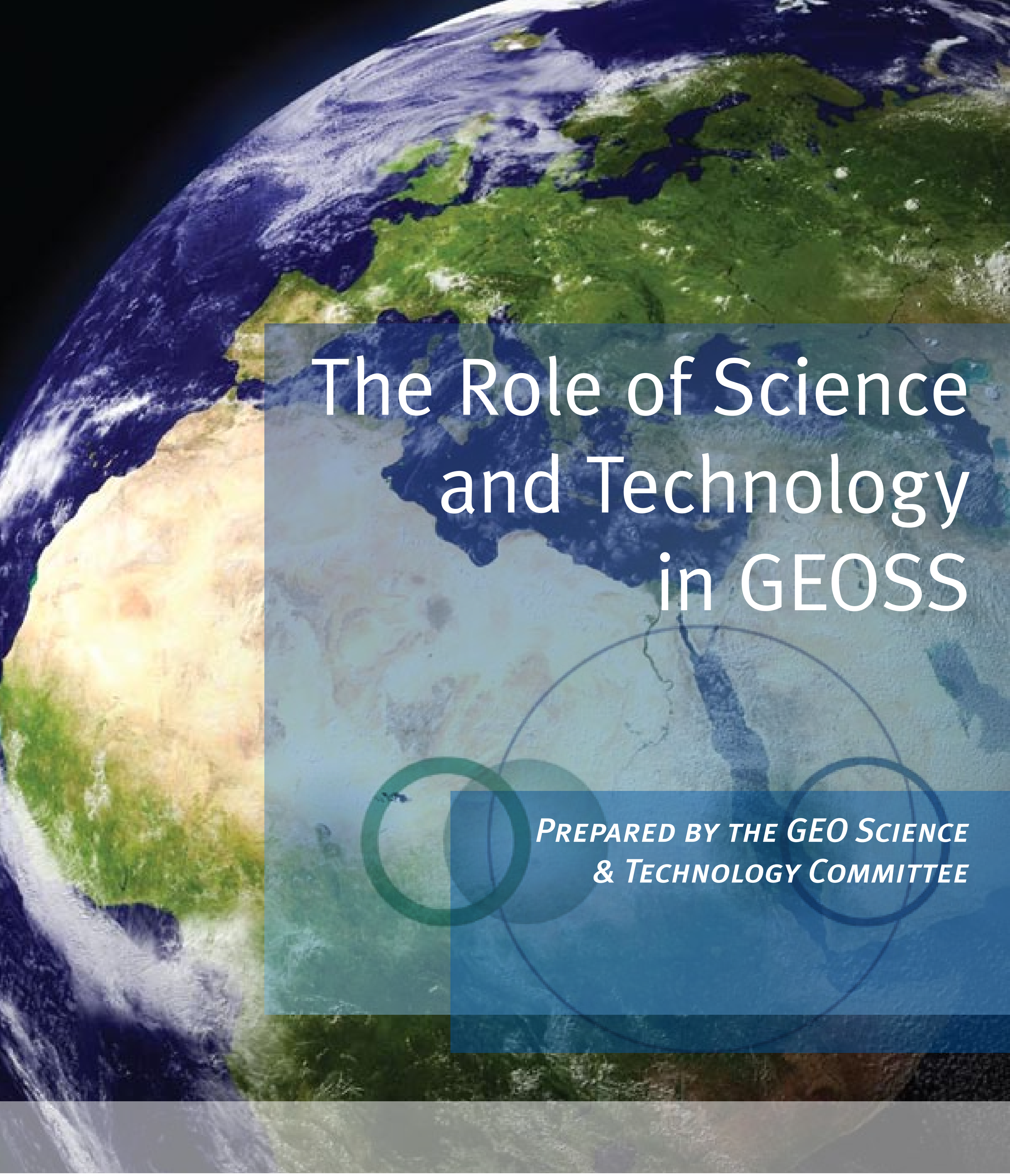

The Role of Science and Technology in GEOSS

Prepared by the GEO Science & Technology Committee

GROUP ON EARTH OBSERVATIONS

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GROUP ON EARTH OBSERVATIONS

The Role of Science and Technology in GEOSS

(prepared by the GEO Science and Technology Committee)

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Table of contents

Introduction

This document describes the role of science and technology in advancing the Global Earth Observation System of Systems (GEOSS) through the Group on Earth Observations' (GEO) 2007-2009 Work Plan. The Science and Technology Committee is working to strengthen this role by encouraging the wider scientific and technology community to participate as contributors to and benefactors of a sustained GEOSS. Because scientific and technological knowledge and research are so vital to our understanding of the global integrated Earth system, this document seeks to sensitise potential partners and relevant funding agencies to the important relationships between GEOSS and science and technology and the many societal benefits that GEOSS can provide (see Figure 1).

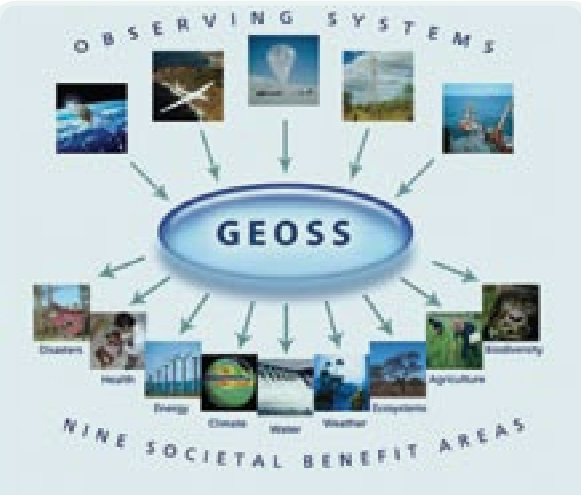

Figure 1: *Illustration of the concept of GEOSS and its nine interconnected societal benefit areas (SBAs). Each SBA requires many observation data and decision-support tools. Each of these data sets and tools can serve many SBAs.*

The document contains five main sections. Section 1 briefly describes the vision of GEO for GEOSS and illustrates the role of science and technology in supporting this vision. Section 2 explains the importance of science and technology in GEO Work Plan activities and introduces the GEO Science & Technology Committee. Section 3 outlines the importance of science and technology in the GEOSS 10-year Implementation Plan (and Reference Document), and in relevant international research programmes and scientific partnerships. Section 4 addresses both the contribution of science and technology to improving GEOSS implementation and the contribution of GEOSS to enhancing global integrated Earth system science and technology. Section 5 concludes the presentation by reiterating how critically important it is that the science and technology community actively contributes to the implementation of GEOSS.

1 Vision

The Group on Earth Observations (GEO) vision for the GEOSS is to "realize a future wherein decisions and actions for the benefit of humankind are informed via coordinated, comprehensive and sustained Earth observations and information" (GEOSS 10-Year Implementation Plan). GEO will achieve GEOSS in order to improve the monitoring of the state of the Earth, increase the understanding of Earth's changing environment and global integrated Earth system processes, and enhance the prediction of the Earth system's behavior – in a fast changing environment.

Achieving GEOSS depends on advances in science, technology, and research and GEOSS will itself be a driver for such advances. As an example of advances, Figure 2 (Upper Panel) shows the increase in forecast skill (measure of the performance of a forecast relative to observed conditions) of different numerical weather prediction centers over the past two decades. Figure 2 (Upper Panel) illustrates the worldwide beneficial result of many years of international investments that produced increases in (i) quantity, quality, and communication of observations; (ii) research and understanding of atmospheric circulation including its interactions with the ocean and land; (iii) data assimilation methodologies; and (iv) computer capability and capacity. Convergence of Northern Hemisphere and Southern Hemisphere (SH) skills clearly demonstrate the impressive role of satellite observations to improve weather forecast skill in the SH because the SH has only sparse in-situ measurements.

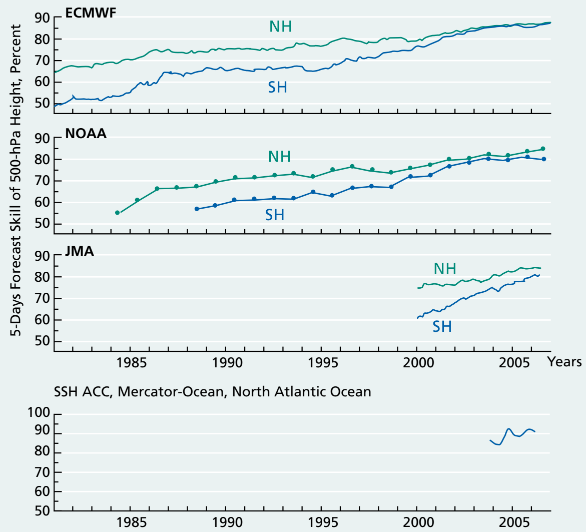

Figure 2: *Time evolution of improvement of forecast skill (anomaly correlation score) for:*

Upper Panel: Operational numerical weather prediction (NWP) 5-day forecasts of 500-hPa geopotential heights over the Northern Hemisphere (NH) and Southern Hemisphere (SH) computed at the European Centre for Medium-range Weather Forecasts (ECMWF – 12-month running average values of monthly-mean skill over 90°S-20°S, 20°N-90°N); U.S. National Oceanic and Atmospheric Administration (NOAA – annual-mean skill over 80°S-20°S, 20°N-80°N), and Japan Meteorological Agency (JMA – monthly mean skill over 90°S-20°S, 20°N-90°N). The NWP centers used different model physics and data assimilation schemes (courtesy of D. Halpern (NASA), K. Koizuma (JMA), S. Lord (NOAA), and A. Simmons (ECMWF)).

Lower Panel: 7-day forecasts of sea level anomaly over the tropical and North Atlantic Ocean computed at Mercator-Ocean (12-month running mean values of weekly-mean skill over 20°S-70°N) (courtesy of N. Ferry (Mercator Ocean)).

2 An Integrated Science and Technology Approach to GEOSS

The interdependence of the nine GEOSS societal benefit areas, the multiple uses of individual environmental observations, and the connectivity of global integrated Earth system processes all call for an integrated science and technology approach. Figure 3 illustrates the central role of GEOSS science and technology in simultaneously advancing societal benefit areas, observations, and global integrated Earth system knowledge – a primary interdisciplinary goal of GEOSS.

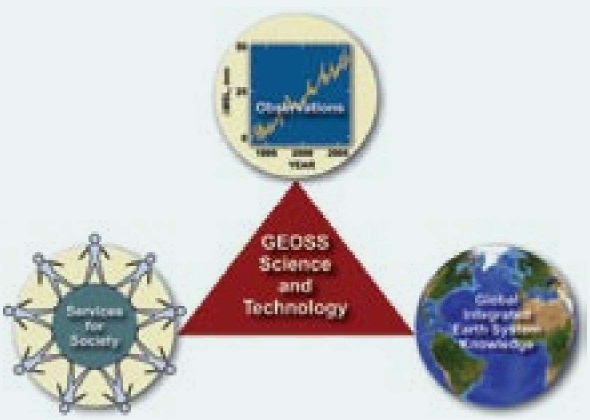

Figure 3: *Upper circle: 60-day running-average fluctuations of global sea level recorded with the Topography Experiment (TOPEX)/Poseidon and Jason satellites during Aug 1992–Sept 2005 and Dec 2001 – Jan 2007, resp. The annual-mean global sea level rise over Jan 1993-Sept 2006 is 3.2 ± 0.4 mm per year. Left circle: Connected people representing the 9 GEOSS societal benefit areas. Right circle: Improved knowledge of the global integrated Earth system - essential for enhanced environmental prediction (courtesy of D.Halpern (NASA)).*

The Role of the GEO Science & Technology Committee

The Science & Technology Committee monitors the tasks of the GEOSS implementation plan under its responsibility (see Annex), and interacts with the other GEO Committees to identify the scientific and technological requirements of GEOSS that need the involvement of the broader scientific community. It recognises the interdependence of the nine GEO Societal Benefit Areas where the multiple uses of individual environmental observations and the connectivity of global integrated Earth system processes call for an integrated science and technology approach. The importance of science and technology in GEO Work Plan activities is reflected in the overall structure of GEO as captured in Figure 4.

Figure 4: *Illustration of the structure of GEO*

3 Science & Technology within GEOSS: The Building Blocks

3.1. Science & Technology in GEO Documents

It has been recognised since the onset of the GEO initiative that the science and technology community is a key target audience among the various sponsors and beneficiaries of GEOSS. *The Ten-year Implementation Plan Reference Document*, for instance, states that scientific and technical communities must be addressed; this audience includes research and development institutions, universities, government laboratories, non-governmental bodies, and industry. The interest of these communities must be drawn to the potential support global 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 GEOSS, and facilitating the transfer of technology and knowledge.

The GEO documents *Ten-year Implementation Plan* and *Ten-year Implementation Plan Reference Document* have initiated this work of addressing the science and technology community. However the explicit or implicit references to science and technology – albeit numerous – are scattered throughout the texts because the documents have purposes other than the outreach to the science and technology community. Thus, it makes it difficult for the community to identify the scientific and technical tasks that are fundamental for the implementation of GEOSS or to identify how GEOSS can contribute to its activities. This section therefore synthesises the references to science and technology in the GEO documents identifying the science and technology building blocks within the GEO initiative.

3.1.1. Ten-Year Implementation Plan

The Ten-Year Implementation Plan clearly acknowledges the role of the science and technology community in the initiative. "The benefits of GEOSS will be realized globally by a broad range of user communities, including … scientific researchers and engineers".[1] The plan adds: "The functions of GEO include:

- Drawing on the expertise of the international scientific and technological communities
- Consulting, coordinating, and liaising with relevant UN Specialized Agencies and Programmes, and international scientific organizations".[2]

The Ten-Year Implementation Plan also refers to the role of the initiative in integrating science and technology developments. "To enable implementation of the GEOSS architecture, GEOSS will draw on existing Spatial Data Infrastructure (SDI) components as institutional and technical precedents in areas such as geodetic reference frames, common geographic data, and standard protocols."[3] The Plan adds: "In the implementation of GEOSS, increased sharing of methods for modelling and analysis needed to transform data into useful products will be advocated".[4]

1 Section 4.2 User Involvement
2 Section 6.1 Functions
3 Section 5.3 Architecture and Interoperability
4 Section 5.1 Observations and Modelling

Moreover, the Plan clearly acknowledges that scientific research and technological development are needed to improve global integrated Earth observation systems: "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 observations on a long-term basis.
- Life-cycle data management, data integration and information fusion, data mining, network enhancement, and design optimization studies.
- Development of models, data-assimilation modules, and other algorithms that enable to produce global and regional products more effectively.

The 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."[5]

It also recognises the role of GEO in capacity building, noting among other things that: "Within 2 years, GEO will … facilitate, together with existing efforts, the maintenance and strengthening of education, training, research and communication, …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, facilitate access to data and models, particularly for developing countries. … Within 6 years, GEO will … facilitate education and training to provide a global base of technical expertise for GEOSS …"[6] .

3.1.2. Ten-Year Implementation Plan Reference Document

The Ten-year Implementation Plan Reference Document supports *the Ten-year Implementation Plan* through substantive information necessary for the implementation of GEOSS. Numerous references to science and technology appear in the Reference Document and the present synthesis cannot be exhaustive. An attempt is made instead to extract general principles outlined in the Reference Document. Specific examples are provided to illustrate these principles, and the examples should not be interpreted as a way of prioritizing the various science and technology references.

The role of science and technology within GEOSS inferred from *the Ten-year Implementation Plan Reference Document* is synthesized following four general principles which are central to the GEO initiative (a rationale for each principle is provided at the beginning of each section):

- Integration of existing national or regional activities at global level.
- Cross-cutting research activities.
- Research activities necessary for emerging global integrated Earth observation systems.
- Research activities necessary for Earth observation capacity building.

Integration of existing national or regional research activities within GEOSS

In the GEO context the global dimension refers to processes with global consequences in aggregate, or with significant global causes, or which require observation enhanced by global systems. Many global observational research activities already exist focussing on particular issues or disciplines (some of which however lack sustainability in funding). Those activities need to be integrated and gaps need to be filled. The focus will be on the harmonization of the measuring methods to better combine observations of the same variable recorded by different sensors, and by different agencies each with their own data sharing policy. The goal should be the timely integration of observations from different observing systems in the global context. Hence, GEO should develop a strategy and plan to reduce limitations on data sharing for successful implementation of a system of observing systems and to ensure the taking into account of existing knowledge as well as to avoid duplication of efforts.

In this respect, the integrating capability of GEO – which will ensure that existing observation systems are coordinated and achieve similar standards everywhere on the planet – and the global dimension of the system of observation systems will fully address the challenges associated with improved understanding of the global integrated Earth System. For example, in developing an operational global carbon observing system (Figure 5), which will be a challenging goal for GEOSS, research and development are needed because monitoring the global carbon cycle addresses a wide range of spatial and temporal scales, from local power plants to carbon dioxide exchanges between the atmosphere, land, and ocean.

5 Section 5.5 Research Facilitation
6 Section 5.6 Capacity Building

Carbon Monitoring in the Climate System

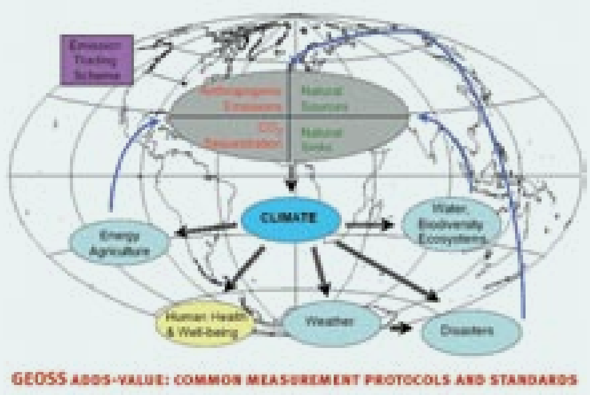

Figure 5: *From a scientific point of view, the establishment of the GEOSS is of crucial importance to answer important questions like the partitioning of CO2 sinks and sources within the global integrated Earth system, including between the marine and terrestrial biosphere, ocean, and the atmosphere, and an accurate monitoring of its temporal evolution (courtesy of P. LeGrand, EC).*

Cross-cutting research activities

Global Earth observation activities are multidisciplinary and of benefit to several societal benefit areas. Scientific communities that are well established can help other communities emerge and develop.

In the GEO context, key objectives include: (i) interoperability between observing systems, modelling systems, and information systems; (ii) data sharing and data dissemination (the GEONETCast system is an early example of what can be achieved; see Figure 6); and (iii) optimization of observations and information for understanding and predicting environmental phenomena.

Also the sustainability of global observations with sufficient space and time resolutions over time periods longer than issues and phenomena and availability of adequate geographical coverage and real-time data need to be addressed (see Figure 7). The integration of various sources of data, e.g., remote sensing and in-situ data, should also form part of this activity.

Global GEONETCast Coverage

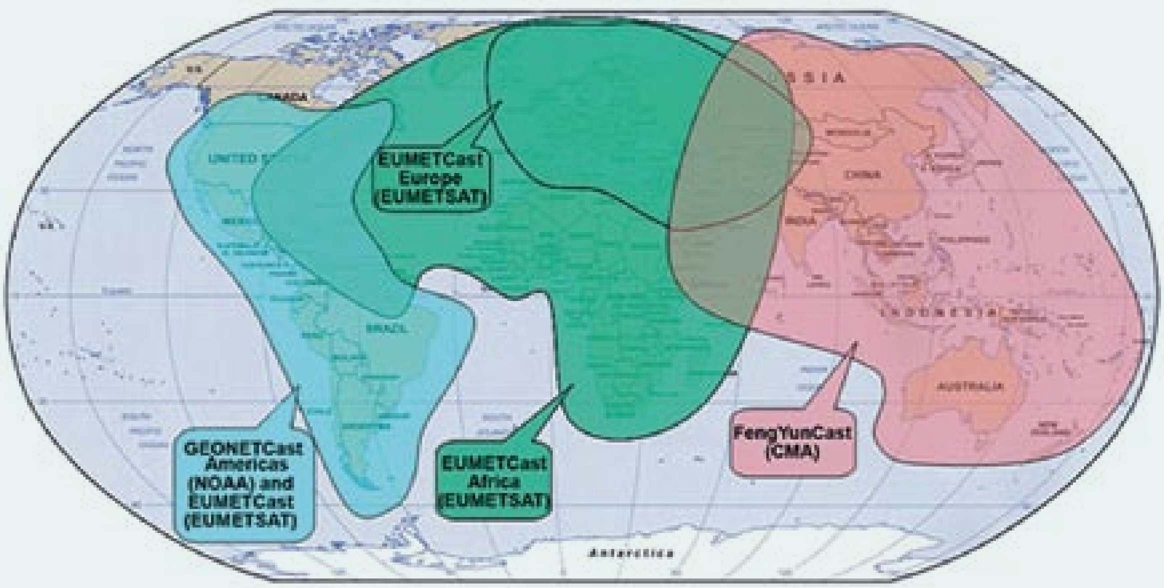

Figure 6: *GEONETCast is a near real-time, global, environmental information delivery system by which in situ, airborne, and space-based observations, products, and services from GEOSS are transmitted to users through communication satellites. Reception equipment is generic, off-the-shelf equipment and is relatively inexpensive (from 2007 GEO Ministerial Summit Early Achievement on "GEONETCast").*

Figure 7: *One of the key objectives of the GEO Asian Water Cycle Initiative is to develop timely, quality, long-term information on water quantity and quality, and their variations as a basis for sound national and regional decision-making. It will build on strong linkages between science communities, space agencies, and decision makers (from 2007 GEO Ministerial Summit Early Achievement on "Asian Water Cycle Initiative")*

Research activities necessary for emerging Earth observation systems

Figure 8: *MERIT (Meningitis Environmental Risk Information Technologies) aims to extend current capabilities to more effectively combine environmental information with knowledge of epidemic meningococcal meningitis. This will have an immediate impact on public health outcomes in Africa through increasing the effectiveness of prevention and response control strategies.*

A number of Earth observation activities address new topics or promote new approaches to outstanding issues (e.g., see Figure 8). These activities should support the development of Earth observation systems and related systems in areas of research where observing, monitoring, and modelling systems are lacking or need to be improved.

Research activity necessary for Earth observation capacity building

Increasing capacity building activities, in particular in developing countries, in the domain of Earth observation have strong implications for global integrated Earth system science and for the science and technological development, including education, of the countries (see Figure 9).

GEO will help scientists of developing countries to be involved in international research programmes (see Section 3.2) as a major capacity building effort. GEO intends for scientists from developing countries to be involved more in observations and science, thus contributing to improved monitoring and assessment of their natural resources (energy, water, raw material, etc.) and environment (climate, forests, etc.). Relevant GEO science and technology tasks should enable policy makers, as well as other stakeholders, in developing countries to be engaged in GEO activities so that education and research competencies in those countries are mobilized through GEO.

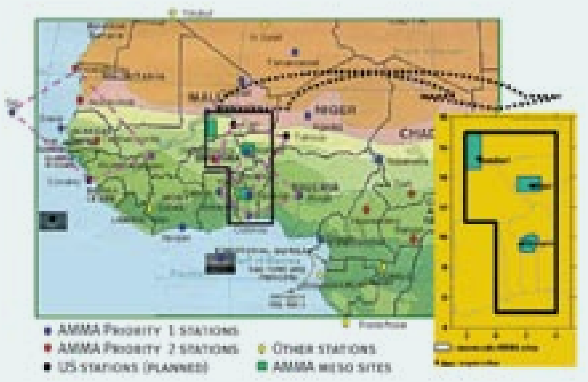

Figure 9: *Field implementation of AMMA (African Monsoon Multidisciplinary Analyses) observations based on nested networks. Circles indicated the atmospheric sounding network activated during the Special Observing Period (SOP) in Northern Hemisphere winter 2006. Enhancement of observations over this period provided a unique opportunity to determine future operational monitoring necessary to improve weather and climate forecasts in the West African region (AMMA International Science Plan).*

3.2. Relevant international research programmes and scientific partnerships

A great number of the existing observation systems of GEOSS derive from the data needs of international scientific programmes focused on improved understanding of the Earth's changing environment, the global integrated Earth system, and global change, as well as of the interrelationships between natural and human systems in the context of population increase, socio-economic development and technological progress. International scientific research programmes and international scientific assessments continue to guide the collection of observations of existing global environmental observing systems and ipso facto the identification of data requirements for the different GEOSS societal benefit areas. Optimal interlinkages between knowledge generation through scientific research, long-term observations, sharing of data and information, scientific assessments, and policymaking will support the GEOSS nine societal benefit areas.

Globally coordinated research programmes and projects related directly to GEOSS include notably the following:

- World Climate Research Programme (WCRP)
- International Geosphere-Biosphere Programme (IGBP)
- International Human Dimensions Programme on Global Environmental Change (IHDP)
- DIVERSITAS (an International Programme of Biodiversity Science)
- Earth System Science Partnership (ESSP), with its four global research projects:
    - Global Water System Project (GWSP)
    - Global Carbon Project (GCP)
    - Global Environmental Change and Food Systems (GECAFS)
    - Global Environmental Change and Human Health (GEC&HH)

Each of these international research programmes of global scale has different institutional sponsors, with WCRP (World Meteorological Organization (WMO), Intergovernmental Oceanic Commission (IOC) of UNESCO)) and DIVERSITAS (UNESCO) having United Nations (UN) organizations among their sponsors, in addition to international scientific organizations. One sponsor common to all of them is the International Council for Science (ICSU), ensuring that the activities are anchored in the worldwide scientific community. The global research endeavours listed above cover six of the nine GEOSS societal benefit areas (agriculture, climate, biodiversity, ecosystems, water and health). The World Weather Research Programme (WWRP) of WMO covers the societal benefit area "weather".

As regards "disasters", a natural and human-induced environmental hazards and disasters research programme is being prepared by ICSU.

While international research programmes of a global scale have been gradually put in place during the last three decades, global scientific assessments relevant to the nine societal benefit areas have developed much more slowly. Apart from notable exceptions (e.g. the Intergovernmental Panel on Climate Change (IPCC) and the Scientific Assessment of Ozone Depletion), international assessment bodies of comparable scope and regular output for other areas have not yet been institutionalized. However, the Millennium Ecosystem Assessment and the still ongoing International Assessment of Agricultural Science and Technology for Development are highly important milestones in their fields for improving the science for policy scheme. Other examples of assessments with mutually beneficial relationships to GEOSS are the World Water Assessment Programme (UN system) and the Global Energy Assessment, recently launched by the International Institute on Applied Systems Analysis (IIASA). For "biodiversity", a consultation process is underway to set up an International Mechanism of Scientific Expertise on Biodiversity (IMoSEB). In the area of "renewable energy", ICSU, the International Council of Academies of Engineering and Technological Sciences and the Renewable Energy Policy Network (REN21) jointly sponsor the International Scientific Advisory Panel on Renewable Energies.

The preparation of global state-of-the-art reports for an integrated global observing strategy was one of the main objectives in establishing in 1998 the Integrated Global Observing Strategy Partnership (IGOS-P). The IGOS-P includes GOS and GAW, GCOS, GGOS, GOOS, and GTOS, the international organizations which sponsor these observing systems, the Committee on Earth Observation Satellites (CEOS), the International Group of Funding Agencies for Global Change Research (IGFA), and some of the international global change research programmes.

The preparation of IGOS-P Theme Reports has brought together the producers of global observations and the users that require them in order to identify products needed, gaps in observations, and mechanisms necessary to respond to needs in the policy and science communities.

In addition to IGOS-P reports, other strategy documents are available dealing with observations in specific domains. For example, in the climate domain, these are notably the GCOS Implementation Plan and strategy documents from WCRP, IGBP and ESSP projects. Comprehensive ocean observing plans for each ocean basin have been developed through the WMO/IOC Ocean Observations Panel for Climate (OOPC), the International Ocean Carbon Coordination Project (IOCCP), and other international panels sponsored by the WCRP Climate Variability and Predictability Program (CLIVAR).

The IGOS-P has started transitioning its themes into GEO. The IGOS-P process will be "embedded" into GEO, thus providing added value in terms of:

- enhanced focus on end-user aspects and implementation plans.
- oversight of relevant IGOS-P processes by the GEO Science and Technology Committee and other GEO Committees.

A concrete example of a proactive approach to engage the science community in GEOSS through international research programmes is that introduced by the European Commission under the environment theme of the European Commission 7th Framework Programme (EC FP7).

The EC FP7 decision makes an explicit reference to the GEOSS initiative: *"contribute to the development and integration of observation systems for environmental and sustainability issues in the framework of GEOSS (to which the European initiative Global Monitoring for Environment and Security is complementary); interoperability between systems and optimisation of information for understanding, modelling and predicting environmental phenomena, for assessing, exploring and managing natural resources."*

The research activities relevant to GEO will be implemented through annual calls for proposals from 2007 until 2013, which is the duration of EC FP7. As indicated in the call for proposals, the research topics will be dealt with through the projects in coordination with the relevant GEO tasks. Thus there should be a direct contribution of the projects to GEO and the projects should benefit from the knowledge and participants within the GEO tasks. The projects are open to all research organisations in the 27 European Union countries, plus the countries associated to the Framework Program of Community Research. Third countries are also invited to participate to those projects, in particular because of the international dimension of the research activities to be carried out in the GEO context.

4 GEOSS and Science

4.1. What can Science do for GEOSS?

Every application of Earth observation builds on scientific results that require process understanding

In order to achieve the goals of GEOSS, formulated through societal benefit areas, the contribution of global Earth observations can only materialize through an understanding of the physical, chemical, biological, and ecosystem processes going on above, on and inside the Earth's surface. This is a task for the scientific community and needs comprehensive Earth observation technologies. Every application of Earth observation that has been developed builds on such a scientific understanding. This understanding is what links the observations, both from space and in-situ, to models of how the global integrated Earth system works. This linking of observations and models to provide quantitative estimates and predictions is a major task for the scientific community. It is also important to realize that this is usually a continuous process, where further scientific understanding in turn will further improve the applications. It is therefore essential that the scientific community be continuously involved in the improvement of existing applications (see Figure 10).

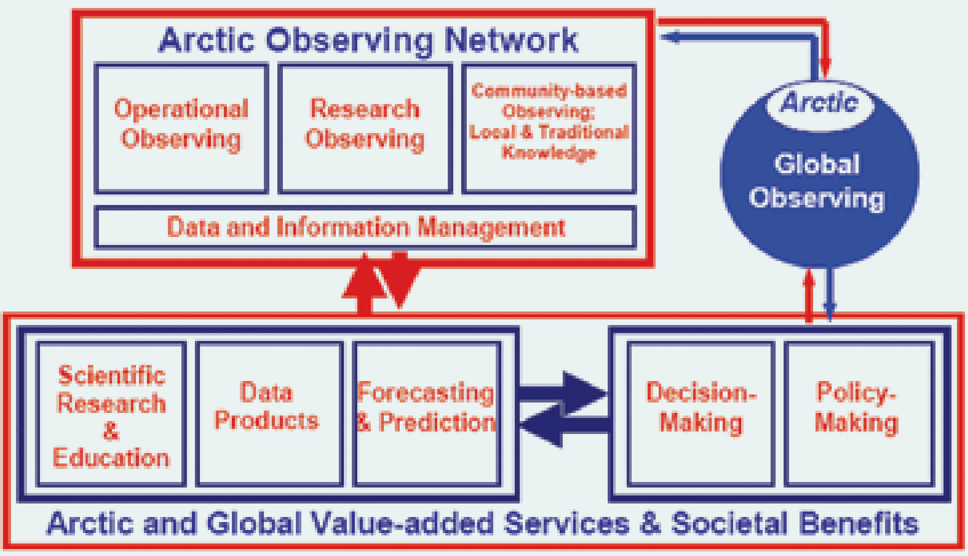

Figure 10: *Conceptual diagram of the Arctic Observing Network and the flows and exchanges of information that represent its contribution to value-added services and societal benefits of regional and global importance, and comprehensive observation of the Earth system (from 2007 GEO Ministerial Summit Early Achievement on "Arctic Observing Network").*

Connecting disciplines and addressing complex issues

The societal benefit areas typically require a cross-cutting scientific approach, building on information from a number of disciplines and data from different sources (see Figure 11). The scientific community needs to address these multidisciplinary questions, where scientists from different fields must collaborate. It necessitates the involvement of scientists from relevant disciplines of both natural and socioeconomic sciences.

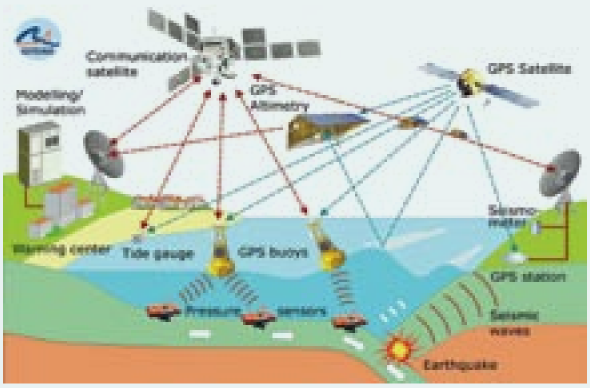

Figure 11: *The German Indonesian tsunami early-warning system is an integral part of a multi-hazard Early Warning System for the registration of other natural catastrophes including earthquakes and volcanic eruptions. The system integrates terrestrial seismologic and geodetic monitoring arrays with marine and satellite-based observation platforms (from 2007 GEO Ministerial Summit Early Achievement on "German Indonesian Tsunami Early-Warning System").*

Need to develop models in order to provide forecasting capabilities

The scientific understanding needs to be formulated to a large degree through models. These models are simplified simulations (approximations) to the actual processes and form the basis for testing the actual scientific understanding and also for developing forecasting capabilities. An essential part of these models is how they make use of the observational data available. The scientific community has been developing more and more sophisticated (high-resolution) models (see Figure 12) and data assimilation techniques. This needs to be done for large sets of data from different sources and with highly varying time and spatial scales. Traditionally these models have been addressing only a part of the global integrated Earth system, where the surrounding environment has been defined through some suitable boundary conditions.

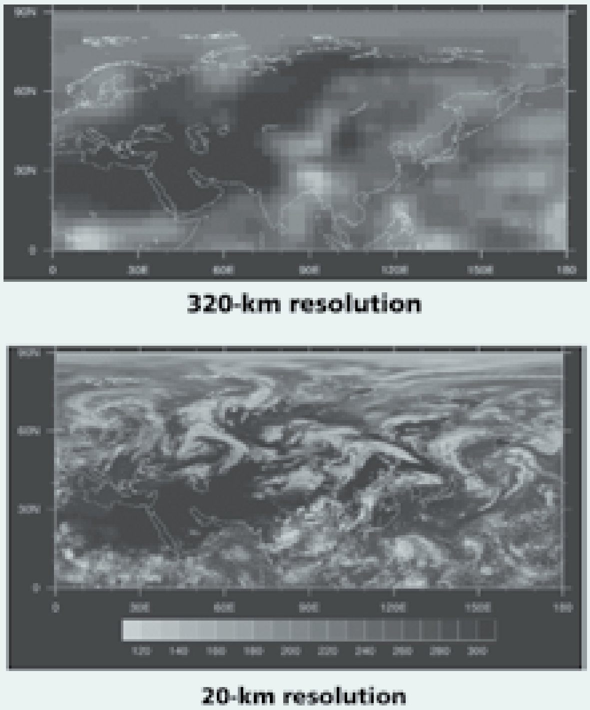

Figure 12: *The global cloud distribution in a present-day 320-km resolution climate simulation experiment (upper panel). Lower panel, same as upper panel, but for a 20-km resolution simulation with the same model (courtesy of T. Enomoto, JAMSTEC).*

Develop new observation and measurement techniques

The scientific community has been creative in inventing new observation and measurement techniques (e.g., see Figure 13). This requires a close cooperation between the scientific agenda and technology development. An integrated approach to the development of new Earth observations that includes surface-based networks, systematic aircraft as well as satellites is needed. Within Earth observation from space, techniques like synthetic aperture radar (SAR) interferometry (InSAR), altimetry and gravimetry are examples of techniques that have been able to facilitate applications of global Earth observation previously not considered possible.

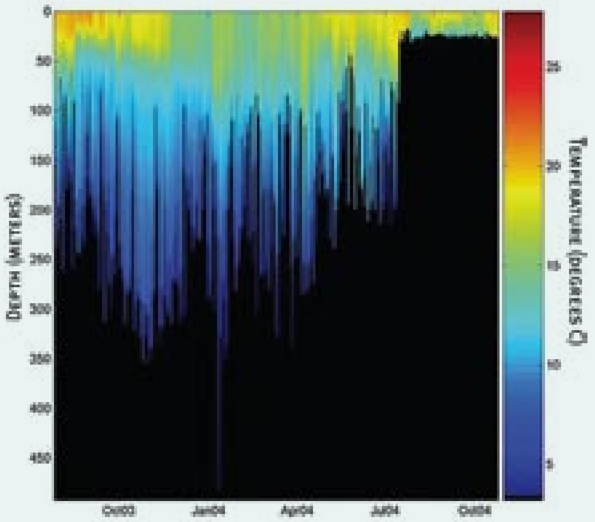

Figure 13: This graphic depicts depth and temperature data sampled along the North American west coast by a bluefin tuna. This is just one example of autonomous measurements of ocean properties that can be collected by sensors placed on oceanic animals (courtesy of B. Block, Census of Marine Life).

Improvement in surface-based observations of aerosols and their composition is critical for managing air quality effectively. For instance, next generation aerosol mass spectrometers will be available for routine monitoring. Vertical profiles of atmospheric chemistry and composition by satellite, aircraft and surface-based ozone and aerosol sensors, including lidar, are essential. It is crucial that the science and technology community continues this synergistic development. This must go hand-in-hand with new model and algorithm developments in order to utilize the new data. The key challenge is that monitoring systems which have been developed as part of scientific research and turned out to be essential for the monitoring of the global integrated Earth system need to be transformed into an operational and sustained mode. New methodologies must be assessed first whether they provide crucial new data and thus justify their inclusion in GEOSS. If so, the funding basis for these monitoring activities must be changed so that they do not dependent on research funds.

Data handling, processing and visualization

In addition to the scientific developments needed for providing the required understanding of the processes and interactions of the global integrated Earth system, there is also a need for a consistent science and technology agenda on issues like data handling, processing and algorithm techniques, semantic interoperability and data visualization. Progress in these fields is required in order to make data available in an efficient manner, to use it in models and to interpret the model results (see Figure 14). Also additional data sources are needed in order to make progress in modelling.

The Regional Visualization & Monitoring System SERVIR

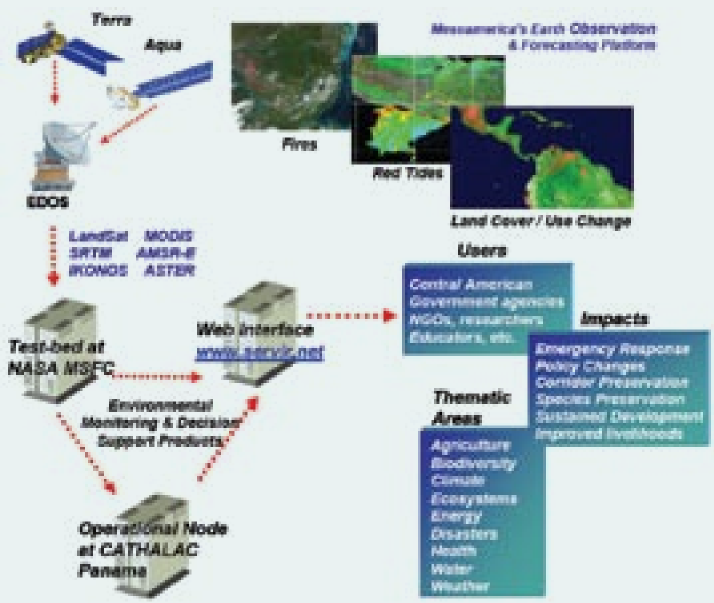

Figure 14: *The SERVIR system is web-based and provides a geospatial data portal, online mapping, thematic decision support tools for the GEOSS societal benefit areas, and three-dimensional, interactive visualization of the Earth and geospatial data (from 2007 GEO Ministerial Summit Early Achievement on "SERVIR: An Earth Observation, Monitoring, and Visualization System").*

4.2. What can GEOSS do for Science?

Linking observations across societal benefit areas

A major role of GEOSS is to promote scientific connections between the observation systems that constitute the system of systems. Thus GEOSS will enhance the value of the observations from an individual component system by extending the application data across societal benefit areas (see Figure 15). Such interactions should also promote the introduction of new scientific techniques and technologies in the component observing systems.

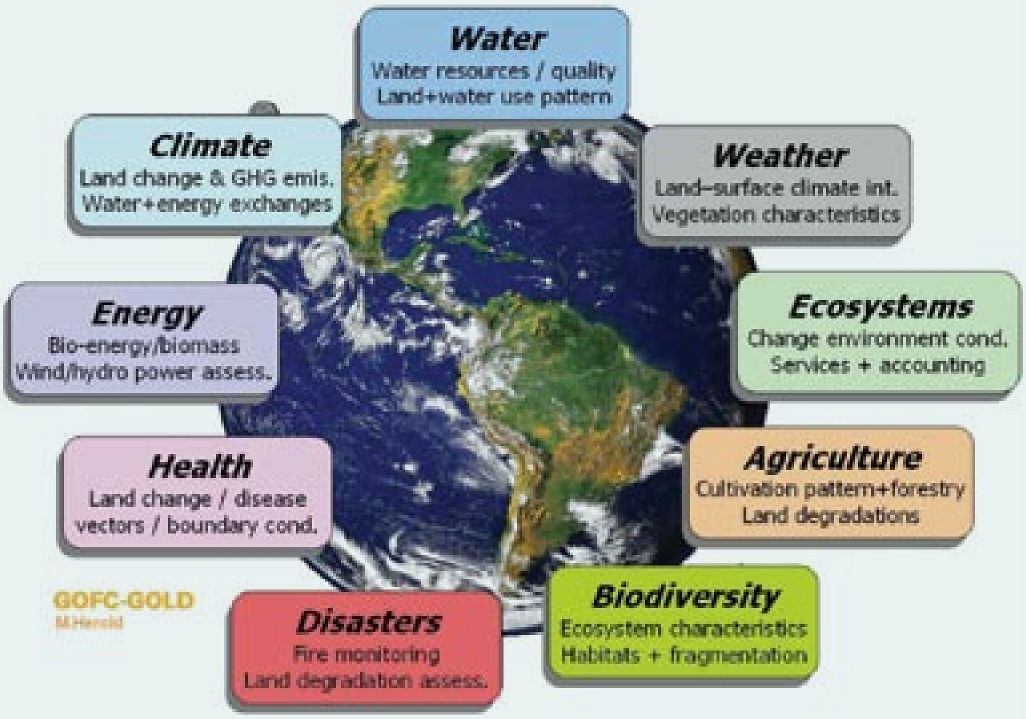

Figure 15: *Information needs and observation requirements for all GEO societal benefit areas emphasize the multitude of benefits from continuous and consistent global land cover observations (from 2007 GEO Ministerial Summit Early Achievement on "Improved global land cover observations and assessments").*

Identify gaps in observations, research and development

Through the definition of its overall goals, GEOSS emphasizes the need for increased scientific understanding to develop the necessary applications. By considering the application of observations across all the societal benefit areas, it should help identify gaps as well as overlaps in the observing systems in order to achieve an optimized data base in technical, operational and funding terms.

Provision of long time series of observations

The provision of long time series of in situ, aircraft and satellite Earth observation is fundamental to the progress in Earth sciences. Such observations are crucially important for detection of trends and, for example within climate change, a number of continuity and quality criteria for observational data have been defined under the "GCOS climate monitoring principles". In order to make possible a reliable detection of trends having a slow rate of change, the data must also be well calibrated and cross-calibrated with data from other sources. Through its societal benefit areas GEOSS identifies the need for such data.

GEOSS should support the sustainability and availability of long-term measurements by promoting this necessity to relevant funding agencies for the benefits, needs, and interests of all societal benefit areas.

Improve access and harmonization of in-situ data

Through GEOSS and its integrated observing components, the scientific community should have easy access to and make optimal use of data from different sources. In particular, the in-situ (see Figure 16), aircraft and satellite observations are highly diverse, not necessarily standardised in terms of formats, etc., and sometimes difficult to access. GEOSS will invest substantial efforts in data harmonization and better access.

Bridge gaps between science and application

GEOSS has the potential to bridge gaps between the societal benefits relevant applications and the necessary scientific developments.

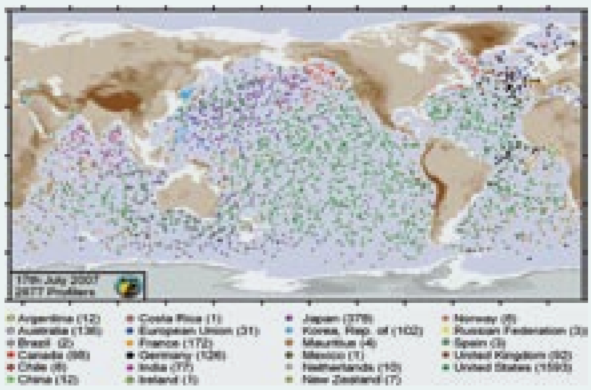

Figure 16: *The broad-scale global array of ocean temperature and salinity profiling floats, known as Argo, already grown to be a major component of the ocean observing system. Deployments began in 2000 (as of July 2007 close to 3000 floats had been deployed by scientists from 23 nations; from 2007 GEO Ministerial Summit Early Achievement on "Argo").*

5 Conclusions

This document describes the central importance of science and technology to GEO and the implementation of GEOSS. Addressing the scientific and technological aspects of the GEO Work Plan is vital to realizing the societal benefits promised by GEOSS and to raising political awareness of these benefits. Fortunately, the science community is becoming more and more involved in GEO, as confirmed by the inclusion of GEO Work Plan Tasks and activities in the programmes and strategies of a growing number of organizations. Some international organizations deeply involved in the shaping and implementation of research programmes are already GEO Participating Organizations and are contributing to the work of the GEO Science & Technology Committee. Increasingly, the connection to GEO has ensured the credibility of a programme or activity and become crucial for fund raising. This document seeks to encourage more scientists, research institutions, and funding agencies to contribute to GEOSS. In addition, it aims to engage the scientific community more fully in the construction of GEOSS in order to encourage further breakthroughs in our understanding of Earth's changing environment and the global integrated Earth system and of all GEO societal benefit areas.

Annex I

GEO 2007-2009 Work Plan Tasks assigned to the Science & Technology Committee

DI-06-03: Integration of InSAR technology

This task is led by IGOS-P and Greece

Point of Contact: Gonéri Le Cozannet (G.LeCozannet@brgm.fr)

Support the improved integration of InSAR (Interferometric Synthetic Aperture Radar) technology for disaster warning and prediction.

HE-07-02: Environment and Health Monitoring and Modelling

No Lead or Point of Contact

Initiate projects to further develop and integrate databases of remotely sensed and in-situ environmental measurements (including baseline geochemical data such as trace-element toxicity and deficiencies) together with new observations characterizing atmospheric, soil, river, lake and coastal marine pollution, and develop models to relate these to exposure and health effects data. This task will lead to the identification of mechanisms for alerting public health professionals on hazardous conditions identified by the monitoring of these parameters, as well as further informing epidemiological modelling studies.

EN-07-02: Energy Environmental Impact Monitoring

This task is led by the Netherlands

Point of Contact: Emile Elewaut (emile.elewaut@tno.nl)

Promote the development of Earth observation systems for the monitoring and prediction of environmental impact from energy resource exploration, extraction, transportation and/or exploitation. Related activities will include: Promote and develop the use of Earth observation data for impact monitoring; support the development of modelling systems helping to quantify and anticipate changes e.g. to freshwater, biodiversity, ecosystems, atmospheric and oceanic composition, and ground elevation, and make relevant synergies with carbon sequestration and greenhouse gas monitoring activities, and with Task US-07-01.

CL-06-01: Sustained Reprocessing and Reanalysis Efforts

This task is led by GCOS and CEOS

Ensure the development of international mechanisms to coordinate and maintain sustained climate data reprocessing and reanalysis efforts. With regard to the reprocessing of historical datasets (to obtain consistent long-time series of satellite records), make relevant synergies with Task CL-06-02.

CL-07-01: Seamless Weather and Climate Prediction System

This task is led by WWRP-THORPEX and WCRP

Point of Contact: Jim Caughey (jcaughey@wmo.int)

Support the development of a WWRP-THORPEX/WCRP initiative on "International Weather, Climate and Earth-system Science", to better address uncertainties associated with climate variability and change, and related societal impacts. Related activities will include: Promote international multi-disciplinary (physics-biology-chemistry) collaboration on the development of a high-resolution seamless weather/climate global prediction system - including coupled atmosphere-ocean data assimilation, and support the development of an international framework for the design and implementation of a unified approach toward weather, climate, Earth system, and societal-economic research.

WA-06-02: Forecast Models for Drought and Water Resource Management

This task is led by Tunisia, IGOS-P, WCRP and USA

Point of Contact: John Schaake (john.schaake@noaa.gov)

Enhanced prediction of the global water cycle variation is a key contribution to mitigation of water related disasters, drought, and sustainable human development. Forecasting methods are to be improved for use by hydrological services throughout the world. The hydrological data and information system infrastructure should be determined, the data from hydrological and meteorological services should be pulled together first on a global level including moisture flux from the air-sea interface, on a national level including terrestrial systems and then on river basin level. The systems should also be made interoperable to facilitate global exchange of data and information. An international symposium is proposed to be held on approaches to Earth observations, drought predictive capabilities and management responses.

WA-07-01: Global Water Quality Monitoring

This task is led by Finland and IGWCO

Point of Contact: Steven Greb (steven.greb@wisconsin.gov)

Many aspects of water quality monitoring and assessment, both in-situ and remotely sensed are severely deficient. Many countries lack the technical, institutional, and financial resources to conduct proper assessments using in-situ water quality monitoring methods for terrestrial sources and in the coastal ocean. Remote-sensed operational systems of global-scale freshwater quality are non-existent. Operational observation systems need to be developed, and the resulting information systems should be made compatible and interoperable as part of the system of systems. This task builds on the outcomes of the water quality workshops in 2006 and 2007 and first pilot projects are being planned to begin in Asia as a result of the Asia Water Resource Management Capacity Building Workshop. This Task has relevant synergies with HE-07-02.

WA-O8-01: Integration of In-situ and Satellite Data for Water Cycle Monitoring

This task is led by Portugal, WMO, IGOS-P, Japan, and GOOS
It represents the merger of WA-06-05 and WA-07-02.
Current capabilities of water cycle observations are inadequate for monitoring long-term changes in the global water system and their feedback into the climate system. In addition, the lack and inaccessibility of crucial data is a major constraint on decision-making for sustainable development of water resources and improvement of water management practices. To address this gap, an integrative initiative is needed, involving different types of scientific- as well as applications-oriented efforts and initiatives (e.g. WCRP/GEWEX/CEOP). It would combine different types of satellite and in-situ observations related to key variables of the water cycle (e.g. precipitation, soil moisture, snow water equivalent, surface water, ground water, streamflow, etc.), eventually with model outputs, for improved accuracy and global coverage. In addition to filling gaps in measurement capability, the initiative should advocate the interoperability of observing systems and standardization of metadata in order to promote the sharing of data and telecommunication infrastructures. The Hydrological Applications and Run-Off Network (HARON) Project is proposed as one of the means to accomplish the operational aspect of these goals, and ultimately provide the most comprehensive water cycle information possible to the science community, water resource managers, and other decision-makers. Other ongoing initiatives related to integrated precipitation products, soil moisture and groundwater will also provide essential contributions.

WE-06-03: THORPEX Interactive Global Grand Ensemble (TIGGE)

This task is led by WWRP-WMO
Point of Contact: Jim Caughey (jcaughey@wmo.int)
Facilitate the development and maintenance of a prototype global operational multi-model ensemble prediction system (e.g. through THORPEX) incorporating easily accessible databases. Development of TIGGE, together with regional ensemble prediction systems (TIGGE-LAM) and the associated data bases, will be an important contribution to the successful implementation of a number of GEO tasks that relate to risk management, early warning systems, major hazards and associated impacts.

WE-07-01: Data Assimilation and Modelling for Operational Use

This task is led by IGOS-P, WMO/GAW, and Australia
Point of Contact: John LeMarshall (j.lemarshall@bom.gov.au)
Advocate and facilitate the development and implementation of advanced data assimilation systems that will be able to fully exploit a broad spectrum of surface-based and space-based Earth observations. In particular, there is a need for a focused effort to develop and support the assimilation of aerosols by weather forecast models that actively couple aerosols to radiation and hence address feedbacks on significant weather including heat waves, extra-tropical storms, monsoon onsets, and breaks.

EC-06-01: Integrated Global Carbon Observation (IGCO)

This task is led by USA and IGOS-P
Point of Contact: Roger Dargaville (r.dargaville@unesco.org)
Support the Integrated Global Carbon Observation (IGCO) development of a global carbon-observing system, in particular improved global networks of in-situ CO2 observations and absorption of CO2 by the oceans and resulting acidification.

EC-06-02: Ecosystem Classification and Mapping

This task is led by the USA and Paraguay
Point of Contact: Roger Sayre (rsayre@usgs.gov)
Continue the work of the Ecosystems Classification Task Force, covering terrestrial, freshwater, and ocean ecosystems, to create a globally agreed, robust, and viable global classification scheme for ecosystems. Establish links to existing databases, such as the Ocean Biogeographic Information System. In parallel with the classification effort, develop, review, and initiate a mapping approach to spatially delineate the classified ecosystems.

EC-07-01: Global Ecosystem Observation and Monitoring Network

No Lead or Point of Contact.
This task will coordinate and improve terrestrial (forests, urban agriculture, woodlands, grasslands, and deserts), freshwater, ice, and oceans ecosystem observation, characterization and monitoring especially in terms of acquisition and use of satellite, aerial and in situ observation. This theme will address the development of a global integrated sampling frame in coordination with the GEOSS Geodesy activities. It will promote characterization, mapping and monitoring of ecosystems at local, national, regional and global scales, and systematic and formal methods for measuring land surface and vegetation attributes, especially for the protected areas systems planning, characterization, and monitoring of protected areas.
Task components include developing formal methods for collecting plot (in-situ) data, and for translating between different systems, produce a manual of fields methods for terrestrial data, and capture existing plot data into an operational information system. The task will also promote the use of Earth observation data to detect the effects of insects, pathogens, water temperature, and elevation and chemical stresses on ecosystems.

AG-06-02: Data Utilization in Aquaculture

This task is led by Spain and Canada

Point of Contact: Cristobal Suanzes (cristobal.suanzes@md.ieo.es)

Consult with scientists and experts from the fisheries, aquaculture, coastal zone management and Earth observation communities at international and regional levels to identify opportunities for enhanced utilization of Earth observations in fisheries and aquaculture.

AG-07-01: Improving Measurements of Biomass

This task is led by the USA.

Point of Contact: Steven Running (swr@ntsg.umt.edu)

In order to enable a sustained use of Earth observation data in the area of agriculture and fisheries, it is necessary to further explore the utility of current Earth observations within the agricultural and marine biology sectors, especially in developing countries with an emphasis on improving classification and quantification of terrestrial and marine biomass.

BI-06-03: Capturing Historical Biodiversity Data

This task is led by GBIF

Point of Contact: James Edwards (jedwards@gbif.org)

Implement the strategic plan for capturing historical biodiversity data from natural history collections and the research community. The Global Biodiversity Information Facility (GBIF), with DIVERSITAS and GTOS, conducted a workshop on "Defining user needs for a global observation system for biodiversity" on 23-25 October 2006.

BI-07-01: Biodiversity Observation and Monitoring Network

This task is led by DIVERSITAS International and the USA.

Point of Contact: Norbert Juergens (Norbert.Juergens@t-online.de)

Develop and implement a biodiversity observation network 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 socioeconomic importance, and which can support the 2010 CBD target. Develop a strategy for assessing biodiversity at both the species and ecosystems level. Facilitate the establishment of monitoring systems that enable frequent, repeated, globally coordinated assessment of trends and distributions of species and ecosystems of special conservation merit. Facilitate consensus on data collection protocols and the coordination of the development of interoperability among monitoring programs.

BI-07-02: Invasive Species Monitoring System

This task is led by the USA

Point of Contact: Anne Simpson (asimpson@usgs.gov)

Invasive alien species (IAS) threaten biodiversity and exert a tremendous cost on society for IAS prevention and eradication. They endanger natural ecosystem functioning and seriously impact biodiversity and agricultural production. It is therefore necessary to characterize, monitor and predict changes in the distribution of invasive species. This task will characterize the current requirements and capacity for invasive species monitoring, identify gaps, and develop strategies for implementing cross search functionality among existing online invasive species information systems from around the globe. The task will be coordinated by members of the Global Invasive Species Information Network (GISIN), including (but not limited to) the USGS National Biological Information Infrastructure (NBII), IUCN/SSC Invasive Species Specialist Group (ISSG), the Global Biodiversity Information Facility (GBIF), the Global Invasive Species Programme (GISP), and CAB International, with collaboration from NASA, the USGS National Institute of Invasive Species Science, Discover Life, Diversitas International, and other information managers working with the invasive species science community.

DA-06-03: Ensemble-Technique Forecasting Demonstrations

This task is led by the UK and Greece

Point of Contact: Craig Donlon (craig.donlon@metoffice.gov.uk)

Facilitate the development of demonstration projects promoting the wider use, in other disciplines, of ensemble-based techniques originally developed for weather forecasting.

Annex II

List of Acronyms

ACC .... Antarctic Circumpolar Current
AMMA .... African Monsoon Multidisciplinary Analyses
CBD .... Convention on Biological Diversity
CEOP .... Coordinated Energy and Water Cycle Observations Project
CEOS .... Committee on Earth Observation Satellites
CLIVAR .... Climate Variability and Predictability Program
EC .... European Commission
EC FP7 .... European Commission 7th Framework Program
ECMWF .... European Centre for Medium-range Weather Forecasts
ESSP .... Earth System Science Partnership
GAW .... Global Atmosphere Watch
GBIF .... Global Biodiversity Information Facility
GCOS .... Global Climate Observing System
GCP .... Global Carbon Project
GECAFS .... Global Environmental Change and Food Systems
GEC&HH ..... Global Environmental Change and Human Health
GEO............. Group on Earth Observations
GEO-IV .... 4th GEO Plenary Meeting
GEOSS .... Global Earth Observation System of Systems
GEWEX .... Global Energy and Water Cycle Experiment
GGOS .... Global Geodetic Observing System
GISIN .... Global Invasive Species Information Network
GISP .... Global Invasive Species Programme
GOFC-GOLD Global Observation of Forest and Land Cover Dynamics
GOOS .... Global Ocean Observing System
GOS............. Global Observing System
GTOS .... Global Terrestrial Observing System
GWSP .... Global Water System Project
HARON........ Hydrological Applications and Run-Off Network
IAS .... Invasive Alien Species
ICSU .... International Council for Science
IGBP .... International Geosphere-Biosphere Programme
IGCO .... Integrated Global Carbon Observation
IGFA .... International Group of Funding Agencies for Global Change Research
IGOS-P .... Integrated Global Observing Strategy Partnership
IGWCO .... Integrated Global Water Cycle Observations
IHDP .... International Human Dimensions Programme on Global Environmental Change
IIASA .... International Institute for Applied System Analysis
IMoSEB .... International Mechanism of Scientific Expertise on Biodiversity
InSAR .... Interferometric Synthetic Aperture Radar
IOC.............. Intergovernmental Oceanographic Commission
IOCCP.......... International Ocean Carbon Coordination Project
IPCC .... Intergovernmental Panel on Climate Change
ISSC............. Invasive Species Specialist Group
IUCN .... The World Conservation Union
JAMSTEC ..... Japan Agency for Marine-Earth Science and Technology
JMA............. Japan Meteorological Agency
LAM .... Limited Area Model
MERIT.......... Meningitis Environmental Risk Information Technologies
NASA .... National Aeronautics and Space Administration
NBII .... National Biological Information Infrastructure
NH............... Northern Hemisphere
NOOA .... National Oceanic and Atmospheric Administration
NWP............ Operational numerical weather prediction
OOPC .... Ocean Observations Panel for Climate
REN21 .... Renewable Energy Policy Network
SAR .... Synthetic Aperture Radar
SBA .... Societal Benefit Area
SDI .... Space Data Infrastructure
SH .... Southern Hemisphere
SOP .... Special Observing Period
SSC.............. Species Specialist Group
SSH.............. Sea Surface Height
THORPEX .... The Observing-system Research and Predictability Experiment
TIGGE .... THORPEX Interactive Global Grand Ensemble
TOPEX .... Topography Experiment
UN............... United Nations
UNESCO ...... United Nations Educational, Scientific and Cultural Organization
USA............. United States of America
USGS .... U.S. Geological Survey
WCRP.......... World Climate Research Programme
WHO .... World Health Organization
WMO .... World Meteorological Organization
WWRP......... World Weather Research Programme

GROUP ON EARTH OBSERVATIONS

Annex III

GEO Members and Participating Organizations represented on the GEO Science and Technology Committee

Members

Argentina
Australia
Canada
China
Croatia
European Commission
Finland
France
Germany
Greece
India
Iran
Italy
Japan
Korea, Republic of
Mauritius
Netherlands
New Zealand
Norway
Portugal
Russian Federation
South Africa
Spain
Switzerland
Thailand
Ukraine
United Kingdom
United States
Uzbekistan

Participating Organizations

AARSE	African Association of Remote Sensing of the Environment
CEOS	Committee on Earth Observation Satellites
COSPAR	Committee on Space Research
DIVERSITAS	An international programme of biodiversity science
ECMWF	European Centre for Medium-Range Weather Forecasts
EEA	European Environmental Agency
EUMETNET	Network of European Meteorological Services/Composite Observing System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EuroGeoSurveys	The Association of the Geological Surveys of the European Union
FDSN	Federation of Digital Broad-Band Seismograph Networks
GCOS	Global Climate Observing System
GOOS	Global Ocean Observing System
IAG	International Association of Geodesy
ICSU	International Council for Science
IEEE	Institute of Electrical and Electronics Engineers
IGBP	International Geosphere-Biosphere Program
IGOS-P	Integrated Global Observing Strategy Partnership
ISCGM	International Steering Committee for Global Mapping
ISPRS	International Society for Photogrammetry and Remote Sensing
POGO	Partnership for Observation of the Global Ocean
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

European Commission

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