfully attracted further governmental and public attention.

8.2 Objectives of GEOSS outreach

The main objectives of outreach activities are to:

- convince key audiences that past, present, and future investments in Earth Observation are delivering tangible socio-economic benefits, and thereby encourage more countries and organizations to participate actively in GEOSS
- show the practical applications of Earth Observation and their relevance to government policy, socio-economic growth, and the interests of citizens
- increase public awareness of GEOSS scientific achievements, technology advances, applications and capabilities, as well as benefits and support to environmental management.

The outreach component has to address a wide range of audiences, including diverse language groups, differing national interests, all age groups, varying levels of technical sophistication, and high to low political influence.

While all materials will be Internet-based, it is essential to recognize that hard copies (paper, CDs) will be necessary to reach all communities.

8.3 Outreach audiences

8.3.1 Decision and Policy Makers

This audience includes, primarily, political-level entities and representatives of GEO Members and Participating Organizations, as well as those responsible or interested in the exploitation of Earth Observation data and information. Typically included in this category are ministers, parliamentarians and specialized government committees, high-level civil servants, relevant national and international organizations, and user groups. All need to be shown, beyond the specific technicalities, the usefulness of Earth Observation information and data to solve their sector issues (e.g. ecosystem management, disaster management, agriculture, energy, health, etc.).

8.3.2 General Public

The general public includes the "man-in-the-street" as well as opinion makers from the media (press, TV, radio), who need to be familiarized, through quality information, with Earth Observation achievements. The goal is to increase confidence in public investment in this sector and raise awareness of the potential contribution that Earth Observation tools and information can provide in everyday life. In today's "information society," the "image" of Earth Observation can be channeled to the general public in an extremely effective way. The requirement is for effective and appealing sets of information.

8.3.3 Industry, Value Adding Companies (VAC) and Service Communities

Existing initiatives already link the industrial, non-governmental, academic and government sectors to promote the understanding and use of Earth Observation for societal and economic benefit. GEOSS could liaise with these types of initiatives to create a better dialogue with the industrial world. Service industries are also to be considered for possible outreach activities, since they are probably not fully aware of the potential economic benefits and markets that can be derived from Earth Observation. Public/private partnership should also be encouraged in this sector. A first set of actions could be directed towards existing, sector-specific industrial associations.

8.3.4 Scientific and Technical Communities

This audience includes R&D institutions, universities, government laboratories, non-governmental bodies, and industry. The interest of these communities must be drawn to the potential support Earth Observation can provide to their research and investigations, also in order to complement and improve their scientific and technical achievements, exploiting the multidisciplinary nature of Earth Observation data, and facilitating the transfer of technology and know-how.

8.3.5 Education Community

This audience includes primary and secondary schools as well as universities. Outreach promotion of Earth Observation to schools is meant to trigger and generate awareness of teachers and students of Earth Observation techniques as part of basic education and of Earth Observation products and services as useful and modern tools for teaching and learning. Today's students will, in the medium term, become decision-makers or potential data users and therefore need to be trained early to fully appreciate the usefulness of, and benefit from, Earth Observation programmes. This will involve the development of *ad hoc* educational curricula.

8.3.6 NGOs and Public Interest Advocacy Groups

NGOs include non-governmental organizations devoted to specific or cross-sectoral issues such as environment, sustainable development, health, agriculture, energy use, cooperation with developing countries, etc. Public Interest/Advocacy Groups include citizen groups capable of influencing public opinion and of lobbying with decision-makers for their specific causes. Outreach promotion activities towards these categories could support and complement actions towards the general public in OECD and developing countries.

8.3.7 International Financial Institutions and Official Development Assistance Agencies

This audience includes international and national investment institutions and technical/development assistance organizations devoted to cooperation with developing countries. Outreach promotion activities directed at these institutions and organizations will increase their knowledge of Earth Observation benefits, thus encouraging the inclusion of Earth Observation programmes in developing country investments, and promoting appropriate partnerships to ensure the related capacity building activities.

8.4 Time frame

8.4.1 Short Term (Two-year)

GEO will produce and begin to implement an outreach plan directed toward key target audiences, including decision-makers and policy makers; educators and trainers; the general public; industry and service communities; scientific and technical communities; non-governmental organizations; public interest advocacy groups; and international financial institutions and official development assistance agencies.

8.4.2 Medium and Long-term (6 to 10 Year)

All target audiences should be reached, although with different priority levels and resources. Decision-makers, educators and trainers, and the general public will remain of highest priority. In the longer term, priority will be given to private sector needs for triple bottom line reporting.

9

PERFORMANCE INDICATORS

9 Performance Indicators

GEO Members and Participating Organizations will require evidence that the implementation of GEOSS is measurably beneficial in order to assure continuing support. This Reference Document has identified a number of specific actions for implementation in the short term (2 years), medium term (6 years), and long term (10 years). This section sets out the proposed mechanism for assessing the performance of the 10-Year Implementation Plan against these goals.

It is proposed to use a broadly recognized four-part system of indicators for assessing the performance of GEOSS as described below. An early task of GEO will be to work out the details of these indicators.

9.1 Input indicators

These quantify the effort and resources committed to the GEOSS implementation. They include:

- Number of staff in the GEO Secretariat, including both those resourced by GEO and seconded to GEO, and classified into professionals and support staff.
- Total budget of the GEO Secretariat, broken down by:
  - fraction spent on human resources
  - fraction spent on operations (meetings, travel, etc.)
  - fraction spent on overheads (office, etc.).
- Number of participating countries and organizations.
- Percentage of due contributions received.

These indicators will be provided annually and will form part of an Annual Report.

The total cost for implementing GEOSS will be significant, but only limited resources will need to be provided through GEO. Most of the resources will be provided through existing national and international mechanisms, and by voluntary contributions to special projects. There are a number of input indicators that could be applied to measuring the global level of resource commitment to Earth Observation systems, particularly those participating in GEOSS.

9.2 Output indicators

These indicators quantify the auditable products delivered in the reporting period. They include:

- implementation plan targets achieved
- reports issued (including standards and protocols and scientific papers published)
- meetings held and documented, including duration, location, outputs, number and origin of participants
- number of users of GEOSS Internet-based resources, data and products.

These indicators will be provided annually and will form part of an Annual Report.

9.3 Outcome indicators

Outcomes are a measure of the effectiveness of the GEOSS process in terms of the improvements to the Earth observing system. In effect, they relate to the specific actions set out in each section and summarized in Section 10, and in relation to the targeted areas of current deficiency and promised improvement described in Section 3. The timeline for this reporting will be consistent with the relevant time-scale of implementation across the ten-year period. Examples of outcomes include:

- new observational products traceable to GEOSS
- percentage interoperability achieved between collaborating systems

- use of GEOSS-sourced products in major assessments
- improvements in the quantity, quality, timeliness and scope of data delivered through GEOSS
- degree to which user requirements for observations are met by systems participating in GEOSS.

9.4 Impacts

This is the assessment of whether the activities of GEOSS have led to significant improvements in human well-being within the societal benefit areas. Almost by definition, many of these are measurable only on the decadal timescale, and are mostly qualitative. The mechanism for assessment is a detailed, external review as directed by GEO.

10

PHASED IMPLEMENTATION AND GEOSS EVOLUTION

GEOSS is a system of systems evolving from and driven by user requirements. This section sets out a broad sequence for its evolution and implementation.

10.1 Phased implementation

GEOSS will implement targets in the short- (2-year), medium- (6-year) and long- (10-year) term for the nine societal benefit areas identified in Section 4, in a step-by-step fashion. It is understood that the societal benefit areas are not at the same level of maturity with respect to having a comprehensive understanding of their Earth Observation requirements. The implementation schedule will therefore necessarily differ from area to area.

Table 10.1 is an attempt to indicate an initial phasing and maturity for GEOSS implementation. It aims to provide an overview as to the current status and prospects for progress in 2-year, 6-year, and 10-year time frames for each element in the nine societal benefit areas. The table was generated from an analysis of targets of the societal benefit areas in Section 4 of this Reference Document. The status of each element is indicated by "P" for being in a planning phase, "I" for an implementation phase and "O" for an operational phase. It has not proved possible to include the Health societal benefit area.

In the table, lines of "observation" indicate deployment of *in situ* and space-based observation systems and their convergence. "Products" indicates generation of key products, data sets produced by modelling and data assimilation, and synergistic products generated by integrating data from different sources. "Data management" includes elements for promoting data sharing and utilization.

In general, the initial 2 years will be devoted to planning how to promote observations and data sharing for all the societal benefit areas. This will be a critical planning phase to lay out a detailed implementation plan, do-able and verifiable in 10 years, within a reasonable resource projection. The 6-year period is another important phase for carrying out the plan, consolidating the basis of observations, product generation and data management. The 10-year period is the target period by the end of which GEOSS needs to be made operational as much as possible. Mechanisms to sustain the observation system of systems beyond the 10 years will need to be in place. The table may assist such overall planning of GEOSS implementation.

10.2 GEOSS evolution

It is important for GEOSS to have a regular system for assessing progress and providing feedback for the evolution of the systems. The assessment has to define, *inter alia,* the extent to which a comprehensive, coordinated, and sustained system of systems can be achieved and what actions are needed to ensure relevant feedback.

10.2.1 Involvement of Users in Defining New Requirements

The need for changes in data and information provision, access, and quality are significant and concern different actors and institutions. Changes will not result from a single grand plan, but require progressive adjustments to be made as opportunities arise (e.g. regular reviews of monitoring programmes and establishment or renewal of observational infrastructures).

For this approach, a distinct and common user requirements database should be established and maintained for GEOSS, building on and linking to existing user requirements databases, such as the CEOS/WMO database of user requirements and observation system capabilities. The database should provide a link between the observation capabilities, data products requirements and societal benefit areas. Furthermore, the database should provide a gap analysis mechanism on the basis of comparison of available observations and data products with the required ones.

Table 10.1 GEOSS Ten-Year Implementation Plan: Relative Phasing and Maturity of Earth Observation Application

An initial synoptic description of the phasing of GEOSS implementation.

Topics	Disaster			Health			Energy			Climate			Water			Weather			Eco-systems			Agri-culture			Bio-diversity		
Periods (years)	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10
Observation:				Representation of the phasing has not yet been determined																							
1 *In situ* and airborne	I	I	I				I	O	O	I	O	O	I	I	O	O	O	O	I	I	O	I	I	O	I	I	O
2 Space-based	I	I	I				I	O	O	I	O	O	I	I	O	O	O	O	I	I	O	P	I	O	P	I	O
3 Convergence of Obs.	P	I	I				P	I	O	I	O	O	P	I	O	O	O	O	P	I	O	P	O	O	P	I	O
4 Continuity	P	P	I				I	I	O	I	I	O	I	I	O	O	O	O	P	I	O	P	P	I	P	I	O
Product:																											
5 Key Products	P	I	O				I	I	O	P	I	O	P	I	O	O	O	O	I	I	O	I	I	O	I	I	O
6 Modeling/Assimilation	P	I	I				I	I	O	P	I	O	I	I	O	O	O	O	P	I	O	P	I	O	P	I	O
7 Synergy of Products	P	I	I				P	I	O	P	I	O	P	I	O	P	I	O	P	I	O	P	I	O	P	I	O
8 Quality Control	P	P	I				I	I	O	P	I	O	P	I	O	O	O	O	P	I	O	P	I	O	P	I	O
Data Management:																											
9 Accessibility	I	I	O				I	I	O	P	I	O	I	I	O	O	O	O	P	I	O	I	I	O	P	I	O
10 Data Exchange	I	I	O				I	I	O	P	I	O	P	I	O	O	O	O	P	I	O	P	I	O	P	I	O
11 Interoperability	P	I	I				P	I	O	P	I	O	P	I	O	P	I	O	P	I	O	P	I	O	P	I	O
12 User Involvement	I	I	I				P	I	O	I	O	O	P	O	O	O	O	O	P	I	O	I	O	O	P	I	O
13 R & D for Observation	I	I	I				I	I	I	I	I	I	I	I	I	I	I	I	P	I	I	P	I	O	P	I	I
Capacity Building:																											
14 Capacity Building	P	I	I				I	I	O	I	I	O	P	I	O	I	I	O	P	I	O	I	O	O	P	I	O

Legend	P	Planning Phase	I	Implementation Phase	O	Operational Phase

For updating user requirements, the WMO experience in setting, reviewing, and updating observational data following their process called the Rolling Review of Requirements (RRR) could be used as a model. All WMO-supported programmes use the RRR process, which has become an effective tool for assessing current capabilities of a global observing system and defining enhancements.

GEOSS will launch a programme to ensure the involvement of users, and to effectively monitor their needs. User requirements, and the extent to which they are being met, will be assessed through coordination meetings with those responsible for the various domain- and agency-based observing systems. GEOSS User Fora should be held regularly to review the overall progress of GEOSS with respect to meeting the user needs within and among societal benefit areas. The outcome of the fora will be important inputs into the updating of the 10-Year Implementation Plan. Further details are provided in Section 6.6.

10.2.2 Involvement of the Science and Industrial Communities

GEOSS needs to involve the science and industrial communities to ensure incorporation of technical developments that could enable existing (and new) requirements to be met, as well as new exploitation techniques that will improve the utility of GEOSS. This activity should be part of the GEOSS User Fora.

Improvements in the observing system require support from research and development in several areas. The most important of these are listed below:

- Improved and new instrumentation for *in situ* and space-based observation.
- Data management, data integration and information fusion, data mining, network enhancement, and design optimization studies. This must include an evaluation of trade-offs in performance based on various hypothetical improvements in the observations.
- Development of models and algorithms that are able to more effectively invert or assimilate raw observations to produce global products.
- Transition from scientific/technical programmes to operational services.

The involvement of standards organizations and certification bodies in the process will facilitate the development of user standards.

The GEOSS evolution is driven by user requirements and available capability. These user requirements and capabilities will grow as time goes by. There will always be an evolution in terms of future requirements and capabilities. There needs to be a consistency check between the user requirements and available capabilities. This is a necessary step to assess how well user requirements are being met by capabilities, and how well future user requirements can be met by future capabilities, thereby making it possible to provide user requirements to capabilities feedback, and vice versa.

The relationship between users, Earth systems, science, technologies, and GEOSS is shown in Figure 10.1. It is important to ensure close links between the user, science and technology communities and GEOSS in order to decide future user needs and technological capabilities, and the societal benefits including scientific outcomes.

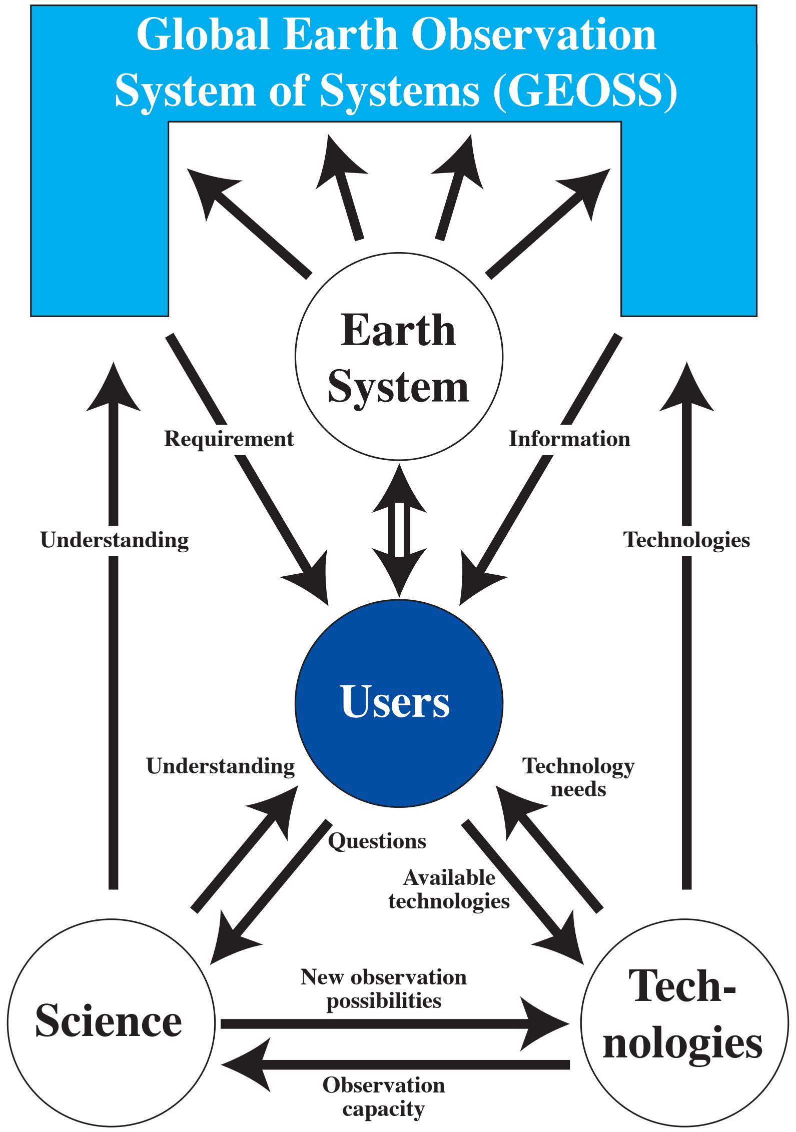


Figure 10.1. Relationship between Users, Earth System, Science, Technologies and GEOSS

Requirements from the users are the main driver of GEOSS. The science and technology communities contribute to GEOSS based on user requirements, and, in turn, provide scientific understanding of the Earth system and available technologies to the user community and GEOSS. The GEOSS must have the capacity to evolve over time, as a result of changes in the Earth system itself, the perceived needs of data users, our developing insights into key processes, and the growing technological capacity to observe them.

11

GLOSSARY AND ACRONYMS

11.1 Glossary of terms

C-band - a category of satellite transmission in the 6 GHz range.

GCOS Implementation Plan - *Implementation Plan for the Global Observing Systems for Climate in Support of the UNFCCC,* GCOS-92 (GCOS, 2004).

GCOS Second Adequacy Report - *Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC,* GCOS-82 (GCOS, 2003).

global positioning - a category of satellite constellations (e.g. United States Global Positioning System, European GALILEO, Russian GLONASS, Japanese QZSS) that provide services for determining position on the Earth.

***in situ* observations** - observations captured locally, i.e. within a few kilometres of the object or phenomenon being observed. These include measurements taken at ground stations, by aircraft and sondes, ships and buoys.

integrated (dataset) - data sourced from multiple systems that are combined in a consistent and scientifically rigorous way.

L-band - the portion of the electromagnetic spectrum allotted for satellite transmission in the 1 to 2 GHz frequency range.

observation(s) - quantitative or qualitative measurements of environmental and social variables obtained by instruments or human observers, either *in situ* or through remote sensing. Such observations frequently include numerical transformations to calibrate or interpolate them.

products (observational) - information that is derived from observations, typically through the processes of collation, synthesis, integration, summarization and interpretation.

realised niche - that fraction of the potential distribution of a species that is actually occupied by it.

remote sensing - in general, observations made at a distance. In the GEOSS context specifically, observations made from satellites in space, in the visible, infrared and microwave parts of the electromagnetic spectrum, at high, medium and low resolutions. Airborne, sonde and other forms of near-surface remote sensing are considered part of *in situ* observations for GEOSS purposes.

services (observational) - activities that are necessary in support of an observation system, but are not themselves observations–for example, the development of standards and the provision of calibrations.

11.2 Acronyms

AFRICOVER	A regional land cover mapping programme in Africa
ALOS	Advanced Land Observing Satellite (Japan)
AMDAR	Aircraft Meteorological Data Relay
APT	Asia-Pacific Telecommunity
Argo	Global array of temperature/salinity profiling floats for ocean climate observations
AVIRIS	Airborne Visible and Infra-Red Imaging Spectrometer
CBD	Convention on Biodiversity
CCD	Convention to Combat Desertification in countries experiencing serious drought and/or desertification, particularly in africa
CDC	Centres for Disease Control (United States)
CEOS	Committee on Earth Observation Satellites
CEPT	European Conference of Postal and Telecommunications Administrations
CGMS	Co-ordination Group for Meteorological Satellites

CITEL	Inter-American Telecommunication Commission
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CORBA	Common Object Request Broker Architecture
CoML	Census of Marine Life
COSMO-SkyMed	Observing system (Italy)
CTBTO	Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization
DAPHNE	Deployment of Asia-Pacific Hazard-mitigation Network for Earthquakes and volcanoes (Japan)
DEMs	Digital Elevation Models
DIVERSITAS	A biodiversity research programme of ICSU, UNESCO, IUBS, and SCOPE
DIWPA	DIVERSITAS Western Pacific and Asia
ebXML	Electronic business Extensible Markup Language
ECMWF	European Centre for Medium-range Weather Forecasts
ECVs	Essential Climate Variables
EEPCo	Ethiopian Electric Power Corporation
EUMETNET	Network of European Meteorological Services
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
ENSO	El Niño/Southern Oscillation
Envisat	Environmental satellite mission of the European Space Agency
ERS	European Remote Sensing Satellites
ESSP	Earth System Science Partnership
EUCOS	EUMETNET Composite Observing System
FAO	Food and Agriculture Organization (of the United Nations)
F-NET	Full Range Seismograph Network (Japan)
GALILEO	ESA/EU Global Navigation Satellite System
GAW	Global Atmospheric Watch (WMO)
GBA	Global Biodiversity Assessment
GBIF	Global Biodiversity Information Facility
GCOS	Global Climate Observing System (co-sponsored by ICSU, IOC of UNESCO, UNEO and WMO)
GCMD	Global Change Master Directory
GCRMN	Global Coral Reef Monitoring Network
GECAFS	Global Environmental Change and Food Systems
GEMS	Global Environmental Monitoring Strategy (WHO)
GEO	Group on Earth Observations
GEO (of UNEP)	Global Earth Outlook
GeoHab	Marine Geological and Biological Habitat Mapping
GEONET	GPS Earth Observation Network System (Japan)
GEOSS	Global Earth Observation System of Systems
GGOS	Global Geodetic Observing System
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GISP	Global Invasive Species Programme
GLC 2000	Global Land Cover 2000
GLCN	Global Land Cover Network of the FAO
GLOBEC	Global Ocean Ecosystem Dynamics Project (of the IGBP)
GLONASS	Global Orbiting Navigation Satellite System (Russia)
GNSS	Global Navigation Satellite Systems
GMA	Global Marine Assessment
GMES	Global Monitoring for Environment and Security
GODAE	Global Ocean Data Assimilation Experiment

GOFC-GOLD	Global Observations of Forest and Land Cover Dynamics
GOOS	Global Ocean Observing System (hosted by IOC)
GOS	Global Observing System (co-sponsored by ICSU, IOC of UNESCO, UNEO and WMO)
GPCC	Global Precipitation Climatology Centre (hosted by Germany)
GPM	Global Precipitation Measurement
GRDC	Global Runoff Data Centre (hosted by Germany)
GSDI	Global Spatial Data Infrastructure
GSN	GCOS Surface Network
GTN-H	Global Terrestrial Network for Hydrology
GTOS	Global Terrestrial Observing System. (co-sponsored by FAO, ICSU, UNESCO, UNEP and WMO, hosted by FAO)
GUAN	GCOS Upper Air Network
Hi-NET	Hi-sensitivity Seismograph Network (Japan)
IAG	International Association of Geodesy
IBMN	International Biodiversity Monitoring Network
IBOY	International Biodiversity Observation Year
ICSU	International Council for Science
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFRC/RCS	International Federation of the Red Cross/Red Crescent Societies
IGBP	International Geosphere-Biosphere Programme (of the ICSU)
IGOS-P	Integrated Global Observation Strategy Partnership. (includes CEOS, FAO, GCOS, GOOS, GOS/GAW, GTOS, ICSU, IGBP, IGFA, IOC, UNESCO, UNEP, WCRP, WMO)
IHDP	International Human Dimension Programme
IKONOS	Satellite observing system (commercial)
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research
InSAR	Interferometric Synthetic Aperture Radar
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCP	International Ocean Carbon Coordination Project
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
IRI	International Research Institute for Climate Prediction
ISCGM	International Steering Committee for Global Mapping
ISDR	International Strategy for Disaster Reduction
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-R	Radio Communication Sector International Telecommunication Union
IUBS	International Union of Biological Sciences
IUCN	International Union for the Conservation of Nature
IWC	International Waterbird Census
IWRM	Integrated Water Resource Management
K-NET/KiK-NET	Kyoshin Network/Kiban Kyoshin Network (Japan)
Landsat	Satellite observing system (United States)
LCCS	Land Cover Classification System
LiDAR	Light Detection and Ranging
LOICZ	Land-Ocean Interactions in the Coastal Zone Project (of the IGBP)
MAB	Man and Biosphere Programme of UNESCO

MDG	Millennium Development Goals
Meteosat	Satellite observing system (EUMETSAT)
MJO	Madden-Julian Oscillation
NASA	National Aeronautics and Space Administration (United States)
NGOs	Non-Governmental Organizations
NOAA	National Oceanic and Atmospheric Administration (United States)
NOAA/OAR	NOAA Office of Oceanic and Atmospheric Research (United States)
NPOESS	The National Polar-orbiting Operational Environmental Satellite System (United States)
NWP	Numerical Weather Prediction
OBIS	Ocean Biogeographic Information System
OECD	Organization for Economic Cooperation and Development
OGC	Open Geospatial Consortium
PAGE	Pilot Analysis of Global Ecosystems
PCBs	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
PHIN	Public Health Information Network (United States)
POPs	Persistent Organic Pollutants
QA/QC	Quality Assessment/Quality Control
QZSS	Quasi-Zenith Satellite System
RADARSAT	Satellite observing system (Canada)
RRR	Rolling Review of Requirements
SADC	Southern Africa Development Committee
SAR	Synthetic Aperture Radar
SCOPE	Scientific Committee on Problems of the Environment
SDI	Spatial Data Infrastructures
SFGC	Space Frequency Coordination Group
SLR	Satellite Laser Ranging
SOLAS	Surface Ocean - Lower Atmosphere Study
SPOT	Satellite Pour l'Observation de la Terre (France, Sweden, Belgium)
SRTM	Shuttle Radar Topography Mission of NASA
SST	Sea-Surface Temperature
TEMS	Terrestrial Ecosystem Monitoring Sites
UDDI	Universal Description, Discovery, and Integration
UML	Unified Modelling Language
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UV-B	Ultraviolet radiation at wavelengths of 290-320 nanometers
VLBI	Very Long Baseline Interferometry
WCRP	World Climate Research Programme
WFS	1996 World Food Summit
WHO	World Health Organization
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization
WSDL	Web Services Definition Language
WSSD	World Summit on Sustainable Development 2002
WWF	Worldwide Fund for Nature or World Wildlife Fund
XML	Extensible Markup Language

ANNEX 1
DECLARATION

Declaration of the Earth Observation Summit

We, the participants in this Earth Observation Summit held in Washington, DC, on July 31, 2003:

Recalling the World Summit on Sustainable Development held in Johannesburg that called for strengthened cooperation and coordination among global observing systems and research programmes for integrated global observations;

Recalling also the outcome of the G-8 Summit held in Evian that called for strengthened international cooperation on global observation of the environment;

Noting the vital importance of the mission of organizations engaged in Earth Observation activities and their contribution to national, regional and global needs;

Affirm the need for timely, quality, long-term, global information as a basis for sound decision making. In order to monitor continuously the state of the Earth, to increase understanding of dynamic Earth processes, to enhance prediction of the Earth system, and to further implement our environmental treaty obligations, we recognize the need to support:

(1) Improved coordination of strategies and systems for observations of the Earth and identification of measures to minimize data gaps, with a view to moving toward a comprehensive, coordinated, and sustained Earth Observation system or systems;

(2) A coordinated effort to involve and assist developing countries in improving and sustaining their contributions to observing systems, as well as their access to and effective utilization of observations, data and products, and the related technologies by addressing capacity-building needs related to Earth observations;

(3) The exchange of observations recorded from *in situ*, aircraft, and satellite networks, dedicated to the purposes of this Declaration, in a full and open manner with minimum time delay and minimum cost, recognizing relevant international instruments and national policies and legislation; and

(4) Preparation of a 10-year Implementation Plan, building on existing systems and initiatives, with the Framework being available by the Tokyo ministerial conference on Earth observations to be held during the second quarter of 2004, and the Plan being available by the ministerial conference to be hosted by the European Union during the fourth quarter of 2004.

To effect these objectives, we establish an *ad hoc* Group on Earth Observations and commission the group to proceed, taking into account the existing activities aimed at developing a global observing strategy in addressing the above. We invite other governments to join us in this initiative. We also invite the governing bodies of international and regional organizations sponsoring existing Earth observing systems to endorse and support our action, and to facilitate participation of their experts in implementing this Declaration.

(Adopted 31 July 2003)

ANNEX 2
FRAMEWORK DOCUMENT

From Observation to Action

Achieving Comprehensive, Coordinated, and Sustained Earth Observations for the Benefit of Humankind

Framework for a 10-Year Implementation Plan

As adopted by Earth Observation Summit II
25 April 2004

1 Introduction

Understanding the Earth system – its weather, climate, oceans, land, geology, natural resources, ecosystems, and natural and human-induced hazards – is crucial to enhancing human health, safety and welfare, alleviating human suffering including poverty, protecting the global environment, and achieving sustainable development. Data collected and information created from Earth observations constitute critical input for advancing this understanding. In 2003, a consensus emerged among governments and international organizations that, while supporting and developing existing Earth Observation systems, more can and must be done to strengthen global cooperation and Earth observations. This Framework Document, while not legally binding, marks a crucial step in developing the 10-Year Implementation Plan for the creation of a comprehensive, coordinated, and sustained Earth Observation system or systems as envisioned by the Washington Declaration adopted at the Earth Observation Summit of 2003.

2 Benefits of Comprehensive, Coordinated and Sustained Earth Observations

2.1 Observing and understanding the Earth system more completely and comprehensively will expand worldwide capacity and means to achieve sustainable development and will yield advances in many specific areas of socio-economic benefit, including:

- Reducing loss of life and property from natural and human-induced disasters;
- Understanding environmental factors affecting human health and well being;
- Improving management of energy resources;
- Understanding, assessing, predicting, mitigating, and adapting to climate variability and change;
- Improving water resource management through better understanding of the water cycle;
- Improving weather information, forecasting, and warning;
- Improving the management and protection of terrestrial, coastal, and marine ecosystems;
- Supporting sustainable agriculture and combating desertification;
- Understanding, monitoring, and conserving biodiversity.

2.2 Globally, these benefits will be realized by a broad range of user communities, including (1) national, regional, and local decision-makers, (2) relevant international organizations responsible for the implementation of international conventions, (3) business, industry, and service sectors, (4) scientists and educators, and (5) the general public. Realizing the benefits of coordinated, comprehensive, and sustained Earth observations (i.e. the improvement of decision-making and prediction abilities) represents a fundamental step toward addressing the challenges articulated in the declarations of the 2002 World Summit on Sustainable Development and fulfilling the Millennium Development Goals agreed at the Millennium Summit in 2000.

2.3 Full participation of developing country members will maximize their opportunities to derive real benefits in the above socio-economic areas. Such participation is supported as it enhances the capacity of the entire Earth Observation community to address global sustainable development challenges.

3 Key Earth Observation Areas

3.1 Coordinated and sustained global cooperation on Earth observations is well established in the crucial area of weather. The World Meteorological Organization's World Weather Watch demonstrates the value of international collaboration in this arena. Improvements in observation networks are still needed and will yield further success through improved accuracy in weather information and long-term prediction.

3.2 Cooperation is less advanced in the areas of land, water, climate, ice, and ocean observation. Nevertheless, some important work and guidance for future action has been developed in a number of areas, for example:

(a) Natural hazard understanding through a range of international observing and early warning systems consistent with the International Strategy for Disaster Reduction (ISDR);

(b) Climate understanding and research through the World Climate Research Program (WCRP), and climate monitoring consistent with the Global Climate Observing System (GCOS) in support of the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC);

(c) Ocean monitoring, modelling and forecasting through the Global Ocean Observing System (GOOS);

(d) A range of observation themes addressed by the Integrated Global Observing Strategy Partnership (IGOS-P) including oceans; carbon; water cycle; solid earth processes, coastal zone (including coral reef); atmospheric chemistry; and land/biosphere.

3.3 In each of these areas, observation efforts to understand dynamic Earth processes have been identified and should be expanded to support action-oriented solutions in the areas of key socio-economic benefit.

4 Shortcomings of Current Observation Systems

4.1 Human knowledge of the Earth system, although advanced in certain areas, is far from complete. Current efforts to observe and understand the Earth system must progress from the separate observation systems and programs of today to coordinated, timely, quality, sustained, global information - developed in accordance with compatible standards - as a basis for future sound decisions and actions.

4.2 Many international organizations and programmes are working to sustain and improve the coordination of Earth observations. However, current efforts to capture Earth observation data are limited by (1) a lack of access to data and associated benefits especially in the developing World, (2) eroding technical infrastructure, (3) large spatial and temporal gaps in specific data sets, (4) inadequate data integration and interoperability, (5) uncertainty over continuity of observations, (6) inadequate user involvement, (7) a lack of relevant processing systems to transform data into useful information, and (8) insufficient long-term data archiving.

5 What is Needed: The 10-Year Implementation Plan for Earth Observations (2005-2014)

5.1 To achieve the many benefits of coordinated Earth observations and to move from principles to action, governments adopting this Framework Document set forth the primary components of a 10-Year Implementation Plan for establishing the Global Earth Observation System of Systems (GEOSS). GEOSS will be:

- *comprehensive,* by including observations and products gathered from all components required to serve the needs of participating members;
- *coordinated*, in terms of leveraging resources of individual contributing members to accomplish this system, whose total capacity is greater than the sum of its parts;
- *sustained,* by the collective and individual will and capacity of participating members.

5.2 GEOSS will be a distributed system of systems, building step-by-step on current cooperation efforts among existing observing and processing systems within their mandates, while encouraging and accommodating new components. Participating members will determine ways and means of their participation in GEOSS. The 10-Year Implementation Plan for GEOSS will be based on the following considerations:

(a) With the socio-economic benefits identified in Section 2 as the roadmap, the 10-Year Implementation Plan will identify, document, and prioritize actions to address user requirements for current and future Earth observations. This process will be based on appropriate dialogue and procedures, taking advantage of and building upon the experience of existing initiatives and infrastructures.

(b) The architecture model will build incrementally on existing systems to create a distributed system of systems, incorporating an observation component, a data processing and archiving component, and a data exchange and dissemination component.

(c) The 10-Year Implementation Plan will elucidate practical methods for filling critical gaps in, *inter alia*, observation parameters, geographical areas, observation specifications, and accessibility.

5.3 The GEOSS will address key challenges of data utilization, including the need for:

- Full and open exchange of observations with minimum time delay and minimum costs, recognizing relevant international instruments and national policies and legislation;
- Assured data utility and usability (including thresholds for validation, calibration, and spatial and temporal resolution);
- Assured continuity and availability of the many observations and products in place or planned;
- A robust regulatory framework for Earth observations (e.g. through protection of radio frequency bands that are uniquely essential for Earth observations).

5.4 The plan will facilitate both current and new capacity building efforts, particularly in developing countries, across the entire continuum of GEOSS activities, which will include education, training, institutional networks, communication, and outreach as fundamental to those efforts. Building on existing local, national, regional, and global capacity building initiatives, GEOSS will:

(a) Focus on training and education for the development and/or utilization of existing human, institutional, and technical capacities for data utilization;

(b) Develop the infrastructure resources necessary to meet research and operational requirements;

(c) Build on globally accepted sustainable development principles – most notably those outlined in the World Summit on Sustainable Development Plan of Implementation.

5.5 The development of GEOSS should take maximum advantage of developments in research and technologies. Conversely it will enable the global scientific community to address key scientific questions concerning the functioning of the Earth system.

6 Outcomes

6.1 The success of the 10-Year Implementation Plan will be measured by the operational achievement of GEOSS. Specific outcomes for GEOSS, both short and long-term, will be elaborated in the 10-Year Implementation Plan, including but not limited to the following:

(a) Enabling global, multi-system information capabilities for each of the following:

- disaster reduction, including response and recovery;
- integrated water resource management;
- ocean monitoring and marine resources management;
- air quality monitoring and forecasting;
- biodiversity conservation;
- sustainable land use and management.

(b) Global tracking of invasive species.

(c) Comprehensive monitoring of global and regional climate on annual, decadal, and longer time scales, and enabling information products related to climate variability and change.

(d) Improving the coverage, quality, and availability of essential information from the *in situ* networks and improving the integration of *in situ* and satellite data.

(e) Involvement of users from developed and developing countries, monitoring their needs and fulfillment over time.

(f) An outreach mechanism to actively demonstrate the usefulness of Earth observation to decision makers in key user communities.

7 The Way Forward

7.1 The adoption of this Framework Document indicates a decision to proceed with the elaboration of the GEOSS 10-Year Implementation Plan along the lines set forth in this Document and a willingness to cooperate on, and participate in, the implementation of the plan. At present, the *ad hoc* Group on Earth Observations (GEO) is a "best efforts" activity with voluntary input from States and advice and support from international organizations.

7.2 For 2005 and beyond, the implementation of the "10-Year Implementation Plan" will require a ministerial-guided successor mechanism with maximum flexibility - a single intergovernmental group for Earth observations drawing on the experience of the *ad hoc* GEO, with membership open to all interested governments and the European Commission, and with representatives of relevant international organizations taking part.

7.3 The GEOSS 10-Year Implementation Plan will elaborate details for this Group, which will provide generally for:

(a) Coordination and planning of GEOSS implementation (*in situ* and remotely sensed).

(b) Opportunities for engagement of all members and relevant international and regional organizations.

(c) Involvement of user communities.

(d) Measuring, monitoring, and facilitating openness of GEOSS to improve cross-flow of observations and products.

(e) Co-ordination and facilitation of the development and exchange of observations and products between members and relevant international and regional organizations.

ANNEX 3
TABLE OF INITIALLY IDENTIFIED SYSTEMS

Category	Sponsor(s)	System
Observing systems	Argentina	SAOCOM 1A and 1 B: Argentine L-Band Full Polarimetric SAR Mission composed of two satellites and provided for in the Argentine National Space Programme
	Canada	RADARSAT C band: an advanced Earth Observation SAR satellite programme developed by the CSA to monitor environmental change and support resource sustainability
	Europe	Global Monitoring for Environment and Security (GMES)
	Italy	COSMO-SkyMed (constellation of 4 X-Band SAR satellites)
	Japan	Deployment of Asia-Pacific Hazard-mitigation Network for Earthquakes and volcanoes (DAPHNE)
		Hi-sensitive Seismograph (Hi-NET)
		Kyoshin Network/ Kiban Kyoshin Network (K-NET/KiK-NET)
		Full Range Seismograph Network (F-NET)
		GPS Earth Observation Network System (GEONET)
	United States	US Integrated Earth Observation System (IEOS)
		Global Seismographic Network (GSN)
	WMO	World Weather Watch Global Observing System (GOS) EUMETNET Composite Observing System (EUCOS) (A regional component sponsored by 19 European national meteorological and hydrological services)
		Global Atmosphere Watch (GAW)
		World Hydrological Cycle Observing System (WHYCOS)
		Global Terrestrial Network for Hydrology (GTN-H)
	IAG	Global Geodetic Observing System (GGOS)
	ISCU, UNEP, IOC of UNESCO, WMO	Global Ocean Observing System (GOOS)
	ICSU, UNEP, IOC of UNESCO, WMO	Global Climate Observing System (GCOS)
	FAO, ICSU, UNEP, UNESCO, WMO	Global Terrestrial Observing System (GTOS)
Modelling and data processing centers	ISCGM	Global Mapping Project
	WMO	World Weather Watch Global Data Processing and Forecast System (GDPFS)
		Global Runoff Data Centre (GRDC) (hosted and funded by Germany)
		Global Precipitation Climatology Centre (GPCC) (hosted and funded by Germany)
	18 European countries and WMO RSMC	European Centre for Medium range Weather Forecasts (ECMWF)
	Argentina	Mario Gulich Institute for Advanced Space Studies
Data exchange and dissemination systems	WMO	Global Telecommunications System (GTS)
		Future WMO Information System (FWIS)
	United States	National Spatial Data Infrastructure (NSDI)