IAG

GGOS Implementation Plan

Participants of 1st GGOS Workshop, GFZ Potsdam, March 2005

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1 Preamble

Sustaining life of an increasingly vulnerable human society on a highly dynamic planet requires a significant advance in understanding the functionality of system Earth with all its components and at all spatial and temporal scales. The interaction of processes in the deep Earth interior with the lithosphere, of the lithosphere with the oceans and atmosphere, and of the oceans with the cryosphere and atmosphere - to name only a few - and their impact on global, regional and local environments ultimately control a multitude of natural risks and threats to the human habitat. Substantial improvement of our present knowledge of the highly complex Earth dynamics calls for the development of a consistent reference model of the Earth system. This requires long-term global to regional data series from a large variety of well calibrated sensors and networks combined with improved data management, high performance computing, sophisticated models and expanded multidisciplinary scientific and technical expertise.

Time has come that geodesy can make a major contribution to the development of such a consistent reference model by providing a new tool to the global geosciences community consisting mainly of high quality services, well defined standards and references , and theoretical and observational innovations.

The International Association of Geodesy (IAG) has therefore adopted in 2003 at the IUGG General Assembly in Sapporo the project GGOS, which stands for Global Geodetic Observing system, and which aims at integrating the existing ground- based geodetic networks and observatories, the altimetric, remote sensing and global navigational satellite systems, and the dedicated geodetic satellite missions

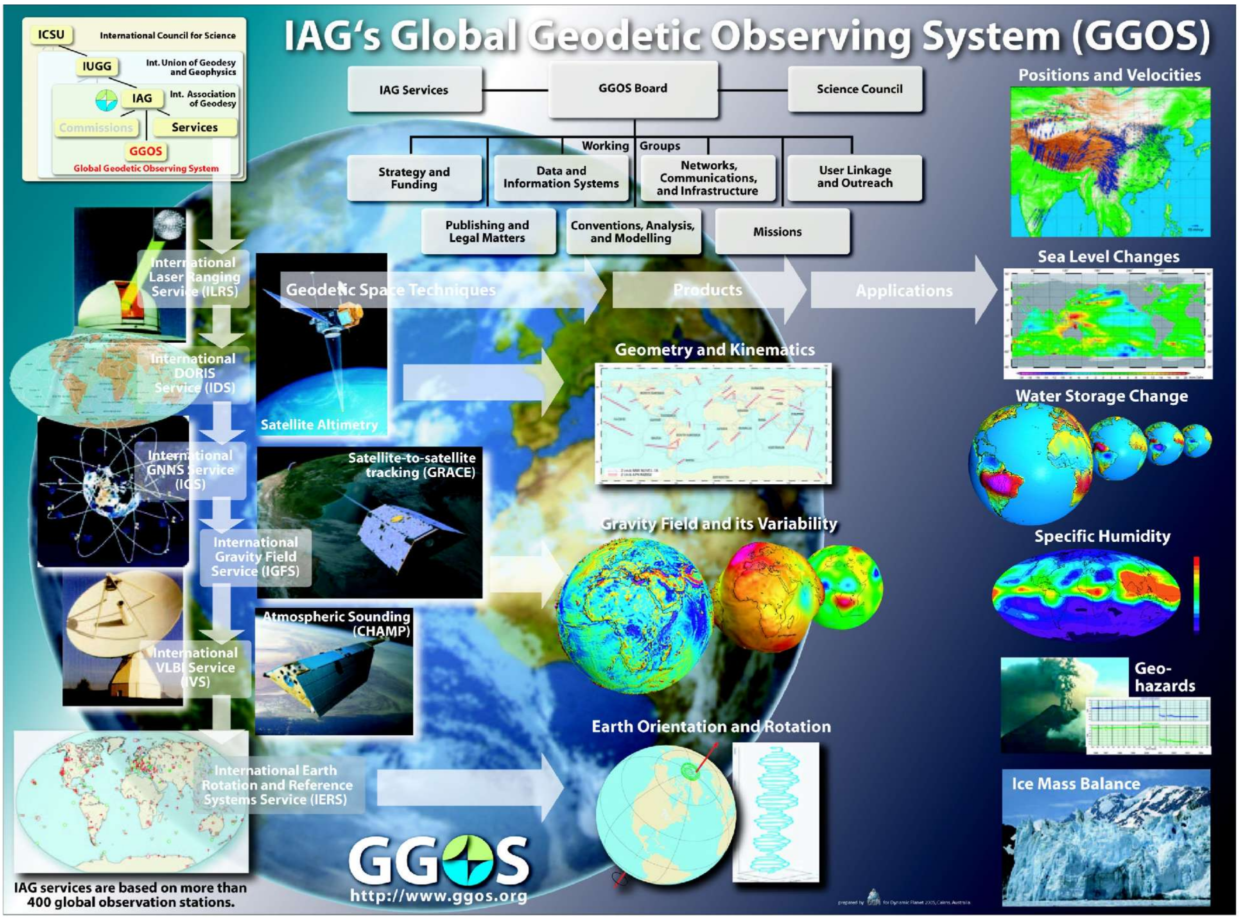


Fig. 1: Sketch of preliminary structure, tasks and contributions of GGOS.

into a coherent observation system The mission of this system is to provide on a global scale the spatial and temporal changes of the three pillars of geodesy – surface geometry, Earth orientation and gravity field- in a consistent way, in an uninterrupted processing sequence and with a resolution and precision adapted to the latest scientific and practical needs of Earth sciences. Such an integrated global geodetic observing system can only be realized through a close cooperation of the existing geodetic services and the supporting agencies and institutions worldwide. An initial version of tasks, functions and structure of GGOS has been worked out by the GGOS pilot project group in the timeframe 2003-2005.

The information provided in the sequel shall support the IAG Executive Committee in its decision process for the GGOS transfer from the Pilot Project phase into an operational activity.

1.1 Documents

The following documents and URLs contain reference material to this plan:

IAG: Geodesist's Handbook, J. of Geodesy, 77, 2004.

Plag, H.-P., G. Beutler, R. Forsberg, C. Ma, R. Neilan, M. Pearlman, B. Richter, S. Zerbini, 2005: The Global Geodetic Observing System (GGOS): observing the dynamics of the Earth system. Document prepared for IGOS-P. Available at http://geodesy.unr.edu/ggos_wgplm/igos-p/index.php

Rummel, R., H. Drewes, W. Bosch, H. Hornik (eds.), 2000. Towards an Integrated Global Geodetic Observing System (IGGOS), IAG Symposia, Vol.120, 260 pages, Springer.

Rummel, R., H. Drewes, G. Beutler, 2002. Integrated Global Geodetic Observing System (IGGOS): A Candidate IAG Project, in: Vistas for Geodesy in the New Millenium, eds: J. Adam and K.-P. Schwarz, IAG Symposia, Vol. 125, pp. 609 – 614 Springer.

GEO homepage http://earthobservations.org

GGOS homepage http://www.ggos.org

IAG homepage http://www.iag-aig.org

IGOS-P homepage http://www.igospartner.org

1.2 Abbreviations

EPIGGOS	European Partners in the Integrated Global Geodetic Observing System
GAGOS	EU 6th Framework Project "Assessing and forward planning of the Geodetic And Geohazard Observing Systems for GMES applications"
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GGOS	Global Geodetic Observing System
GGOS-D	Joint GGOS project of German research institutes within national R&D program 'Geotechnologien'
IAG	International Association of Geodesy
IGOS-P	Integrated Global Observing Strategy Partnership
INDIGO	Inter-Service Data Integration for Geodetic Operations
NGO	US National Geodetic Observatory
NGOS	Nordic Geodetic Observing System

2 GGOS Objectives

The general objectives of GGOS are derived from its mission, which is the integration and coordination of the different geometric and gravimetric observation techniques, analysis models and evaluation approaches, and the promotion of geodesy in science and society. They aim at ensuring the consistency of geodetic products and providing the scientific basis for all geodynamic and global change research. These general objectives are laid down in the initial GGOS Terms of Reference (Geodesist's Handbook, J. of Geodesy, 77, 673-676, 2004) and may be summarized in three principal groups: geodetic observations, geodetic products and the representation of geodesy in science and society.

- *Observations*: GGOS aims at maintaining the stability of and providing the ready access to the existing geometric and gravimetric reference frames by ensuring the generation of uninterrupted time series of state-of-the-art global observations related to the three pillars of geodesy, namely the Earth's surface geometry, Earth rotation and Earth gravity field.
- *Products*: GGOS focuses on all aspects relevant to the consistency of geometric and gravimetric products. This requires the consistency between all the geodetic constants and conventions used in the geosciences community. The targeted overall accuracy and consistency of GGOS products is in the order of 10^{-9} or better.
- *Representation*: GGOS shall promote and improve the visibility of the scientific research in geodesy. It shall be established as an official partner in IGOS, the United Nation's Integrated Global Observing Strategy, and other relevant international bodies in order to achieve maximum benefit for the scientific community and society in general.

These general objectives may be further concretized by specifying some shortcomings of present geodetic methods and procedures, and by discussing possible improvements and innovations to be implemented through the coordination of GGOS. Only a thorough analysis of the status and the study of new options will enable effective measures for future corrections.

Geodetic observations using different techniques are presently done – in general – independently. Observation instruments are co-located at a geographical location mainly for logistic reasons rather than for the mutual benefit of the observed data. The measured local ties between instruments are often of lesser quality than the computed coordinate differences from global networks. Results of different techniques are not always consistent. We have, e.g., different temporal coordinate changes (station motions) at the same geographical site without physical explanation. Reduction models (e.g., for the atmosphere) vary between different techniques. The objective of GGOS is to coordinate the different techniques by, e.g., encouraging and promoting precise local surveys of all geodetic sites and by recommending identical models for the reduction of the observations.

The processing of the observation data is not always done using identical constants, conventions, models and parameters. In particular the geometric and gravimetric approaches differ partly. This is largely due to natural circumstances (geometric and physical reality) but also induced by man made conventions. Examples of such inconsistencies are listed in Table 1. The objective of GGOS is to exploit all possibilities to bring the geometric and gravimetric community together in order to use the same approaches and conventions for their data analysis. This will not always be feasible by exactly the same numbers but a strict relationship between geometric and gravimetric parameters has to be guaranteed. GGOS shall also coordinate the improvement of common models by using information from all available data of the different techniques (e.g., solid Earth tides, atmosphere and hydrosphere loading).

		Geometric parameters	Gravimetric parameters
Definition	of origin	centre of network: X_0, Y_0, Z_0	centre of mass: C_{10}, C_{11}, S_{11}
	of orientation	rotation axis: X_P, Y_P	axes of inertia: C_{21}, S_{21}
	of scale	c: speed of light	GM
Models	for tides	tide free	zero tide
	for deformation	geometric only	dynamic
Product	reference	ITRF, GRS80	variable
	update	regularly	episodic

Table 1: Examples for possible inconsistencies in geodetic conventions and models.

Geodetic products are increasingly important for many branches in science, practice and society. While the classical task of geodesy is the measurement and mapping of the Earth's surface, we have now a broad variety of scientific and practical applications, e.g., geodynamics and global change research, astronautics, navigation, global spatial data infrastructure, land management, geo-information, engineering, cadastre, etc. The community of different users expects ready access and easy understandability of products like coordinates, sea and land surface, and gravity data. They shall be accurate, reliable, unequivocal, consistent and clear. The objective of GGOS is to assist the IAG services to meet the expectations. GGOS shall stimulate close cooperation, identify gaps in the products and develop strategies to close them. Examples are given in Table 2.

Geodetic field	Missing service or product
Solid Earth geometry	Unified global height reference system (global vertical datum)
	Vertical deformation models (tectonic, isostatic, loading, ...)
Ocean surface	*Open, ready access to sea surface data (satellite altimetry service)*
Earth orientation	Consistency of celestial and terrestrial reference frames, and of Earth orientation parameters
Gravity field	Free availability of all terrestrial gravity data

Table 2: Examples of gaps in services and products.

The International Terrestrial Reference Frame (ITRF) provided by IAG's services (IERS and technique-specific services) as the unique global geometric reference has become a fundamental tool for almost any precise positioning on land, on sea and in the air all over the world. Satellite orbits are freely available to the users and refer to the same system as the terrestrial positions. An adequate unique gravimetric reference, however, is still missing. The geometric and gravimetric products are not always fully compatible, i.e., the users cannot combine them directly but they have to perform transformations, which are not easily understandable for outsiders. The missing knowledge of the characteristics of the data complicates or even makes impossible the proper use of geodetic products. The objective of GGOS is to coordinate the generation of consistent and compatible products and to stimulate their continuous and reliable generation.

The *representation of geodesy* in public is a fundamental requirement in our information society. It is obvious that geodesy is not well known in society and politics, and that other disciplines are not really aware of geodesy's fundamental metrological role and capacity in science. Geodetic products are often taken as naturally-given information without appreciating the efforts necessary for their generation.

GGOS will have the main objective to make geodesy more visible in science, politics, economics and society in general. GGOS wants to make a wider community aware of the fact that geodesy provides the basis for all positioning, orientation and dynamic parameters in space and time, and that the support of society for geodesy is needed in return.

Many results of geodetic research are not sufficiently known by politicians and decision makers.. Signals of global change and geodynamics are not always correctly interpreted because they are not clearly documented and presented. Public discussions on geoscientifically relevant topics proceed often without the required seriousness because of incomplete information. The objective of GGOS is to disseminate all geodetic products and results with the requested explanations and metadata. It shall provide the politicians with the information for their planning and decision making. GGOS shall participate in the relevant international groups in order to represent geodesy in the important bodies to the benefit of science and society.

Internat. organisation	**Geodetic activity (membership, partnership, participation)**
United Nations (UN)	UN Educational, Scientific and Cultural Organization (UNESCO) *International Council for Science (ICSU)* • Committee on Data for Science and Technology (CODATA) • Committee on Space Research (COSPAR) • Federation of Astronomical and Geophysical Data Analysis Services (FAGS) • Scientific Committee on Antarctic Research (SCAR) • Scientific Committee on the Lithosphere (SCL)
Intergovernmental	Integrated Global Observing Strategy (IGOS) • IGOS Partnership (IGOS-P) • IGOS Themes (e.g., geohazards, global water cycle) • Global Observing Systems (G3OS): Climate, Ocean, Terrestrial Group on Earth Observations (GEO) • GEO Plenary • Global Earth Observation System of Systems (GEOSS) • Working Groups (Architecture and Data, Science and Technology, Capacity Building and Outreach, User Interface)

Table 3: Examples of geodetic activities in international bodies.

3 Scientific Rationale

The Earth with its atmosphere, oceans, ice sheets, land surfaces, and its interior is subject to a multitude of dynamic processes covering a broad variety of spatial and temporal scales. The Earth's motion is driven by a large number of interior and exterior forces. These processes are influenced by man-made effects as well; to a largely unknown extent. Earthquakes, volcano eruptions, tectonic deformations, land slides, de-glaciation processes, sea level rise, tsunamis, floods, desertification, storms, global warming and many more are typical and well known phenomena of this highly dynamic "engine". All phenomena affect our life and the life of future generations. Major decisions facing human societies will depend on a much deeper understanding of this complex system. Large international efforts on the governmental and the scientific levels are currently underway towards improving our understanding of the system Earth.

The International Association of Geodesy (IAG) will contribute a new and very important segment to the study of the system Earth. IAG will provide on a global scale the spatial and temporal changes of the figure of the Earth, of the ocean surface, of ice covers, and land surfaces. It will deliver a global picture of surface dynamics of our planet and will provide an assessment of mass anomalies, mass transport and mass exchange processes in the Earth's system. Furthermore, IAG delivers time series of Earth rotation. They reflect, among other, the exchange of angular momentum between Earth system components. The combination of these elements is the key to the understanding of the global mass balance and it is an important contribution to the understanding of the global energy budget of our planet.

The Global Geodetic Observing System (GGOS) will fully exploit (and try to extend) the unique constellation of satellite missions relevant to this goal, which is in orbit now and which will be launched within the next decade by integrating them into one measurement system. The backbone of an integration of this type is given by the already existing global ground network, based on the geodetic space techniques VLBI, SLR, GPS and DORIS. The space segments and global ground network will be complemented by airborne and terrestrial campaigns serving the purpose of calibration and validation, of regional densification, and of refinement, identification, and separation of individual effects. Assimilation of the geodetic observations into models of weather, climate, ocean, hydrology, ice, and solid Earth will fundamentally enhance the understanding of the role of surface changes and mass transport for the dynamics of our planet.

Research challenges of GGOS

Geodesy is traditionally concerned with the measurement of, *firstly*, the changes of the surface geometry of the Earth i.e., the variations of ocean surfaces and ice covers and of horizontal and vertical deformations of land surfaces (geometry part), *secondly*, the fluctuations in the orientation of our rotating planet in space, commonly divided into precession, nutation, polar motion, and changes in the spin rate (Earth rotation part), and, *thirdly*, the variations in space and time of the Earth's gravitational field, usually expressed as anomalies of gravity and of the geoid (gravity part). Furthermore, through the analysis of the dense array of microwave rays continuously travelling from the GNSS satellites through the atmosphere to receivers on satellites in low orbits (low Earth orbiting satellites, LEOS) and on the Earth's surface, a powerful new method emerges for probing key quantities of the atmosphere and ionosphere.

In the past, geophysical research concerned with the three geodetic components, namely geometry, Earth rotation, and gravity, as well as with the sounding of the atmosphere, was focused on individual processes rather than on the added-value, which can be drawn from their integration. GGOS intends to give to these fundamental fields of geodesy a new quality and dimension in the context of Earth system research by combining them to one observing system with utmost precision and in a well-defined and reproducible global terrestrial frame. The observing system, in order to meet its objectives, has to combine highest measurement precision (a relative precision of one part-per-billion, 1 ppb=10^{-9}) with utmost consistency in space, time, and in the applied data modelling, and with stability over decades. The various aspects related to GGOS are discussed in greater detail in (Rummel et al., 2000) and (Rummel et al., 2002).

The integration of geometry, Earth rotation, and gravity will permit - as a part of global change research – a comprehensive mapping of surface deformation processes, a quantification of mass anomalies and mass transport inside individual components and mass exchange between the components of the Earth's system and a determination of the exchange of angular momentum in the system Earth. These quantities serve as an input to the study of the physics of the solid Earth, the ice sheets and glaciers, of the hydrosphere and the atmosphere. They are of particular value for the study of complex phenomena such as glacial isostatic adjustment, the evolution of tectonic stress patterns, sea level rise and fall, the hydrological cycle, transport processes in the oceans, the dynamics of the atmosphere including troposphere and ionosphere (see Fig. 2).

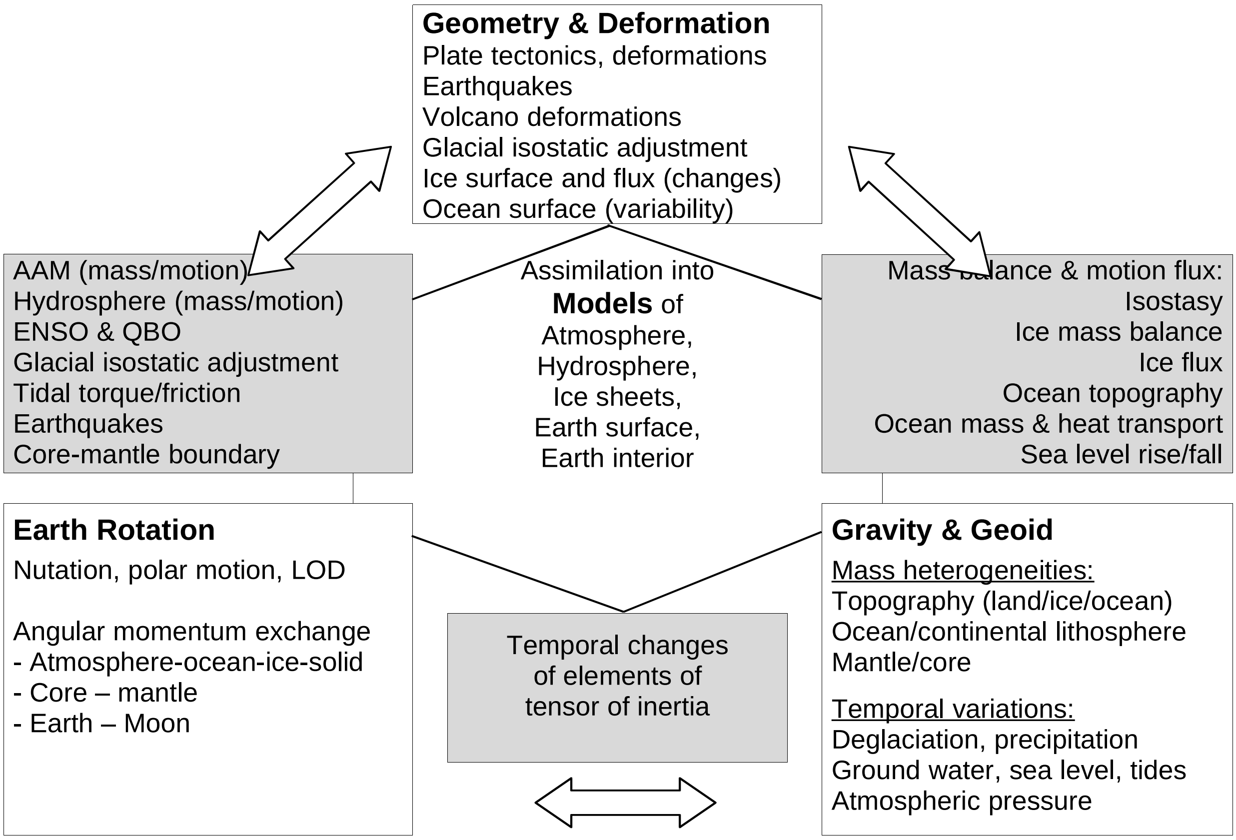


Fig. 2: Mass transport, mass exchange and angular momentum exchange in the Earth system.

The quantities to be delivered are small and therefore difficult to determine. Furthermore, in order to be useful for global change studies, they have to be derived free of biases and consistently in space and time. In general they cannot be measured directly but are derived indirectly from the combination of complementary sensor and observation systems. For example, dynamic ocean topography has to be derived from the accurate measurement of the actual mean ocean surface by radar altimetry in combination with the hypothetical ocean surface at rest, the geoid surface, and from satellite gravimetry. The ice mass balance has to be established from the joint use ice altimetry, interferometric SAR, gravity and surface GPS. These two examples show that a variety of sensor systems, mission characteristics and tracking systems have to be combined with utmost precision. The resulting research challenges can be divided into the following three main areas:

1. The various satellite sensor systems as well as the ground based geodetic space techniques have to operate as one global entity and in one global reference frame. This implies that geometric space techniques (SLR, GPS, DORIS, (differential) INSAR, ocean altimetry, ice altimetry), gravimetric space techniques (orbit analysis, high-low satellite-to-satellite tracking, low-low satellite-to-satellite tracking, satellite gradiometry), geodetic space techniques delivering Earth rotation (VLBI, LLR, SLR, GPS as well as the relevant astrometric techniques and missions) Atmospheric sounding techniques (GNSS-to-low Earth orbiters and GNSS to Earth) have to be integrated at the 1 ppb level. They have to function as

one global measurement device. This requires, in turn, the available global terrestrial network (VLBI, SLR, GPS, DORIS) as well as the global height systems to be combined and unified at the same precision level and with the same long term stability.

2. The space segment has to be complemented by terrestrial, airborne and marine techniques and campaigns. These techniques have a threefold purpose. They serve for the calibration and validation of the space segment, they lead to a regional densification in terms of spatial and temporal resolution and accuracy, and they are needed for the separation of individual effects. The land, ice and ocean surface changes are to be monitored with high spatial resolution. The required resolution depends on the surface type (land, ice, ocean) and on the region (tectonically active zones, ocean currents etc.). The latter implies the necessity of integration of existing and organisation of new regional projects (science and government projects) in areas of particular geophysical interest. These projects have to comply with the overall standards of GGOS. The development of new terrestrial and airborne/shipborne techniques has to be encouraged.

3. A link has to be established between the global time series of newly derived geodetic parameters (related to deformation processes, mass changes and exchange of angular momentum) and all relevant geophysical models. This is a highly interdisciplinary task and asks for a close cooperation with geophysicists, geologists, glaciologists, oceanographers, hydrographers and atmosphere(!!!) physicists. It asks geodesists to get deeply involved into Earth modelling. The ultimate goal is the development of comprehensive numerical Earth models, which are able to assimilate time series of global surface, mass transport and mass exchange processes. They should lead to a deeper understanding of solid Earth processes such as glacial isostatic adjustment (GIA), tectonic motion, volcanic activity or earthquakes, of ice mass dynamics and balance, and of the dynamics of sea ice, to a deeper insight into ocean circulation, mass and heat transport in the oceans, in the various components of sea level change, as well as their quantification, in the global water cycle and atmospheric dynamics.

Figure 3 illustrates the interaction of the three fields geometry, Earth rotation, and gravity, with the measurement techniques on the one hand and with geophysical modelling on the other hand.

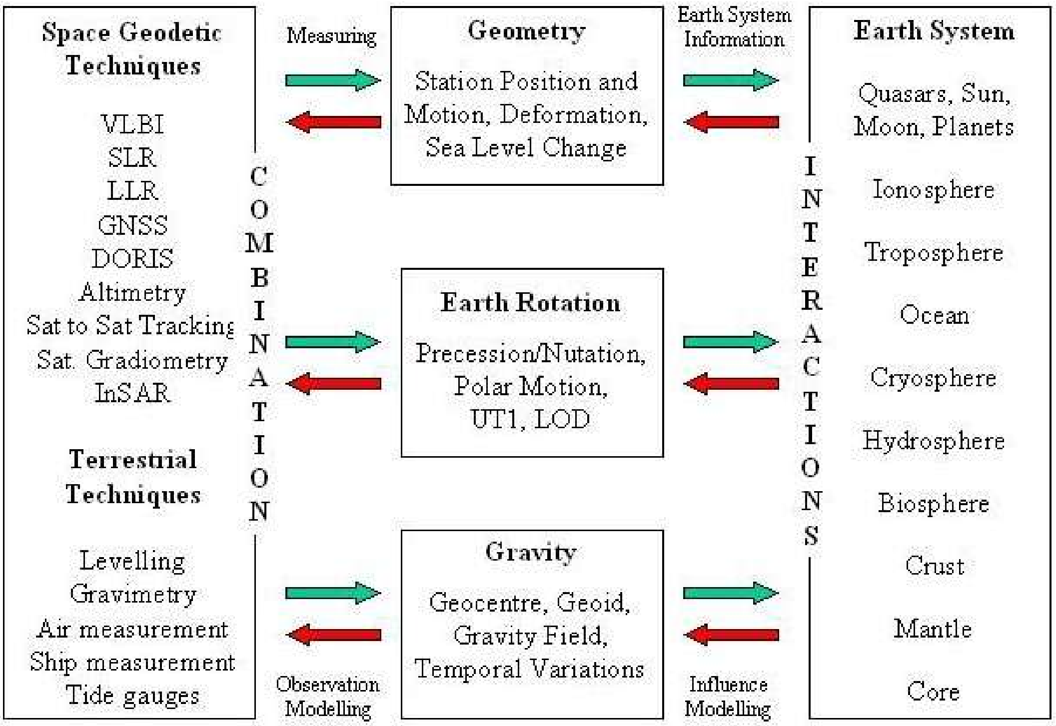


Fig. 3: Measuring and Modelling the Earth System.

The measured temporal variations of Earth rotation and gravity represent the total (integral) effect of all mass changes in Earth system. Therefore, methods have to be conceived for their separation into the individual contributions. This is a difficult but important task requiring the development of a sophisticated over-all strategy. The use of complementary satellite techniques, tailored sampling strategies, satellite formation flights, terrestrial calibration sites, permanent recordings, dedicated campaigns, and geophysical models will be the important tools for this purpose. The problem of aliasing due to the limited resolution in time and space, in general, of satellite missions is of a similar type.

GGOS provides a central theme to all research and developments performed within the IAG. In order to meet the objectives of GGOS a master plan concerning technology development, required terrestrial, airborne and satellite observation programmes, data connection, flow, archiving and processing, theory and methodology, collaboration with other Earth sciences, education, and outreach, as outlined above, underlies GGOS. GGOS is geodesy's contribution to Earth system monitoring and science. Geodesy is capable of providing unique, central and important information to the study of global change.

4 Purpose of this Implementation Plan

The purpose of this plan is to provide the information required for IAG to decide on the final implementation of the GGOS project, that is, to provide a description of the GGOS pilot project activities in the period 2003-2005, to describe in short the system requirements, emanating from the central science theme of GGOS as laid down by GGOS science board and to summarize the short- to medium-term steps to be undertaken, immediately and over the next 5-10 years, by IAG, its services and the services' contributing agencies, organizations and institutions around the globe to make the Global Geodetic Observing System fully operational and a powerful actor within the recently emerged Global Earth Observing System of Systems (GEOSS).

4.1 Developments

Over the last decade IAG has established a system of services which provides a great number of observation and data products to a wide range of scientific and non-scientific users. These services have established a considerable technical and scientific infrastructure, comprising global ground-based networks of sites for geometric and gravimetric observables, central bureaus, global and regional data and information centers and analysis centers for the various techniques. These services provide tracking and calibration/validation support for dedicated satellite missions and give access to data and data products through their data management systems. Organizationally, most of these geodetic services are structures very similar to the International GNSS Service (IGS), are all based on the 'best effort' principle, and depend on voluntary contributions of many globally distributed agencies and institutions.

To cope with the central science theme of GGOS and the research challenges, as itemized in the previous section, great efforts will have to be made to improve the observational infrastructure (tracking, receiving and monitoring stations), the data management systems and their inter-operability, and the performance of the processing systems for the uninterrupted generation of high-quality background models, high-resolution geo-potential models, deformation maps, Earth orientation products and imaging results, enabling continuous monitoring of the ongoing variations of processes within the individual components of the Earth system.

In view of the remarkable situation

- where a great number of Earth sciences-related satellites is already available or will become available within the next years for observing the Earth's gravitational and magnetic fields (CHAMP, GRACE, GOCE, SWARM), the sea surface (ERS, TOPEX, JASON), the ice sheets (ICESAT, CRYOSAT) and the land surface (ERS, ENVISAT, TerraSAR-X, ALOS), and other environmental phenomena (ENVISAT, AQUA, COSMIC, METOP),
- where more than 50 global navigation satellites will become available with GPS and GLONASS and the upcoming realization of GALILEO (cf. Fig. 4),
- and where growing international efforts are underway for extending the present global ground station coverage, the data communication capabilities and the data reduction techniques,

we expect a major breakthrough in geodesy's contribution to answers of key questions of Earth system sciences within the next 5-10 years. Geodesy will thus significantly contribute to the development of a realistic synthetic Earth model and to a better understanding of geo-hazard events.

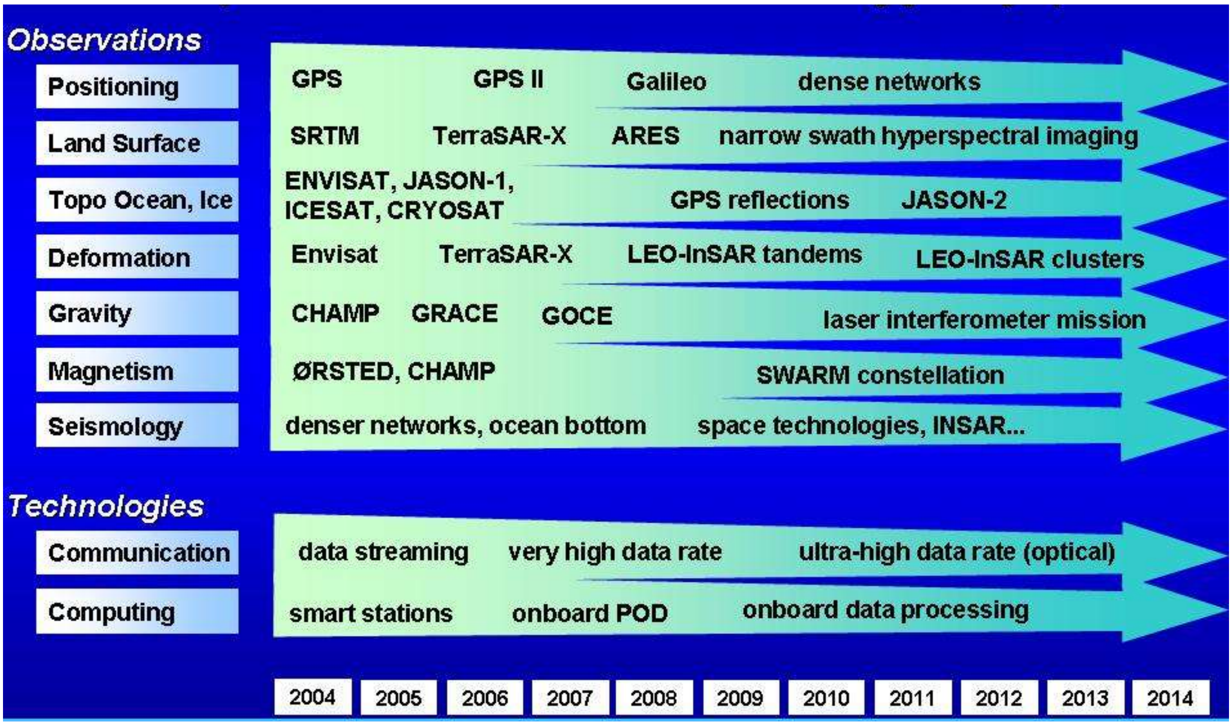


Fig. 4: Observational and Technological developments.

These observational and technological developments and steadily increasing scientific demands, accompanied by a rapidly increasing volume of data from satellites, aircraft and ground stations, will generate extraordinary requirements on future data management, processing systems and modeling techniques as characterized in Fig. 5.

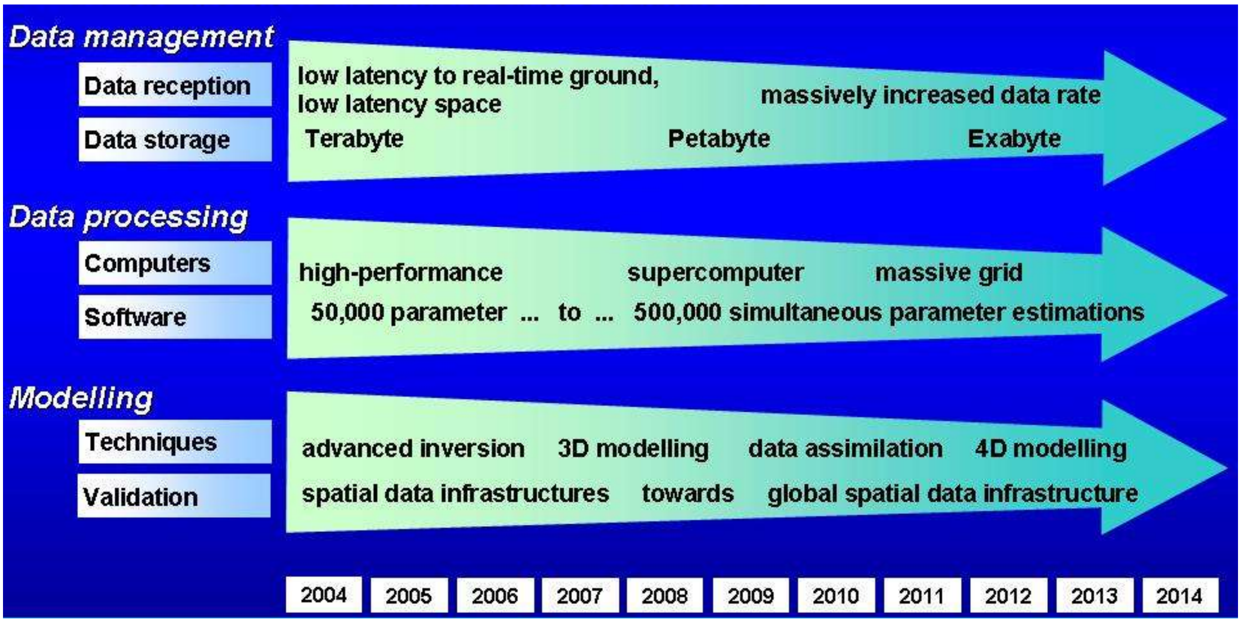


Fig. 5: Requirements on future data management, processing systems and modeling techniques.

4.2 GGOS Role in Earth Observation

As described in chapter 3, in order to significantly contribute to Earth system research, GGOS intends on one hand to give to the three fundamental fields of geodesy – positioning, Earth rotation and gravitation – a new quality and dimension by combining them to one observing system with utmost precision and in a well-defined and reproducible global terrestrial reference frame, and plans in addition to build a well-defined interface to the other Earth observing systems and the overarching system of systems GEOSS. In order to meet its objectives, GGOS has to fulfill a number of internal and external tasks, a few of which are summarized below.

Internal tasks:

GGOS shall

- push the development, deployment and application of geodetic observation systems in marine areas,
- establish a distributed GGOS data archive for handling the massively increasing data volumes, enforcing interoperability between components by following international standards for metadata, data exchange formats and common code tables,
- enforce real-time data communication and real-time data processing capabilities as geodetic contribution to early warning systems,
- enforce the integrated (single-step) multi-satellite, multi-layer (space, ground) processing of various measurement types,
- combine 1 ppb (10^{-9}) precision for data and data products with consistency in space and time, between numbers and metadata and in modeling and secure stability over decades,
- facilitate coordination of dedicated missions, special validation/calibration campaigns etc. and introduce measures for performance and quality assessment.

External tasks:

GGOS shall

- act as unique interface for GEOSS and users in the GEOSS environment,
- ensure that its interface is fully interoperable with other systems contributing to GEOSS,
- contribute to IGOS-P themes,
- establish a GGOS portal and enforce outreach effort to promote GGOS Earth science related products.

5 Status of GGOS in 2005

The pilot project phase 2003-2005 of GGOS was filled up with reconsiderations of science issues, with a vitalization and stepwise remodeling of the working group structure organisation, fund raising of regional GGOS initiatives and an intensive engagement into the fast developing intergovernmental/inter-organisation GEO/GEOSS process and the IGOS-Partnership programme. To promote the GGOS project, presentations were given at various events and a GGOS web presentation was developed. A description of the main outcomes is given in the following sections. Detailed information on GGOS pilot phase events can be found on the homepage http://www.ggos.org.

5.1 GGOS Main Activities 2003 – 2005

Oct. 2003: NGO initiative on the US side and Indigo proposal

Dec. 2003: Discussion with APSG representatives in Shanghai

Jan. 2004: EPIGGOS group constitutional meeting and ToR establishment

Feb. 2004: Submission of GAGOS SSA proposal to EC by GFZ/NMA/DGFI for EPIGGOS

Feb. 2004: Participation in IGOS-P International Workshop in Tokyo (Reigber)

Feb. 2004: GGOS presentation at IVS 2004 General Meeting in Ottawa (Drewes)

Apr. 2004: 1st GGOS working meeting in Nice with decision on GGOS/WG membership and most urgent tasks

Apr. 2004: IAG president's letter to GEO co-chair Lautenbacher requesting IAG's representation in GEO

Apr. 2004: Concept Note on Dynamic Earth Theme proposal submitted to IGOS-P chairman

May 2004: Presentation of Dynamic Earth Theme Concept at 11th IGOS-P meeting in Rom (Reigber)

May 2004: Participation in GEO II summit Tokyo and approval of IAG as GEO participating organisation (Beutler)

June 2004: GGOS presentation at ILRS Workshop in San Fernando (Drewes)

June 2004: Nomination of IAG representatives in GEO subgroups to GEOSEC

July 2004: GGOS presentation at 35th COSPAR meeting in Paris (Drewes)

July 2004: 1st Submission geodetic input to draft 10Yr Implementation Plan and Reference Document

Aug. 2004: GGOS presentation in Geodesy Dept., University Bogota (Drewes)

Sep. 2004: Participation in GEO Governance Meeting in Paris (Bye, Reigber)

Sep. 2004: 2nd Submission geodetic input to draft 10Yr Implementation Plan and Reference Document

Oct. 2004: GGOS presentation at Congress on Earth Sciences in Santiago, Chile (Drewes)

Nov. 2004: Participation in GEO-5 meeting Ottawa (Bye, Plag, Richter, Reigber)

Dec. 2004: Meeting WG Data and WG Infrastructure at AGU

Feb. 2005: Participation in GEO-6 and EO III Summit in Brussels (Bye, Plag, Richter, Reigber)

Mar. 2005: First GGOS workshop in Potsdam

Apr. 2005: GGOS presentation at FIG Working Week 2005 / GSDI-8 and at Joint Board of Geospatial Information Societies meeting, Cairo (Drewes)

May 2005: Participation in 1st GEO Session, Geneva (Reigber)

May 2005: Submission of paper for a Dynamic Theme in IGOS-P

June 2005: GGOS presentation at 8th United Nations Regional Cartographic Conference for the Americas, New York (Drewes)

5.2 Link to GEOSS

The ad-hoc Group on Earth Observation (GEO) was established by a declaration of 33 nations plus the European Commission on the occasion of the Earth Observation Summit (EOS I) in Washington, DC, on July 31, 2003. The declaration is a political commitment to move toward the development of (a) comprehensive, coordinated, and sustained Earth observation system(s). The summit postulates the need

- for the availability of global information as a basis for sound decision making;
- 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 environmental treaty obligations.

The main objectives of the GEO are to improve coordination of strategies and systems for observations of the Earth, to assist developing countries in improving their contributions to observations, and to exchange observations recorded by in-situ, aircraft, and satellite networks. The primary task is that of preparing a 10-year implementation plan taking into account existing activities and building on existing systems and initiatives.

GEO Organization and Funding

The GEO welcomes and is open to all interested governments and the European Commission. It also invites the participation of organizations, international bodies, and individual experts. Presently GEO counts more than 50 member countries and more than 30 participating organizations. The International Association of Geodesy (IAG) became a participating organization in May 2004.

The GEO established five subgroups to address *architecture, capacity building, data utilization, international cooperation,* and *user requirements and outreach*. Administrative secretariat support to the GEO is provided by the United States, other costs arising from activities relating to the GEO are covered by the members or participants.

Activities of the GEO

The main activities since the establishment of the GEO were the meetings to implement the structure and work plan of the Group. The most important meetings were the

- 1st GEO Meeting 1-2 August, 2003, immediately after the EOS I in Washington;
- 2nd GEO Meeting: 28-29 November 2003, Baveno, Italy;
- 3rd GEO Meeting: 25-27 February 2004, Cape Town, S. Africa;
- 4th GEO Meeting: 22-23 April 2004, during the EOS II in Tokyo, Japan;
- GEO Special Session on Governance: 27-28 September 2004, Brussels, Belgium;
- 5th GEO Meeting: 29-30 November 2004, Ottawa, Canada;
- 6th GEO Meeting: 14-15 February 2005, before the EOS III in Brussels, Belgium
- GEO I 1st GEO Session (GEO-I): 3-4 May 2005, Geneva, Switzerland.

The development of a 10-Year Implementation Plan (10-Yr. IP) was a major topic of all meetings.

10-Year Implementation Plan of a Global Earth Observation System of Systems

GEOSS plans to realize a future where decisions and actions to the benefit of humankind are based on coordinated, comprehensive, and sustained Earth observations.

It shall 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.

It includes all components of the Earth's system (Fig. 6).

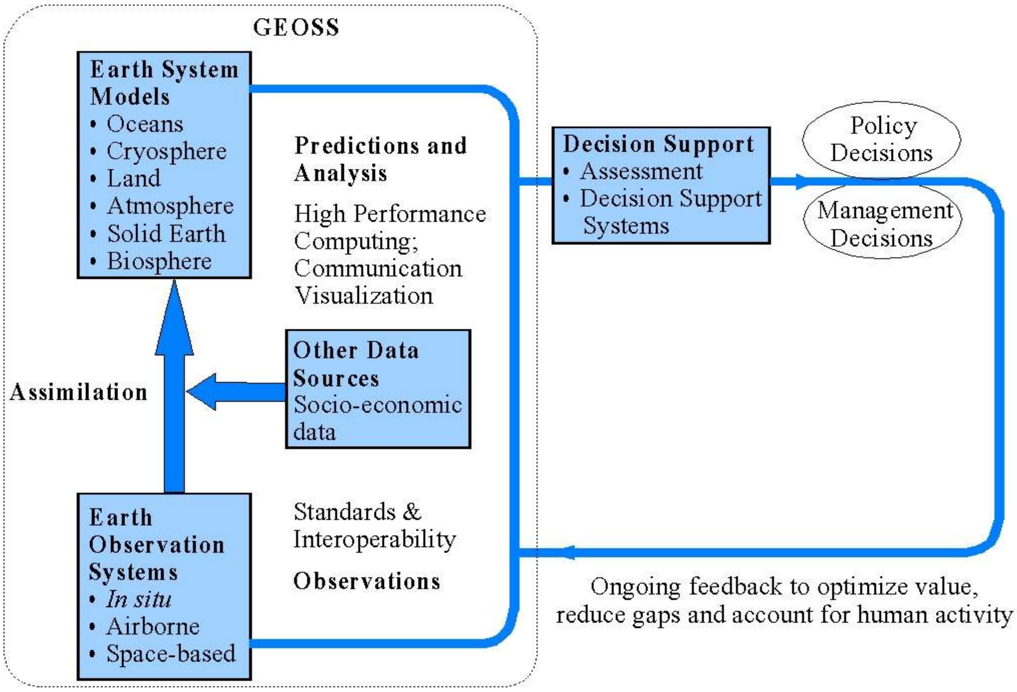


Fig. 6: End-to end nature of data provision, feedback loop, and the role of GEOSS.

The Case for a Global Earth Observation System of Systems (GEOSS)

Clear improvements can be made to existing Earth observations by adopting a coherent global approach. 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 benefit that can arise. In most cases, global information arises from the voluntary contribution of data collected by national systems for national purposes. The GEOSS 10-Year Implementation Plan addresses these facts in the following way:

- Arrangements to make systems interoperable and to share data;
- Collective optimisation of the observation strategy;
- Cooperative gap filling;
- Observational adequacy and continuity;
- Data transfer and dissemination;
- Collaboration on capacity building;
- Harmonization of methods and application of observation standards

Architecture of GEOSS

Observations, data processing and dissemination are to be interfaced together with Spatial Data Infrastructures and service-oriented information architectures.

Five functional components are identified in the GEOSS 10-Yr IP:

1. User requirements
2. Observations
3. Data processing
4. Data transfer and dissemination
5. Interoperability arrangements

The *user requirements* are closely related to the societal benefits of a GEOSS. For the following areas was a recognition that clear societal benefits could be derived from a coordinated global observing system:

- Reducing loss of life and property from natural disasters;
- Understanding environmental factors affecting human health;
- Improving management of energy resources;
- Understanding, assessing and predicting climate change;
- Improving water resource management through better understanding of the water cycle;
- Improving weather information, forecasting and warning;
- Improving the management and protection of ecosystems;
- Supporting sustainable agriculture combating desertification;
- Understanding, monitoring and conserving biodiversity;

These benefits can only be achieved by **common** observations and data utilization of the individual Earth observation systems.

With respect to *observations and data processing*, a goal of GEOSS is to provide timely data for local, national, regional and international policy makers. This requires the convergence of observations of different systems, and continuity of observations and data sampling. The data processing shall lead to common products of data and information, modelling and data assimilation. This includes a data and product quality validation.

The *data transfer and interoperability* require to solve problems with respect to the data collection from remote sites and the communication management. The interoperability of systems refers to the ability to operate across otherwise incompatible systems. It must be based on non-proprietary open standards and precisely defined syntaxes for data traversing interfaces using complex systems as assemblies of components that interoperate primarily by communication services.

GEOSS Capacity Building

The primary goal of capacity building is to strengthen the capability of all countries to

- use Earth observation data and products in a sustainable, repeatable manner with results or outputs that are consistent with accepted Earth observing standards;
- contribute in situ observations to global networks, and access and retrieve relevant data from global data systems for in situ applications;
- analyse and interpret data to derive nationally, regionally and globally relevant information and provide decision-support systems and tools useful to decision-makers,

- integrate Earth observation data and information from other sources for a comprehensive understanding of problems in order to identify sustainable solutions.

The GEO will produce a comprehensive review and gaps analysis based on existing capacity building efforts as a first step in the implementation of GEOSS. It will then produce methodologies to monitor and evaluate capacity building initiatives relating to Earth observation systems and facilitate the maintenance and strengthening of education, training, research, and communication so that each country reaches a level of capability to participate in GEOSS.

GEOSS Outreach

The outreach activities of GEOSS shall convince a key audience that past, present, and future investments in Earth observation are delivering tangible socio-economic benefits. The practical applications of Earth observation and their relevance in government policy, socio-economic growth, and the interests of citizens shall be shown. Thereby the public awareness of GEOSS scientific achievements, technology advances, applicants and capabilities as well as benefits and support to environmental management will increase.

The audience consists, primarily, of decision and policy makers. The general public to be informed includes the "man-in-the-street", but also opinion makers from the media (press, TV, radio), who need to be familiarized with Earth observation achievements. Industry, value adding companies and service communities shall be informed and encouraged to become partners. The scientific, technical and educational communities, non-governmental organizations as well as financial institutions and development assistance agencies are envisaged as possible audience, as well.

IAG Participation in the Development of the GEOSS 10-Year Implementation Plan

Two representatives of IAG were nominated to the GEO plenary and to each of the five GEO subgroups:

- GEO plenary: G. Beutler (IAG), Ch. Reigber (GGOS)
- Sub-group Architecture: B. Richter, M. Rothacher
- Sub-group Capacity Building: J. Manning, H. Drewes
- Sub-group Data Utilization: R. Forsberg, T. Schöne
- Sub-group International Cooperation: R. Neilan, B.-L. Bye
- Sub-group User requirements & outreach: C. Boucher, H.-P. Plag

Several geodetic components were brought into the GEOSS 10-Year Implementation Plan by these representatives. We mention in particular the existing geodetic stations cited as an opportunity for co-located observation sites, and the geodetic services advocated for continuity and interoperability of satellite systems providing positioning. The geodetic reference frames are understood as a necessity for a ground truth and common geographic data integration. The Global Geodetic Observing System (GGOS) is recognized as one of the existing systems to be integrated into GEOSS.

IAG Representation in GEO after EOS III

By the third Earth Observation Summit (EOS III) the transfer of GEOSS into a concrete activity was approved. Accompanied with this transfer is a re-structuring of GEO which is still underway. A principal re-designation of representatives from GEO members and GEO organizations was called for. Simultaneously the installation of new GEO workgroups was initiated. It started with a Science and Technology Workgroup and a User Interface Workgroup. The corresponding IAG representatives are:

- GEO Principals: Ch. Reigber, G. Beutler
- GEO Science and Technology Workgroup: B. Richter, S. Zerbini

- GEO User Interface Workgroup: H.-P. Plag, C. Boucher

In August 2005 there was a second call for designation of members in the Workgroups on Capacity Building & Outreach and Architecture & Data. The IAG representatives have still to be nominated until end of August, 2005..

5.3 Link to IGOS-P

When setting up GGOS as a project, the IAG Executive Committee asked the GGOS Steering Committee to establish also a relationship with the Integrated Global Observing Strategy Partnership IGOS-P. IGOS-P addresses a number of problems and components of Earth observation systems in the frame of specific Themes. The IGOS-P Theme process will also be an important mechanism for the development of the components of the GEOSS.

In order to ensure that the implementation of GGOS is in agreement with the Integrated Global Observing Strategy (IGOS), and that GGOS optimally serves the needs of GEOSS and the different IGOS-P Themes, GGOS has applied for membership in IGOS-P. Moreover, GGOS has suggested a new 'Earth System Dynamics' Theme, focusing on the observation system for mass transport and dynamics of the Earth system in the frame of a 'whole system' approach.

The IGOS "seeks to provide a comprehensive framework to harmonize the common interests of the major space-based and in-situ systems for global observation of the Earth. It is being developed as an over-arching strategy for conducting observations relating to climate and atmosphere, oceans and coasts, the land surface and the Earth's interior. IGOS strives to build upon the strategies of existing international global observing programmes, and upon current achievements. It seeks to improve observing capacity and deliver observations in a cost-effective and timely fashion. Additional efforts will be directed to those areas where satisfactory international arrangements and structures do not currently exist.}" (cite from http://www.igospartner.org). IGOS is a strategic planning process, providing a structure that helps determine observation gaps and identify the resources to fill observation needs. It is also a framework for decisions and resource allocation by individual funding agencies and provides governments with improved understanding of the need for global observations, thereby helping to reduce unnecessary duplication of observations. IGOS focuses primarily on the observing aspects, and it is intended to cover all forms of data collection concerning the physical, chemical, biological and human environment including the associated impacts. Like GEOSS, IGOS is user driven, and the results will increase scientific understanding and guide early warning, policy-setting and decision-making for sustainable development and environmental protection. Moreover, IGOS provides opportunities for capacity building and assisting countries to obtain maximum benefit from the total set of observations.

IGOS-P was established in June 1998 by a formal exchange of letters among the 13 founding Partners for the definition, development and implementation of the IGOS. Today, IGOS-P brings together a number of international bodies concerned with the observational component of global environmental issues, both from a research and a long-term operational programme perspective. IGOS-P has the principal objectives to address how well user requirements are being met by the existing mix of observations, including those of the global observing systems, and how they could be met in the future through better integration and optimization of remote sensing (especially space-based) and in-situ systems. IGOS-P serves as guidance to those responsible for defining and implementing individual observing systems, while the implementation of the Strategy, i.e. the establishment and maintenance of the components of an integrated global observing system, lies with those governments and organizations that have made relevant commitments.

IGOS-P has adopted an incremental "Themes" approach to aid the development of the strategy based on perceived priorities. It is the goal of IGOS-P to establish a small number of Themes with strong linkages to critical social issues. The Process of Themes selection is based on an assessment of the relevant scientific and operational priorities for overcoming deficiencies in information, as well as analysis of the state of development of relevant existing and planned observing systems. In general, all IGOS-P Themes will address space-borne or air-borne observations that require highly accurate positioning of the sensors, and thus are linked to the global geodetic networks through their requirements for access to an accurate and stable reference frame.

The existing and planned Themes have the following objectives and explicit links to geodesy (besides the requirement to have access to a reference frame):

- Atmospheric Chemistry Theme: ensure the long-term continuity and spatial comprehensiveness of the monitoring of atmospheric composition and to integrate ground-based and space-borne measurements using models and assimilation tools.
- Carbon Observations Theme: enhance the scientific understanding of the global carbon cycle, provide for advanced Earth system observation capabilities, and deliver an improved knowledge base for better policy-making.
- Geohazards Theme: integrate disparate, multidisciplinary, applied research into global, operational systems, and through this improve the provision of timely, reliable and cost-effective information to those responsible for managing geohazards. Plate tectonics, pre-, co- and post-seismic strain, processes associated with volcanoes, early warning for tsunamis, subsidence, precarious rocks, landslides, and local and regional predictions of sea level rise are examples of topics that link this theme to geodetic observations.
- Ocean Theme: develop a strategy for an observing system for the oceans that serves the research and operational oceanographic communities and a wide range of scientific and non-scientific users. Ocean circulation, sea level rise, isostacy, dynamic sea surface topography, are linked to the three geodetic quantities, both for the monitoring and studies of the ocean's variability as well as model validation.
- Water Cycle Theme: provide a framework for guiding decisions regarding the maintenance and enhancement of water cycle observations that support monitoring of climate, water management and water resource development, provision of initial conditions for numerical weather forecasts and climate predictions, and research related to the water cycle. The geodetic observations provide a unique tool to monitor the global to local scale movements of water through the Earth system and the theme is strongly linked to geodesy.
- Coast Observation Theme: coordinate and strengthen present and future coastal observational capabilities, both in situ and space-borne as a basis for a better understanding of the changes in the coastal zone and a service to the decision-making process (under development). Sea level and ocean circulation are relevant parameters influencing the dynamic processes in the coastal zone and linking the theme to geodesy.
- Coral Reef Sub-Theme: develop a strategy for the observation system of this particular ecosystem taking into account the unique characteristics of coral reefs requiring special observation techniques.
- Cryosphere Theme: create a framework for improved coordination of cryospheric observations and the generation of data and information needed for both operational services and research (proposal in preparation). Ice mass balance, glacial isostacy, and induced sea level variations all are important parameters, that are directly observed by the geodetic observation techniques.
- Land Theme: provide a global strategy for a land observations system focusing on globally needed observations for topics such as land cover and land use, human settlement and population, managed and natural ecosystems, soils, biogeochemical cycles, and elevation changes (under development). Changes in the elevation are directly observed by geodetic techniques.

Many of the burning questions related to the water cycle, the climate, global change, and geohazards, which are addressed by the IGOS-P Themes, cannot be solved without sufficient knowledge of mass transports throughout the Earth system and the associated dynamics. All these processes affect the three fundamental geodetic quantities, namely the Earth's figure (geometry), its gravity field and its rotation.

In order to foster the implementation of GGOS and to further detail the science basis for GGOS, as well as to strengthen its linkage to existing and new Earth observing systems, such as GEOSS, the IAG has taken a first step to propose a specific IGOS-P Theme addressing the dynamics of the Earth system from a focus on mass movements. The proposal was presented and discussed at the 11-th Meeting of IGOS-P in June 2004 in Rome. In its response, the IGOS-P members requested that "IAG/GGOS should study the IGOS Process Paper as well as existing IGOS Theme reports to identify complementary or competing elements and to demonstrate that the idea of launching a Dynamic Earth Theme could be realised without repetition or overlap".

In response to IGOS-P, a document was prepared (Plag et al., 2005) and submitted to IGOS-P for consideration at the 12-th meeting in May 2005 in Geneva. In that document, the following action plan was recommended:

(1) GGOS becomes a member of IGOS-P as a new Global Observing System;

(2) GGOS establishes links to the existing IGOS-P Themes, allowing GGOS to influence the development of the different theme-specific strategies and to determine the way in which GGOS can best serve the observing systems implemented under these strategies;

(3) GGOS together with relevant members of IGOS-P develops the 'Earth System Dynamics' Theme further and prepares a proposal for consideration by the IGOS-P members.

This action plan was accepted by IGOS-P. Currently, a formal membership application is in preparation for the next IGOS-P meeting in November 2005.

The suggested 'Earth System Dynamics' Theme aims at establishing the overall strategy, requirements, and background for a global observing system that consistently monitors the mass movements and dynamics of the Earth system at an accuracy level required in particular by the IGOS-P Global Water Cycle, Geohazards, Ocean, Coastal, and Cryosphere Themes. The full exploitation of the potential of the geodetic observations for such an observing system will not be possible without taking a comprehensive system approach considering all mechanical interactions between the different system components. The theme will provide the science basis for the implementation of GGOS and ensure that

GGOS can be fully integrated in the frame of IGOS. The theme takes into account the fundamental difference between GGOS and other observing systems in that GGOS requires an Earth system approach for its full development.

While most of the existing themes focus on sub-systems (like the Ocean Theme) or specific problem areas (like the Geohazards Theme), the proposed 'Earth System Dynamics' Theme is truly a whole system theme, comparable in this whole-system aspect only to the Global Water Cycle Theme.

The 'Earth System Dynamics' Theme has the task to ensure that the integrated observing system for the dynamic Earth system focusing on mass movements and dynamics is built in a cost-effective way to serve most of the existing themes in two major areas: (1) provision of a stable and accurate global reference frame as well as tools to access this frame anywhere on the globe including air- and space-borne sensors, and (2) provision of long-term observations of the time-variable shape, gravity field and rotation of the Earth, which are related to mass transport and dynamics, both for research in the frame of the other themes as well as applications in the areas addressed by these themes.

The suggested 'Earth System Dynamics' Theme thus provides a basis for some of IGOS-P Themes and fosters the exploitation of links between them. Without this new theme (or a similar approach outside the IGOS-P frame), the development in the different themes might easily result in competing, theme-specific implementations of parts of the geodetic observing system, and the neglection of other parts, that do not directly serve a specific theme but are crucial for the overall performance of GGOS.

5.4 Regional Activities

Regional activities directly liked to GGOS developed in the USA with the NASA-funded INDIGO project and in Europe with the EPIGOSS and NGOS initiatives and the EU-funded project GAGOS as well as the BMBF-funded German R&D project GGOS-D.

EPIGOSS: European Partnership in GGOS

In view of the planned consolidation of the global geodetic observing activities under the umbrella of GGOS and considering that the success of GGOS as well as the full exploitation of the geodetic contribution to GEOSS will depend on contributions from different regions with Europe as a strong contributor, the group of European physical geodesists agreed that there is a need to coordinate on a European level the broad geodetic research and operational activities and to integrate them into a global Earth observing system. Therefore, a European platform was established for a dialog of all geodetic groups in order to coordinate their efforts in contributing to improve Earth system observations. An inauguration meeting for this partnership platform took place on January 14, 2004 in Potsdam.

<u>Objectives</u>

The main objective of EPIGGOS is to provide a platform for a dialog between all relevant European geodetic institutions and organisations active in research and operations contributing to Earth monitoring. EPIGGOS aims to bring together representatives of these entities as well as European representatives of the relevant international geodetic organisations and thus to create a body that has a mandate to speak for geodesy in Europe. In particular, EPIGGOS has the goal to represent the geodetic community in interdisciplinary groups working towards a cross-discipline integration of Earth observation systems.

EPIGGOS aims to facilitate the coordination and stimulation of European geodetic research and operational activities contributing to the global Earth observing systems and other relevant international programmes, such as the emerging European capacities GMES and GALILEO, in co-operation with existing services.

<u>Tasks</u>

EPIGGOS has the task

- to identify key issues related to the contribution of geodesy to Earth system observations and to propose European research activities, both multi-domain and multi-discipline,
- to identify deficiencies in the observation networks and the modelling of the Earth system, and to coordinate its improvement,
- to assist the European geodetic institutions to improve their contributions to the networks and to incorporate research into operational networks,
- to stimulate the development of interfaces between the different disciplines and networks,
- to develop and encourage the use of new measurement techniques,
- to provide the European institutions and organisations with the necessary consistent, integrated and quality controlled geodetic products to serve the international geodesy, climate and biosphere programmes,
- to represent geodesy in the interaction with other disciplines (solid Earth, atmosphere, ocean, cryosphere, hydrosphere) aiming to actively contribute to the Integrated Global Observing Strategy (IGOS).

A key problem to be addressed by EPIGGOS will be the provision of a framework for existing or future services to ensure their long-term stability and consistency.

EPIGGOS will also participate in activities addressing the cross-domain standardisation of networks, communication, and operational routines as well as the establishment of an integrated Earth observation database including tools for the standardised access to the database.

With respect to coordination, EPIGGOS will assess which organisational forms provide on the one hand the flexibility and openness to allow for a relatively easy participation of organisations under different national conditions, and on the other hand sufficient stability to result in a stable long-term observation system. Issues like legal commitment, liability, integrity of the observations, validation of products, just to give some examples, will have to be addressed.

EPIGGOS will represent the European partners contributing to global Earth observation both through research and operational activities in the presently on-going dialog to develop the concept of the GMES capacity and the European contribution to IGGOS.

The work of EPIGGOS is carried out through coordination meetings, e-mail exchanges and working groups.

NGOS

NGOS stands for the Nordic Geodetic Observing System and is an initiative of the Scandinavian countries Denmark, Sweden, Norway and Finland. It integrates fundamental geodetic techniques for the long-term observation of Earth system parameters that are important in the context of change in and on our planet. The NGOS is an infrastructure for geodetic observations required for a wide range of scientific and practical applications both in the Nordic region and on global level. For the Nordic countries, a main focus will be on crustal motion, dynamics of glaciated areas and sea level.

The new structure of IAG beyond 2000 defines projects as an entity of coordinated long-term activities. At the XXIII General Assembly of the IUGG in Sapporo, Japan, July 2003, the NGOS has been established as such a project.

The Nordic Geodetic Commission established a Task Force in 2002 with the mission to prepare a document providing the definition and draft for the implementation of the NGOS. The NGOS is proposed as a system that will constitute the regional implementation of the observational network required to realize GGOS.

GAGOS

GAGOS is a Specific Support Action (SSA) on Assessing and forward planning of the **G**eodetic **A**nd **G**eohazard **O**bserving **S**ystems for GMES applications. It is an EU FP6 GMES funded SSA activity of the European Partners in GGOS (EPIGGOS) with the main contractors GFZ Potsdam, DGFI Munich and NMA Hoenefoss. The project was kicked off in May 2005.

<u>Objective</u>

The objective of the GAGOS SSA is to contribute to an assessment of the in-situ capabilities in Earth observation systems of relevance for GMES with the main goal to identify necessary adaptations of the existing infrastructure (including data management) and new deployments.

The SSA will provide in its initial phase an assessment of two major components of the Earth observing system, namely the global geodetic observing system and the global geophysical observing system, with the latter being particularly focused on geohazards narrowed down to earthquake hazards, volcanic hazards and ground instability hazards. The assessment will identify the relevant quantities to be observed for GMES and measure the available infrastructure against the spatial and temporal characteristics of the signals to be observed. As a major outcome, the assessment will identify gaps in the observation system in terms of quantities observed as well as spatial and temporal coverage and suggest necessary adaptations of particularly the in-situ infrastructure. In a second phase, the SSA will provide consultancy for the implementation of adaptations and potential new deployments in the terrestrial domain as well as the global geodetic networks.

The assessment is carried out in view of the three major goals of GMES, namely (1) provide information for the definition, negotiation, implementation and verification of European environmental policies, national regulations and international conventions, (2) to be a contribution to global monitoring of the Earth system environment aiming at the provision of the data and information base required for a successful quest for sustainable development, and (3) to constitute, on a regional and global level, monitoring capacities required to ensure security for the population. Thus, the existing in-situ observing infrastructure will be assessed in the context of global monitoring and it will be assessed with respect to threats from natural and man-made hazards. Moreover, the capability of the infrastructure to provide necessary information for the implementation of international conventions will be considered.

The assessment will consider the capacity and capability of the in-situ networks with respect to the applications of the Global Earth Observing Systems and additional GMES services. We will also take into account the compliance of the networks and the data systems with the GGOS, GEOSS and IGOS initiatives, and will consider criteria such as the overall continuity, comparability of the in-situ observations with space data, interoperability, synergies through co-location. Moreover, a goal of the assessment will also be to identify unnecessary redundant data collection.

INDIGO

INDIGO stands for Inter-Service Data Integration for Geodetic Operations and is an initiative of the US NGO group. It has been receiving funds from NASA since July 2004. INDIGO funding supports the three Central Bureaus of IAG services located in the USA and adds specific responsibilities to develop data and information services to support multi-technique studies.

The INDIGO project will enable improved performance, accuracy, and efficiency in support of NASA's Earth science and international user community by developing and providing uniform access to heterogeneous space geodetic data systems. This collective effort will built upon data and information systems of space geodetic observations that have served users effectively over the last decade. Key observations come from the techniques of the Global Positioning System (GPS), Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR), which are fundamental for defining and maintaining the precise reference system of the Earth and the Cosmos. The unique history and success of the community-based international scientific services - the International GPS Service (IGS), International VLBI Service (IVS) and International Laser Ranging Service (ILRS) - stem from committed support to evolve data information systems well-suited to users' needs. These services fundamentally support the International Earth Rotation Service (IERS) and therein the generation and maintenance of the International Terrestrial Reference Frame (ITRF). Recognizing current scientific concepts and requirements as described in the National Geodetic Observatory (NGO) plan and the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG), it is timely to unify these data systems. These systems will be integrated, upgraded and enhanced in response to user requirements, initiating first steps towards realizing NGO/GGOS scientific objectives. User interface and access will be streamlined and seamless with state-of-the-art web-based services. Extensive user participation in the formulation of the new system is ensured, as this is the approach of the geodetic services. INDIGO will extend the GPS Seamless Archive (GSAC) philosophy to all data types. INDIGO is well aligned with the SEEDS philosophy and anticipates full engagement with SEEDS working groups INDIGO should be viewed as a resource that contributes to the goals of IAG/IGGOS.

5.5 GGOS Current Structure

During the First GGOS Workshop in Potsdam, 1-2 March 2005, the initial architecture of GGOS was discussed. There was a general consensus that it should be based on the carriers of the observing systems, the sensors, the mission operation systems, the network observatories, the info & data systems, and the processing systems. The products should include the Physics of the Earth (geopotential, geokinematics, orientation, reference frames), structure imaging and mass exchange processes. After a long discussion the following modified structure was adopted.

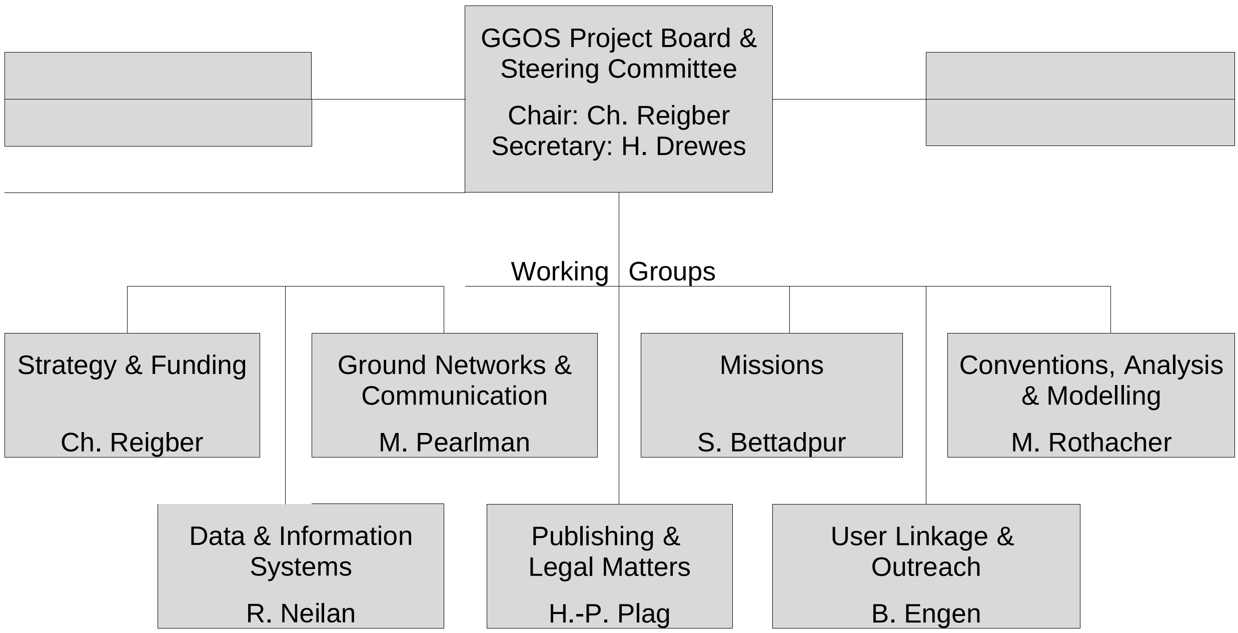


Fig. 7: GGOS Structure (Status after 1st GGOS workshop discussion, 02 March 2005).

The Working Groups started immediately their own organizational activities and developed WG-specific work descriptions. Charters, membership and first activities are to be found on the GGOS homepage (http://www.ggos.org). Several meetings of the Working Groups were held during the months from March to August 2005.

6 Proposal for Future Developments of GGOS

The development of GGOS is driven by the objectives defined in chapter 2 and the scientific rationale described in chapter 3. It sets long-term goals which have to be worked on over years up to decades. In this chapter we shall discuss the urgent necessities for the nearest future, i.e., the short-term tasks over the next two years and the required intermediate structure to fulfil them. Depending on the success of this implementation period, the future procedure may be identified and specified in the long-term work plan. As the activities concern various IAG entities, they can be performed only in close cooperation with the IAG Services and Commissions. The existing excellent structure and operation of the services will allow an unproblematic transition from the GGOS planning and initial phase into its full function.

6.1 Short-term Tasks

The short-term tasks are those required activities that have to be started immediately, i.e., during the next months. We may split them into two major areas, the external and the internal activities. The external activities are related to the representation and integration of GGOS and/or IAG in the international bodies mentioned in chapter 5. The internal objectives concentrate on the coordination and integration within geodesy, in particular within IAG.

After the end of the GGOS initial phase 2003-2005, the most urgent decision to be made is the installation of the GGOS Steering Committee which will direct the complete implementation of the required GGOS structure (see chapter 6.2). According to the IAG Bylaws the IAG Executive Committee has to appoint the new Chairperson of GGOS and the IAG Commissions and Services have to appoint their representatives. The Steering Committee has to meet immediately for its constituting meeting and propose two members-at-large who have to be approved by the IAG EC. This procedure should be completed as soon as possible in order to enable the official action of GGOS.

External Activities

The Group on Earth Observation (GEO) is developing extremely rapidly at present. The elaboration of the work plan for the next two years is in full progression. In order to be represented in the relevant groups (GEO Plenary, GEO Committees – formerly Workgroups), close contacts have to be maintained with the GEO Executive Committee and Secretariat. The new structure, issued on 10 June 2005 (Fig. 8), will be completely implemented until the end of 2005.

Another urgent task is to decide on the relationship of GGOS to IGOS-P. Three options have been discussed during the GGOS initial phase 2003 - 2005 (see chapter 5.3):

- To become a member of the IGOS Partnership (IGOS-P) as a Global Observing System;
- To establish links to existing IGOS-P themes;
- To develop an independent theme, eventually in cooperation with other members of IGOS-P.

The decision of the most promising option has to be made soon in order to take part in the future activities and developments of IGOS. The most far-reaching integration of GGOS into IGOS would be a partnership like the G3OS (Global Climate Observing System, GCOS, Global Ocean Observing System, GOOS, Global Terrestrial Observing System, GTOS). This would require the strong support of other IGOS-P members, i.e., contacts to those have to be established immediately. The success of an application to become an IGOS partner is open, i.e., alternatives have to be discussed.

The second best option seems to be the installation of an IGOS-P theme, e.g., the “Earth System Dynamics Theme” proposed by GGOS. Such a theme would have to be well coordinated with the existing themes, particularly with the “Geohazard Theme”, the “Ocean Theme” and the “Water Cycle Theme”. The overlapping of GGOS with these themes is evident and a good separation and specialization of the geodetic character of the theme has to be well documented. The initiative for the “Earth System Dynamics Theme” has been started, the procedure has to be followed carefully.

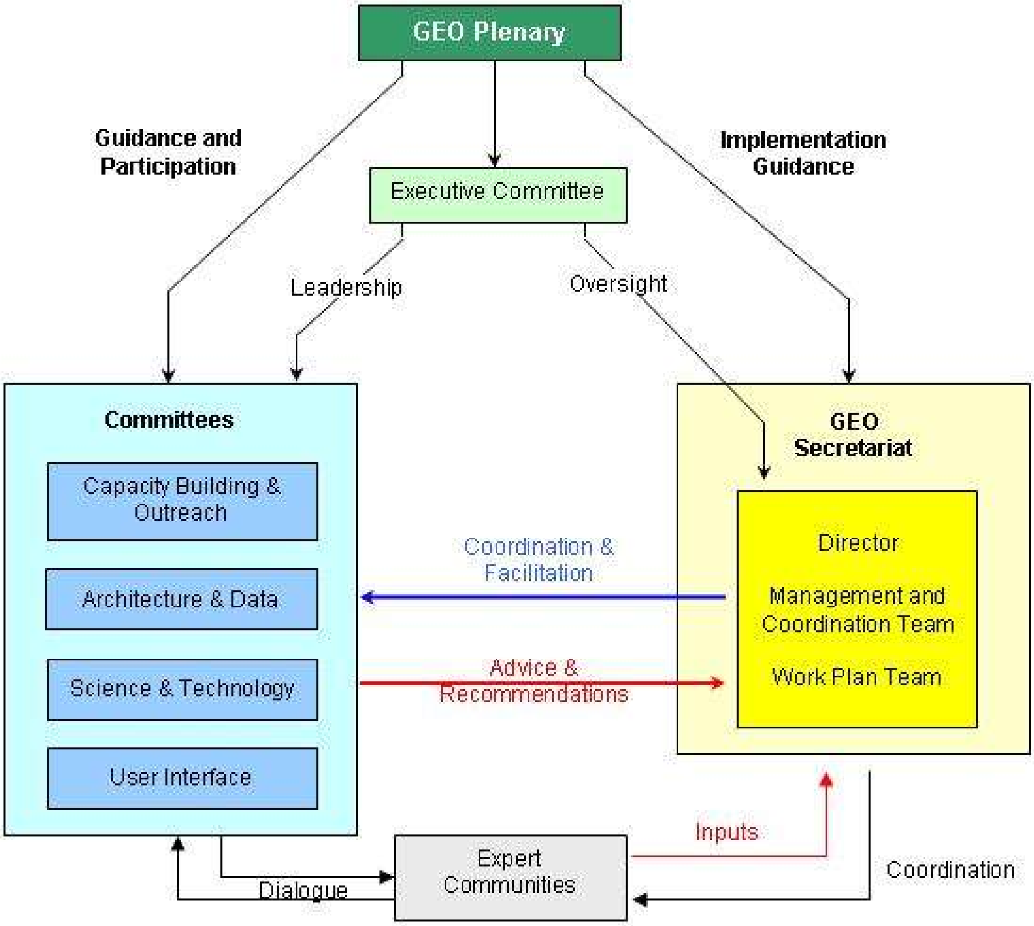


Fig. 8: New structure of GEO (10 June 2005).

The easiest relation to IGOS would be the establishment of links to the existing themes mentioned above. GGOS could possibly be integrated into these themes by accepting their terms of reference and following their objectives, goals and rules. It seems doubtful whether geodesy would very much be visible under this option.

An obvious but very important short-term external task of GGOS is to improve the visibility of geodesy in public and to inform publicists and politicians on geodetic results. The implementation of GGOS has to include the regular and intensive information to outside our community. GGOS has to release popular documents about geodetic findings on all relevant actual events that move the public, like earthquakes, volcano eruptions, tsunamis etc. It should be a first activity of the GGOS team to install close connections to influential persons in society and politics.

Internal Activities

The activities within IAG and the geodetic community include with highest priority the close contacts and the cooperation with the services. There is an urgent need to bring the different components of the services regularly together (stations, data centres, analysis centres) in order to discuss issues of common interest and to coordinate principal topics like constants, conventions, models and parameters used in the data processing. This holds in particular for the relationship between geometric and gravimetric services. It is recommended to establish inter-service working groups immediately and to agree on the role of GGOS and the procedure how to handle the validation and dissemination of information and results provided by different services.

With respect to the geodetic measurements, the discussion and activity on fundamental observation stations should be continued by GGOS. It is an essential part of a global observation system to link the instruments of the different techniques, geometric and gravimetric, in terms of geometric and physical parameters. Good local surveys of the stations with co-located techniques (local ties between instruments) are an indispensable requirement. A team from the individual services, assisted by GGOS, could solve one of the most urgent problems in inter-technique combinations.

The linkage of data centres of the different techniques is another short-term task of GGOS. In a first step it should be striven for coordinated structures and formats in the data holdings. A sophisticated structure of metadata for all existing and upcoming archives is a first step. The users of geodetic data must be able to find the wanted information without problems. The homepages of the services should provide direct and easy access to the most needed data (coordinates, velocities, gravity, geoid). The ftp-servers are too complicated for many users. GGOS can assist in the establishment of unique data systems according to the requirements of the users (including non-geodesists).

The use of identical constants, conventions, models and parameters in the processing of data and the generation of products is essential for the appropriate application of geodetic results. GGOS should start immediately a discussion with the services about the adoption of common conventions. In the new structure of IAG there is no longer an entity for Standards (like the former Special Commission 3), and it is not completely covered by the IERS Conventions. GGOS was asked by the IAG Executive Committee to take over this task, and it should do so immediately.

Another immediate activity should be the identification of gaps in the services' products. GGOS should review the present structures and recommend changes or new installations. Examples are the needed altimeter service and the unification of physical height systems. A proposal should be made how the services not directly linked to IERS or IGFS, like the PSMSL, can be integrated into a broader group of services. As an option it might be discussed whether a new altimeter service and PSMSL could form a common International Service for Sea Surface (ISSS).

All the main activities of GGOS should be reported in a routine manner to the IAG Executive Committee and the IAG services in order to keep all the relevant entities informed. The installation of such an information system – besides the GGOS homepage - should be started immediately.

6.2 Required intermediate structure

The objectives, the scientific rationale, and the internal and external goals as described above require a structure for the implementation of GGOS that allows an immediate, effective start of the work. The basis of the activities are the IAG Services. They shall be represented in all the components of GGOS. The IAG Commissions have to be involved, in particular, in the development and maintenance of the science plan, i.e., they shall be represented in the Science Council.

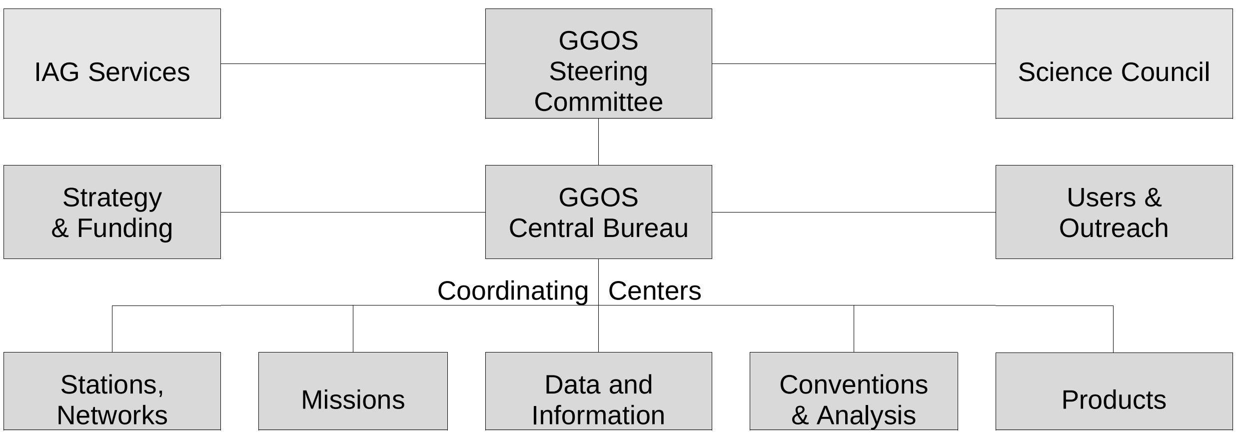


Fig. 9: Proposed GGOS structure for the implementation phase.

The overall coordination of GGOS is done by a Steering Committee, in accordance with the IAG Bylaws. Its chairperson is appointed by the IAG Executive Committee. The members are representatives from the IAG Commissions and Services, two members at large, and the chairpersons of the project's sub-groups. The GGOS Central Bureau performs the current work, takes care of the adherence of the strategy, and looks for funding opportunities. It also keeps the contact to the users and cares for the outreach. Coordinating Centers (CC) are installed for the major tasks of the Observing System, i.e., the station network, the missions, data and information, conventions and analysis, and the products. A call for participation shall be released for all the components of the structure.

The CC for the Stations and Networks will deal with all the issues concerning the terrestrial stations and the networks of the Observing System. This has to be done in close contact with the respective components of the IAG Services. It includes in particular the mutual exchange of information and data, the local surveys, i.e., the local ties between the observing instruments of the different techniques, and the communication to users and the public.

The Missions' CC shall maintain the contact to all the missions relevant to GGOS. These are in particular the satellite missions for gravity, altimetry, and the positioning systems, but also supra-regional terrestrial, airborne and planetary missions. Close relations have to be established with the agencies operating the missions in order to get free access to the data and cooperate in the data analysis and interpretation.

The Data and Information CC is responsible for the accessibility of all the data and relevant information achieved in the framework of GGOS. This has to be done in close connection with the IAG Services. The collection, archiving, and distribution of data has to be coordinated in order to make it easily accessible for the international and interdisciplinary users community. Advances in data transfer and handling have to be provided to the services.

The CC for Conventions and Analysis shall look after the adherence of the conventions of IAG and other geo-scientific organizations by the services and official IAG entities. Products shall be analyzed and controlled on its consistency with respect to the constants, models and conventions, and with respect to other IAG products. New constants, models and conventions shall be proposed by the CC for adoption by the IAG Executive Committee if necessary.

The Products' CC concentrates on the final control of official IAG products with respect to its clearness, reliability and importance. It shall take care of the correctness of products and information used in geodesy and going to outside geodesy. These are in particular the other geo-sciences, but also users not familiar with geodetic products, such as politicians, publicists, economists. The CC shall also encourage the generation of new products if required.

All the CC have to include in their internal structure a close connection to the services, i.e., representatives of the services have to be included in all the components and all the activities. The IAG Communication and Outreach Branch has to be included in all the issues concerning the public. Regular meetings of the GGOS components with the Services and the Communication and Outreach Branch will guarantee an effective work.

7 Appendices

7.1 Appendix 1: IUGG Resolution on IGGOS

GGOS was established through the decision of the IAG Executive Committee at the 23rd IUGG General Assembly, 2003 in Sapporo, Japan. This decision was supported through the below IUGG Resolution of the same assembly.

Resolution 3: Integrated Global Geodetic Observing System (IGGOS):

IUGG Recognizing,

1. The great progress made in the use of space and terrestrial techniques for monitoring the phenomena and processes in the System Earth during the last decades; and
2. The efforts made towards the integration of space techniques in the management of observations, data processing, evaluation, and modelling of the observable parameters, in particular by the different international services; and
3. The urgent need to further develop and strengthen the scientific and organizational collaboration of geodesy within the geosciences;

and

4. The necessity of generation and accessibility of consistent products for users in Earth sciences, neighbouring disciplines and society in general.

Considering,

That the International Association of Geodesy (IAG) has taken an initiative towards the realization of IUGG Resolution no.1 adopted at the 22nd General Assembly in Birmingham 1999 by installing the integrated Global Geodetic Observing System (IGGOS).

Strongly supports the establishment of the IGGOS Project within the new IAG structure as geodesy's contribution to the wider field of geosciences and as the metrological basis for the Earth observation programs within IUGG and the international organizations mentioned in the 1999 Resolution no.1.

and **Urges**,

That Associations cooperate with the new project by providing data, models, products, and know-how useful for IGGOS and the benefit of geosciences; and

The participating in the IGGOS project by joining the relevant components in its structure and assisting its symposia and meetings.

7.2 Appendix 2: GGOS Charter

Integrated Global Geodetic Observing System (GGOS)

Chair: Ch. Reigber (reigber@web.de)

Secretary: H. Drewes (drewes@dgfi.badw.de)

TERMS OF REFERENCE

Following the IAG ByLaws, GGOS was developed by a planning group from 2001 to 2003. The proposal prepared by the GGOS Planning Group was accepted by the IAG Executive Committee and the IAG Council at their meetings at the XXIII IUGG General Assembly in Sapporo in summer 2003. The GGOS was endorsed by the IUGG through Resolution No. 3 at the same General Assembly.

GGOS stands for *Integrated Global Geodetic Observing System*. “System” should be understood as the basis on which future advances in geosciences can be built. By considering the Earth system as a whole (including the geosphere, hydrosphere, atmosphere and biosphere), monitoring Earth system components and their interaction by geodetic techniques and studying them from the geodetic point of view, the geodetic community provides the global geosciences community with a powerful tool consisting mainly of high quality services, standards and references, theoretical and observational innovations.

The **vision of GGOS** may be characterized as follows:

- GGOS integrates different techniques, different models and different approaches in order to achieve a better consistency, long-term reliability and understanding of geodetic, geodynamic and global change processes.
- GGOS provides the scientific and infrastructure basis for all global change research in Earth sciences.
- In the frame of GGOS, the Earth system is viewed as a whole by including the solid Earth as well as the fluid components, the static and time-varying gravity field in its products.
- GGOS is geodesy’s contribution (products and discoveries) to Earth sciences and the bridge to the other disciplines; it asserts the position of geodesy in geosciences.
- GGOS integrates the work of IAG and emphasizes the complementarity of the broad spectrum of geodetic research and application fields.

The **mission of GGOS** is:

- to collect, archive and ensure the accessibility of geodetic observations and models;
- to ensure the robustness of the three fundamental fields of geodesy, namely
  - *geometry and kinematics,*
  - *Earth orientation and rotation, and*
  - *gravity field and its variability;*
- to identify a consistent set of geodetic products and to establish the requirements concerning the products‘ accuracy, time resolution, and consistency;
- to identify IAG service gaps and develop strategies to close them;
- to stimulate close cooperation between existing and new IAG services;
- to promote and improve the visibility of the scientific research in geodesy;
- to achieve maximum benefit for the scientific community and society in general.

GGOS is geodesy‘s central interface to the scientific community and to society in general.

OBJECTIVES

- GGOS aims at maintaining the stability of and providing the ready access to the existing time series of geometric and gravimetric reference frames by ensuring the generation of uninterrupted time series of state-of-the-art global observations related to the three pillars of geodesy.
- GGOS focuses *in the first phase* on all aspects relevant to ensure the *consistency of geometric and gravimetric products*. This includes space-borne and terrestrial aspects.
- The targeted overall accuracy and consistency of GGOS products is of the order of 10-9 or better.
- GGOS ensures the consistency between the different geodetic standards used in the geosciences community, in agreement with the international unions.
- GGOS aims at improving the geodetic models at the level required by the observation.
- GGOS shall be *established* as an official partner in the *IGOS*, the United Nation's *Integrated Global Observing Strategy*.

SCIENCE RATIONALE

GGOS shall have a *central theme and a master product*. The theme **Global deformation and mass exchange processes in the System Earth** must be scientifically sound, broad and include all the activities GGOS might envisage in future.

Under the umbrella of *geometry* plus *Earth rotation* plus *gravity field* this theme encompasses virtually all facets of geodesy. In addition, it may easily be translated and broken down into tangible individual sub-themes and -products. From the general theme one *general product* may be derived, encompassing the following scientific questions/areas:

- The global patterns of tectonic deformation (global with, in addition, "enlargements" of regional maps) including inter-plate and intra-plate deformation,
- The global patterns of height changes (in one datum, and on all time scales, of geodynamic as well as of anthropogenic origin) on land, of ice covers (including glaciers), and of sea level,
- Deformation (loading as well as expansion) due to the mass transfer between atmosphere, hydrosphere including ice and solid Earth,
- Separation of effects of mass changes from motion and from thermal expansion,
- Separation of ocean effects from solid earth effects ("absolute" sea level),
- Quantification of angular momentum exchange, and mass transfer,
- Assessment of the angular momentum and mass balances in the Earth system model, and
- Quantification of mass exchange between the components of the System Earth.

The above list is not meant to be final and will be further developed.

The master theme and the results (products) derived from it will address the relevant science issues related to geodesy and geodynamics in the 21st century, but also issues relevant to society (global risk management, natural resources, climate change, ocean forecasting and others). It is an ambitious project of a dimension that cannot be achieved by the geodetic community alone, and which requires a strong cooperation inside and outside this community.

In order to shape GGOS through its master-theme and its master-products, a sound and comprehensive GGOS Science Plan is required. The **GGOS Science Plan** shall provide a logic framework for the work of GGOS. The master theme and the corresponding product(s) must be put into a broader science and application context. It should also include an analysis of the state-of-art in the science field under discussion, strength and deficiencies, recommendations of what should be done.

The GGOS Science Plan should serve as the basis for the implementation of GGOS in 2005. A work plan should be derivable from it. Furthermore it should become an attractive document for presentation to potential future partners and clients.

STRUCTURE

The GGOS Planning Group proposed to establish the following key elements of GGOS:

1. The ***GGOS Project Board*** as the central oversight entity.
2. ***Working Groups***. The tasks of the working groups are to a high degree independent of the tasks of the IAG services.
3. A ***Science Council*** representing the geodetic and geophysical community.

The proposal was accepted by the IAG Executive Committee.

The IAG ByLaws ask for the establishment of a Steering Committee consisting of members appointed by the commissions, two members at large, and the chairs of the IAG project sub-groups. The Steering Committee is a subset of the GGOS Project Board. The Steering Committee members are marked by an asterisk in the following list of members of the initial GGOS Project Board:

GGOS Project Board and Steering Committee (2003-2005)

- Chair: Chris Reigber*
- Members related to reference frames: Claude Boucher, Hermann Drewes (Repr. Commission 1*), Markus Rothacher
- Members related to gravity field and sea level: Rene Forsberg (Repr. Commission 2 *), Reiner Rummel, C.K. Shum
- Members related to Earth rotation and geodynamics: *Veronique Dehant, Kosuke Heki, Suzanna Zerbini* (Rep. Commission 3 *)
- Members related to services for geometry: *Norman Beck, Chopo Ma, Mike Pearlman*
- Members related to services for gravity and sea level: *Fernando Sanso, Phil Woodworth, Mike Watkins*
- Members related to networks: Wolfgang Schlüter, John Manning, Ruth Neilan

The initial composition of the project board is to a large extent the same as the composition of the GGOS Planning Group (2001-2003).

Working Groups

Setting up the GGOS working groups the following general principles are observed:

- GGOS will be based on the existing IAG Services. It is in particular not taking over tasks of existing, and well working IAG services. GGOS will provide a framework for existing or future services and ensure their long-term stability.
- New entities will be established only if there is a stringent requirement.
- GGOS must be the recognized by partners outside IAG, e.g., by UNESCO, ICSU, IGOS, GOOS, GTOS, governments, inter-government organizations, WCRP, IGBP, etc., as geodesy's most important contribution to Earth sciences. For this purpose contacts have to be established to these organizations.

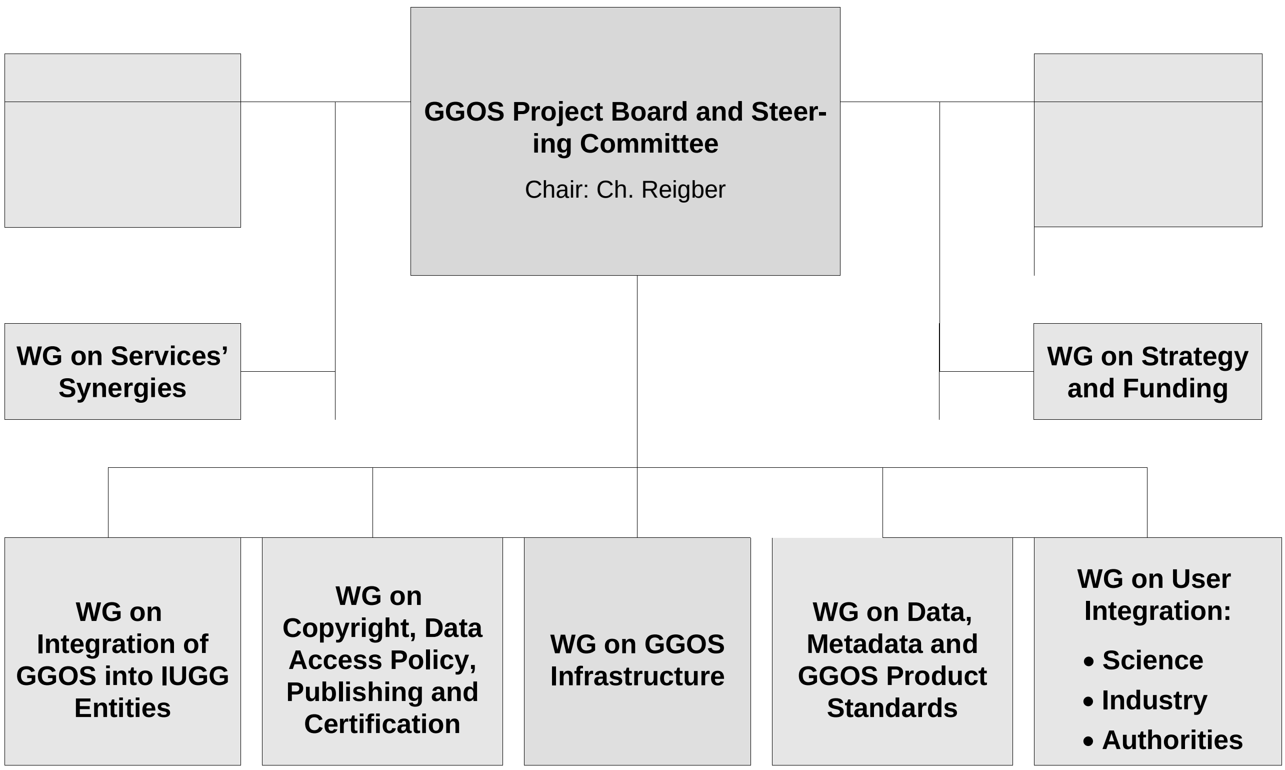
- GGOS must promote its master product and the related sub-products.
- GGOS must promote interdisciplinary research in geodesy.
- GGOS will provide standards and enforce quality management (validation, calibration, ensure the 1 ppb level) either by a new GGOS entity or by delegating this task to one or several of the existing services.

Science Council

The primary task of the science council is to develop the GGOS science plan based on the science rationale. The Inter-Commission Committee on Theory shall be represented in the Science Council.

The initial GGOS structure (for the definition phase 2003-2005) is illustrated by Figure 1.

Figure 1: Initial GGOS Structure



PROGRAM OF ACTIVITIES

WG on IAG Services' Synergies: The key issue within this WG is a thorough analysis of the existing IAG structure. Does it make sense to combine certain services into one? What new services should be set up? Is it correct to distinguish within IAG between *level 1 services* (e.g., IGS, ILRS, IVS), dealing with raw observations and generating products which are more or less based on these observations only, and *level 2 services* (e.g., IERS) using the products of several level 1 services and generating new products, which are consistent with all the information from level 1? Shall additional level 2 services be established?

WG on Strategy and Funding: In the long run, funding has to be addressed by all permanent IAG entities requiring a complex infrastructure. As GGOS per se (at least initially) will be based – exactly like all IAG services – on voluntary contributions of the relevant research organizations in the field, an GGOS funding strategy must be developed in close coordination with these organizations. It seems therefore appropriate to establish a working group related to this topic. This aspect is clearly not dealt with at a sufficient rate within the existing IAG services structure.

WG on Integration of GGOS in IUGG entities: This WG has the task to set up (so-to-speak) the foreign ministry of GGOS. It must be the goal to have GGOS acknowledged as a member in the important international programs dealing with global change, etc. The IGOS is but one important example.

WG on Copyright, Data Access Policy, Publishing and Certification: This WG should deal with the consistent assignment of the *Digital Object Identifier* (DOT®) framework for GGOS products and the usage of *Data Set Citation* rules in metadata documents for the definition and realization of copyright, data access, publishing and certification objectives.

WG on Data, Metadata, and GGOS Product Standards: This WG has to deal with GGOS products and standardization issues. The definition of GGOS *Products* consisting of data and metadata, driven by user, application and service requirements using international *Standardization* specifications, constitutes the precondition for the creation of state-of-the-art value-added public and science GGOS services.

WG on User Integration: This task is in part dealt with by the IAG services. A common policy on the IAG level is, however, missing. This WG must be set up in close cooperation with the services.

Schedule for the Realization of GGOS

The following plan to develop GGOS is based on the decisions taken at the last GGOS planning group meeting in Sapporo.

1. The GGOS definition phase lasts from 2003-2005. The main tasks are:
   - Definition of the final GGOS structure
   - Development of the GGOS Science Plan
2. The “final” GGOS structure and the science plan will have to be approved by the IAG Executive Committee at the IAG Scientific Assembly in Cairns, Australia.
3. The GGOS, as IAG’s first project, should become operational in 2005.
4. GGOS, in particular the science plan developed between 2003 and 2005, will be a central issue of the IAG Scientific Assembly 2005.