The Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG)

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ABSTRACT

The International Association of Geodesy (IAG) installed the Global Geodetic Observing System (GGOS) in July 2003 during the XXIII General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Sapporo, Japan, as the first and only Association Project. According to the IAG bylaws, Association Projects are of broad scope and of highest interest for the entire field of geodesy. They serve as the Association's flagship for long periods (decade or longer). The mission of GGOS is to coordinate the different geodetic observing techniques and modelling approaches, and to integrate them in a consistent generation of products in the three fundamental fields of geodesy: Geometry and kinematics of the Earth's surface, orientation and rotation of the Earth in space, and the gravity field of the Earth and its variability. The geodetic products shall be made visible in science, practice and society, and they shall be provided to policy makers and economists as a basis for their decisions related to, e.g., global change, natural hazard and disaster prevention.

INTRODUCTION

A completely new structure was established by the International Association of Geodesy (IAG) during the XXIII General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Sapporo, Japan, July 2003. The basic motivation for this step was to meet the needs of the 21st century taking into account the recent changes in geodetic science. Geodetic observations have been revolutionized during the last decades by modern space techniques (in particular radio astrometry and satellite methods). The consequent globalisation of data generation, handling and processing lead to the establishment of international scientific services which evolved from the excellent cooperation of geodetic researchers around the world. These services are in general based on individual observation techniques or the generated products. They coordinate international observation programmes, guarantee the open access of data, integrate the data processing by analysis centres, and provide the results to science and society. The great success of the services in the past affected basically the geodetic science and formed a considerable part of the IAG activities.

The "Committee for the Realization of the New IAG Structure" analysed these facts during the years 2002 to 2003 and proposed a new structure which includes scientific commissions and services at the same level. As the scientists involved in the services (table 1) separate mainly into two groups, corresponding to the fields of geometric and gravimetric methods, there had occurred some divergence of the work during the last decades. The consequences were the adoption of different conventions, use of different constants and models, and representing the results by different parameters. In this way, the geodetic (geometric and gravimetric) products were not always sufficiently consistent and could not easily be

combined with each other. Therefore, a central IAG project, the Global Geodetic Observing System (GGOS), was proposed in the new structure to integrate and coordinate all the activities, guarantee the consistency of products and provide them to the broad users community. The proposal was accepted by the IAG, and the IUGG strongly supported the GGOS by its Resolution No. 3 adopted during the XXIII General Assembly in Sapporo 2003.

Table 1: Services of the International Association of Geodesy (IAG)

<table>
<tr><th>Geometry</th><th>Gravimetry</th><th>Sea Level</th></tr>
<tr><td>International Earth Rotation and Reference Systems Service (IERS)</td><td rowspan="5">International Gravity Field Service (IGFS)

International Gravimetric Bureau (BGI)
International Geoid Service (IGeS)
International Centre f. Earth Tides (ICET)</td><td>Permanent Service for Mean Sea Level (PSMSL)</td></tr>
<tr><td rowspan="2">International GNSS Service (IGS)
International Laser Ranging Service (ILRS)</td><td>Time</td></tr>
<tr><td>Bureau International de Poids et Mesure – Time Section (BIPM)</td></tr>
<tr><td rowspan="2">International VLBI Service (IVS)
International DORIS Service (IDS)</td><td>Bibliography</td></tr>
<tr><td>IAG Bibliographic Service (IBS)</td></tr>
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Directly after the Sapporo 2003 meeting an initial phase of GGOS was set up by nominating a Project Board. The first meeting of this Board took place before the EGU General Assembly, Nice, April 24, 2004. During this meeting the objectives were revised and the first structure was installed nominating initial chairpersons. The first GGOS Workshop held in Potsdam, Germany, March 1-2, 2005, reviewed the work of the first period, adopted a modified structure and set up the action items for the next future.

THE VISION OF GGOS

The vision of GGOS as IAG's flagship may be highlighted as follows:

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

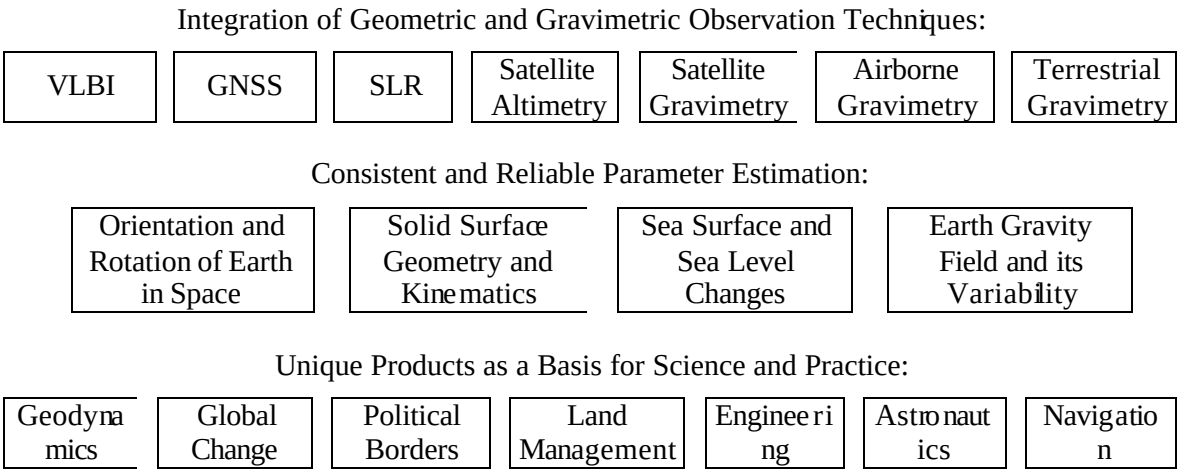


Figure 1: The vision of GGOS as an integrating body for observations and products

THE MISSION OF GGOS

Following these basic ideas, the mission of GGOS may be seen twofold, the coordination within geodesy and the representation of geodesy in other sciences and in public. The internal matters are summarized by the tasks

- to collect, archive and ensure accessibility of geodetic observations and models;
- to ensure the robustness of the three fields of geodesy: geometry and kinematics, orientation and rotation, and gravity field of the Earth;
- to identify geodetic products and to establish the requirements concerning its accuracy, time resolution, and consistency;
- To stimulate close cooperation between IAG services, to identify service gaps and develop strategies to close them.

If we look at the present situation in geodesy we may find some significant deficiencies with respect to the listed tasks. The robustness of the three fields of geodesy is not sufficiently exhausted due to some inconsistencies in the used models and provided products in the different areas. The requirements concerning accuracy and time resolution should be similar for all parameters. However, while we get 10^{-9} accuracy for the geometric parameters (surface coordinates) we are far off this level in gravimetric parameters (geoid, gravity anomalies). In geodetic services we are missing, e.g., a unified global height reference system (global vertical datum), vertical deformation models (tectonic, isostatic, loading, ...), time dependent sea level models from (satellite altimetry), free availability of terrestrial gravity data.

The representation of geodesy in other sciences and in public means in particular

- to promote and improve the visibility of geodetic research;
- to achieve maximum benefit for the scientific community and for society in general.

It is obvious that geodesy is not well-known in society although geodetic products (surface coordinates, Earth orientation parameters, gravity potential) are used in surveying, cadastre, engineering, global spatial data infrastructure, rural and urban development, space-travel, navigation etc. People have to know that it's geodesy that provides the basis for these applications. Publications have to include popular literature, too, not only scientific journals.

To achieve more visibility and effect, data and information have to be exchanged with geosciences and other sciences in an easily understandable way. Policy makers and publicists have to be provided with the necessary information for their decisions and reports. This part of geodesy has widely been neglected in the past.

THE OBJECTIVES OF GGOS

The specified objectives of GGOS may be derived from the tasks mentioned in its mission:

- GGOS aims at maintaining the stability of time series of geometric and gravimetric ***reference frames***;
- GGOS ensures the consistency between geodetic ***standards and conventions*** used in the geo-scientific community;
- GGOS aims at improving the geodetic ***models*** to the high level required by the modern precise observations;
- GGOS focuses on all aspects to ensure the consistency of geometric and gravimetric ***products***;
- GGOS shall be established as an official partner in the United Nations' ***Integrated Global Observing Strategy, IGOS***,
- GGOS shall represent IAG in the inter-governmental ad hoc ***Group on Earth Observations, GEO.***

The necessity of looking seriously after the consistency of standards, models and reference frames in geodetic products may be seen from the examples given in table 2. We have several options to define and realize the parameters. As a matter of fact, there is no complete homogeneity in the use of these parameters. The origin, orientation and scale of reference frames is defined differently in geometric and gravimetric applications. Its consistency is not always proven. The models, e.g., for reducing the effects of Earth tides are not identical in geometric and gravimetric products. While the permanent effect of Sun and Moon is normally included in gravity data and models, it is reduced in geometric parameters (e.g., coordinates). This means, that the basic formula h = H + N (ellipsoidal height = orthometric height + geoid height) is not fulfilled if we take h, H from geometric and N from gravimetric results.

Table 2: Examples for inconsistencies in geodetic conventions, models and reference frames

	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, DUT	axis of inertia: C_{12}, S_{12}
... of scale	c	GM
Models for tides	tide free	zero tide
... for deformation	geometric only	dynamic
Product reference	ITRF, GRS80	variable
... update	regularly	episodic

THE SCIENTIFIC RATIONALE OF GGOS

The Global Geodetic Observing System has the *central theme* "Global deformation and mass exchange processes in the System Earth" which includes all the activities of GGOS in the future:

- The study of all global patterns of tectonic deformation;
- Investigations on global patterns of all types of height changes;
- Deformation due to mass transfer between solid Earth, atmosphere, and hydrosphere including ice, of geodynamic as well as of anthropogenic origin;
- Quantification of angular momentum exchange and mass transfer.

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

Geodesy is capable of providing information on the mass exchange between all elements (components) of the Earth's system by observing

- deformation of the solid Earth (geometry and kinematics) by precise positioning;
- water circulation in oceans, ice covers, atmosphere, solid Earth by satellite radar and laser altimetry, atmospheric sounding, terrestrial and satellite gravity measurements;
- mass exchange between the atmosphere, the hydrosphere and the biosphere via the angular momentum by observing variations of Earth rotation and the gravity field.

ACTUAL ACTIVITIES OF GGOS

The activities of GGOS within the geodetic community are done continuously by close interaction with the IAG Services. The twelve services (table 1) are cooperating more and more closely in order to overcome inconsistencies of conventions, models and parameters as well as to close gaps in service products. While the geometric services are working together intensively, there could be some improvement of cooperation within the gravimetric services and between both.

For the representation of geodesy in international bodies, GGOS started some important activities during the last two years. It submitted a concept note for a "Dynamic Theme" within United Nations' Integrated Global Observing Strategy (IGOS) and was encouraged to develop a proposal for a new theme following the IGOS-P regulations and coordinate the proposal preparation with the geo-hazard theme, the ocean theme and the water cycle theme.

IAG has become a participating organization in the intergovernmental ad-hoc Group on Earth Observations (GEO) and nominated the GGOS Chair as its representative to the GEO plenary. GGOS participated in the development of a 10-year implementation plan for a Global Earth Observing System of Systems (GEOSS) by working with ten members in the five corresponding subgroups.

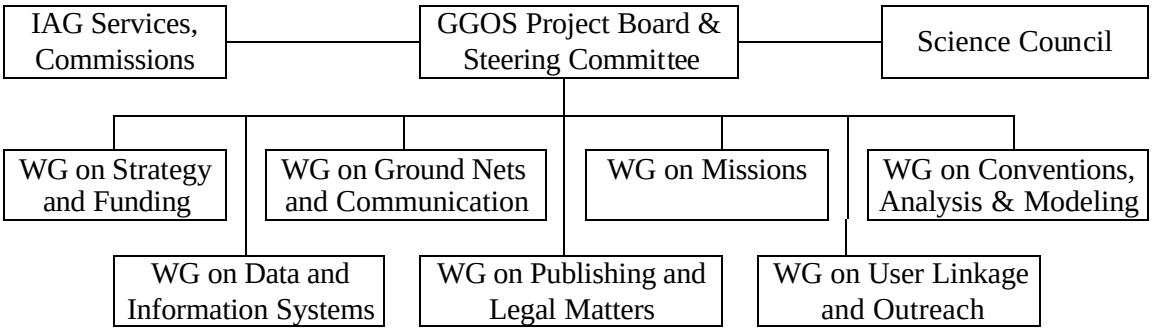
Some regional activities were also started to support GGOS:

- In the USA the Project "Inter-Service Data Integration for Geodetic Operations" (INDIGO) will enable improved performance, accuracy, and efficiency in support of NASA's Earth science and inter-national user community by developing and providing uniform access to heterogeneous space geodetic data systems;
- The EU project on "Geodetic And Geohazard Observing Systems (GAGOS)" of the European Partners in GGOS (EPIGGOS) has the main goal to identify necessary

adaptations of the existing infrastructure (including data management) and new deployments for the assessment of in-situ capabilities in Earth observation systems.

The actual structure of GGOS was established during the first GGOS Workshop in Potsdam, Germany, 1-2 March 2005. It divides into seven Working Groups (see figure 2).

Figure 2: GGOS Structure (March 2005)



CONCLUSION

There are two principal aspects in the mission of GGOS:

1. "Internally" to guarantee the reliability of geodetic products by ensuring the consistency of conventions, models, parameters, and reference systems used in the three fields of geodesy: Earth geometry, Earth orientation, and Earth gravity field.
2. "Externally" to promote and improve the visibility of geodetic research and results, to represent geodesy in international bodies, and to achieve maximum benefit for the scientific community and for society in general by providing data and products.