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

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SUMMARY

The Global Geodetic Observing System (GGOS) is an essential component of the International Association of Geodesy (IAG). It aims at advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time. This is based on the mission of GGOS:

- to provide the observations needed to monitor, map, and understand changes in the Earth's shape, rotation, and mass distribution,
- to provide the global geodetic frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications, and
- to benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built.

For this purpose GGOS works with the IAG components to provide the geodetic infrastructure which is necessary for monitoring the Earth system and for global change research.

Obviously, this is a cross-cutting issue both of IAG regarding its commissions, services, and inter-commission committees and of external stakeholders. Hence, the structure and the activities of GGOS have to deal with various facets of the establishment, maintenance, operation and further development geodetic observation and data infrastructure such as networks, hardware, standards and products. This presentation gives a general overview of the present state of GGOS. In particular, it focuses on the structure of GGOS which is optimized and streamlined regarding role and purpose of GGOS. Moreover, it outlines feasible results of GGOS in support of the work of the UN Committee on Global Geospatial Information Management (GGIM) and its Sub-Committee on Geodesy.

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1. INTRODUCTION

The Global Geodetic Observing System (GGOS) is an essential component of the International Association of Geodesy (IAG). It aims at advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time. This is based on the mission of GGOS: to provide the observations needed to monitor, map, and understand changes in the Earth's shape, rotation, and mass distribution, to provide the global geodetic frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications, and to benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built. For this purpose GGOS works with the IAG components to provide the geodetic infrastructure which is necessary for monitoring the Earth system and for global change research.

In principle, GGOS integrates the so-called three pillars of Geodesy – kinematics, gravity field and rotation of the Earth – by consistently combining geodetic observation techniques based on an appropriate infrastructure and on numerical process models of the Earth system (see Fig. 1). This allows one the one hand to derive an integrated geodetic reference frame for geometric positions and physical heights. On the other hand it is the essential basis for Earth system research. Fig. 2 gives a detailed view on the space-geodetic techniques and their relation to the geodetic observation of Earth system processes.

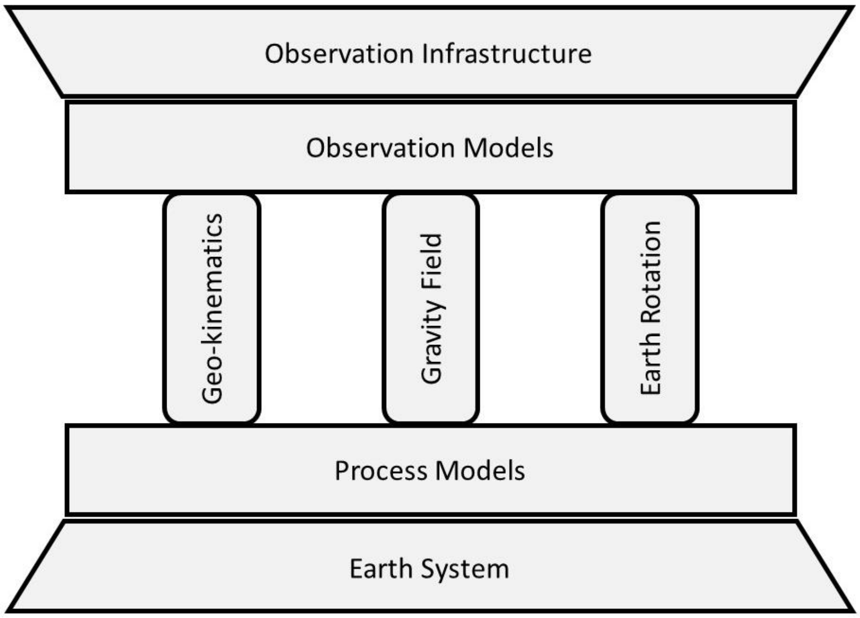

Fig. 1: Overview on the three pillars of Geodesy and their link to observation infrastructure and the Earth system

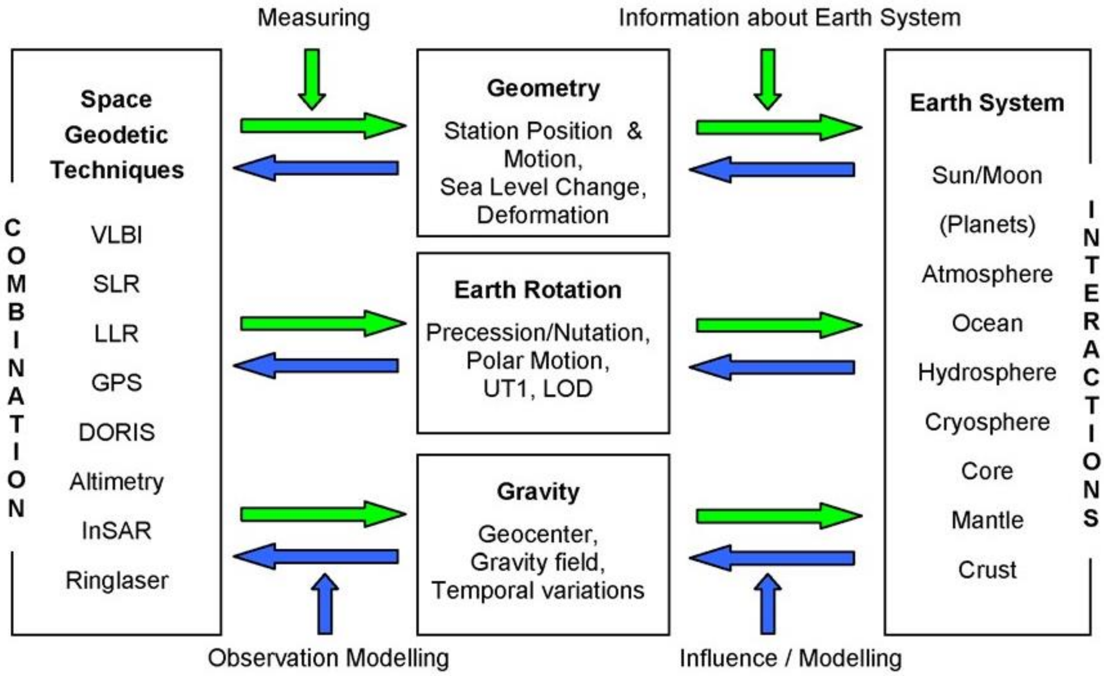

Fig. 2: Detailed view on the geodetic observation of processes in the Earth system (according to Rothacher 2008)

In this contribution two fundamental issues of GGOS are considered: GGOS as an observing system and GGOS as an organization. Beyond that, GGOS also serves as a cumulative label of all respective work and products of the IAG. For a comprehensive introduction on GGOS see Plag and Pearlman 2009 as well as the GGOS website www.ggos.org.

2. GGOS AS AN OBSERVING SYSTEM

2.1 IAG Services

During the last decades geodetic observation techniques improved significantly in terms of sensitivity and accuracy as well as in operational performance and global relevance. In particular the upcoming of space-geodetic techniques allowed more and more to provide highly precise global geometric reference frames, global gravity field representations with high spatial and even temporal resolution and Earth rotation time series with high temporal resolution. On the one hand this was fostered and advanced by a multitude of research activities in the Scientific Commissions of the IAG and its Inter-Commission Committee on Theory (ICCT) and on the other hand by the development, implementation and operation of scientific services of the IAG, some of them jointly operated with other scientific associations.

IAG services contributing to GGOS are – among others – the following:

- International VLBI Service for Geodesy and Astrometry (IVS),
- International GNSS Service (IGS),
- International Laser Ranging Service (ILRS),
- International DORIS Service (IDS),
- International Earth Rotation and Reference Systems Service (IERS),
- International Service for the Geoid (ISG),
- Internation Gravity Field Service (IGFS).

Note the following abbreviations in the previous list: Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS), Doppler Orbitography Integrated by Satellite (DORIS). Laser ranging refers to both Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR).

All these services rely on observation infrastructure in terms of satellites, geodetic observatories and geodetic networks which are in most cases operated by space agencies and national mapping agencies. The original work of the individual services address the complete chain of data processing, evaluation and analysis. Each of these services provide general information as well as their products through their websites which can be found via the IAG website www-iag-aig.org.

2.2 Observation Architecture of GGOS

As parameters of the relevant processes of the Earth system can be observed with different geodetic observation techniques, there is both redundancy and complementarity due to the individual sensitivity of the observation. VLBI, e.g., is the only geodetic technique which allows to observe Universal Time (UT1). Moreover, all these observation are influenced by the same processes of the Earth system.

Therefore it is evident that an integrated analysis based on the thorough combination of all relevant geodetic observations and corresponding numerical models of Earth system processes will increase the overall consistency of the existing products. This is one of the main ideas behind GGOS. Its respective observation infrastructure is given in Fig. 3. It consists of five different layers:

- Layer 1: Terrestrial infrastructure,
- Layer 2: Low Earth Orbiters (LEO),
- Layer 3: Mean Earth Orbiters (MEO),
- Layer 4: Moon and planets,
- Layer 5: Extra-galactic objects.

Looking at this concept, GGOS can be considered as an observing “system of systems” in analogy the Global Earth Observing System of Systems (GEOSS) of the inter-governmental Group on Earth Observation (GEO; https://www.earthobservations.org/index.php).

Besides the pure observation infrastructure a data infrastructure is required to implement GGOS. This infrastructure relies on the one hand on the contributions of the IAG services and on the other hand on own, unique components of GGOS.

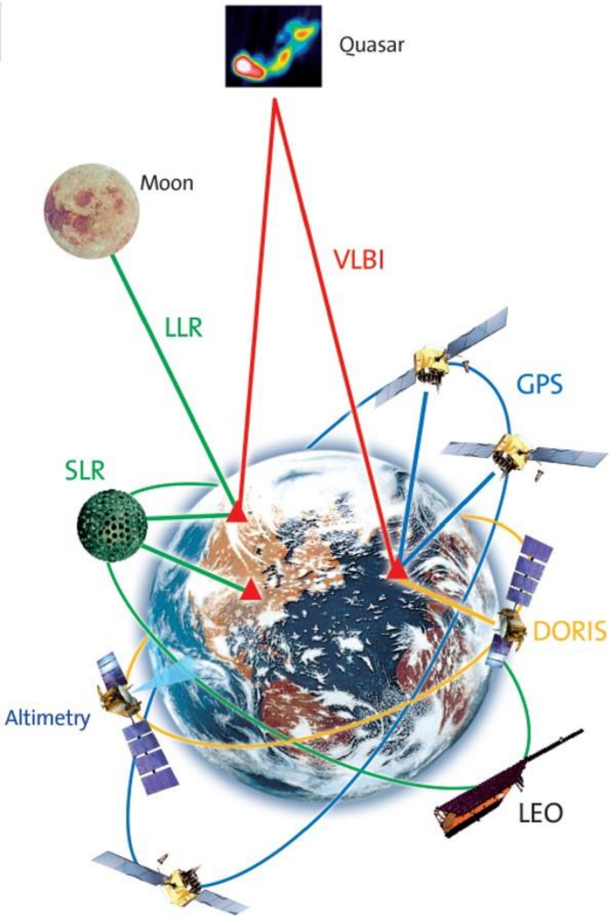

Fig. 3: GGOS observation architecture (Rothacher et al. 2009)

In more detail, Layer 1 consists of the following components:

- the global network of VLBI radio-telescopes, coordinated by IVS,
- the global network of GNSS stations, coordinated by IGS,
- the global network of SLR/LLR telescopes, coordinated by ILRS,
- the global network of DORIS stations, coordinated by IDS,
- the global network of super-conducting gravimeters, coordinated by the Global Geodynamics Project, together with the network of absolute gravity stations,
- the global network of tide gauges, coordinated by the Intergovernmental Oceanographic Commission (IOC),
- the global network of time stations.

GGOS Core Sites are the central components of this concept. At minimum they provide the following instrumentation:

- two or more VLBI telescopes for continuous operation,
- one SLR/LLR telescope,
- three GNSS receivers,
- one DORIS beacon,
- highly precise time and frequency normal,

- a super-conducting and an absolute gravimeter,
- a seismometer,
- additional sensors such as for meteorological, hydrological or geotechnical parameters.

The Geodetic Observatory Wettzell, Germany, is such a GGOS Core Site (www.fs.wettzell.de).

Layer 2 consists of present or future low-orbit satellite missions such as for global gravity field determination (CHAMP, GRACE, GOCE) or for altimetry (ERS-2, JASON-1). Layer 3 comprises all GNSS satellites as well as SLR satellites (LAGEOS). Layer 4 refers to SLR reflectors on the moon and to future planetary missions. Layer 5 means quasars and other compact radio sources.

The accuracy goals of GGOS are challenging. They are given in Plag and Pearlman 2009 (pp. 220ff). The required accuracy for the terrestrial reference frame and for the time varying geoid may serve as examples: both accurate to 1 mm and stable to 0.1 mm/yr. Hence, achieving these goals is not only a technological issue but an outstanding task of geodetic and related sciences as well.

3. GGOS AS AN ORGANIZATION

For the operation of GGOS as a global geodetic observing system it is mandatory and even indispensable to define and implement an organizational structure; see Fig 4. All relevant information on GGOS is given in the most recent version 2016 of the Geodesists Handbook (http://link.springer.com/article/10.1007/s00190-016-0948-z). An overview is given below.

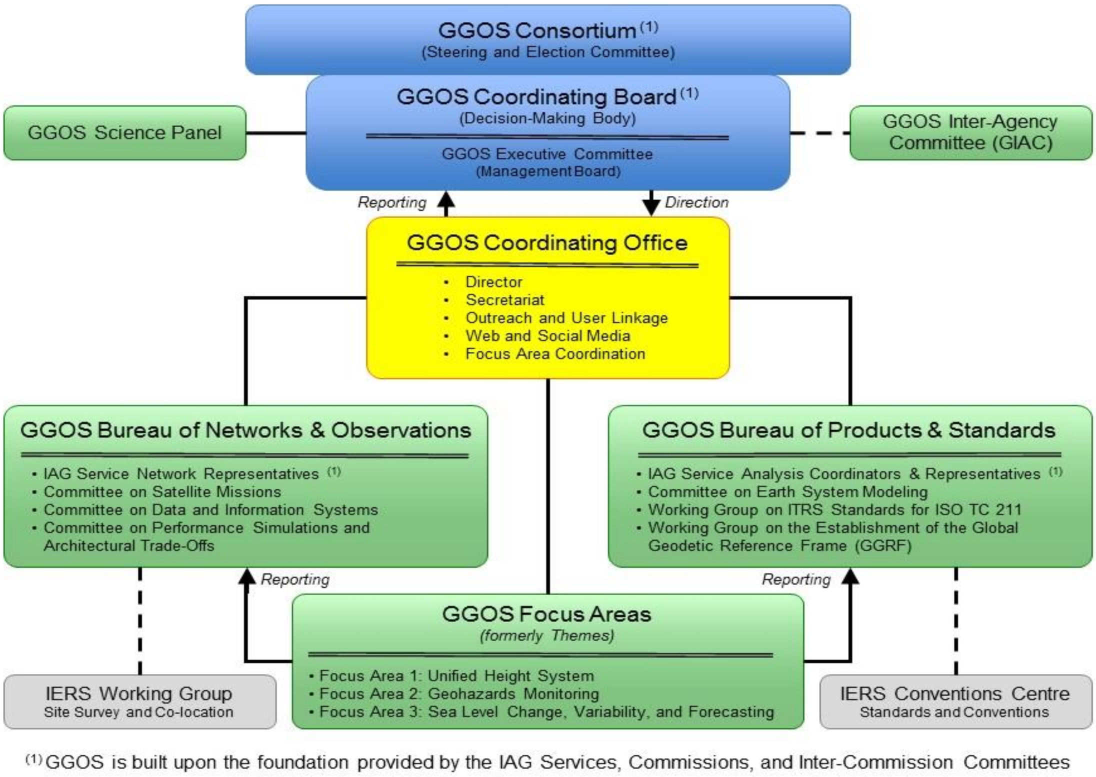

Fig. 4: Organizational chart of GGOS

There is the main distinction between the strategic level and the operational level of GGOS. The strategic level consists of the GGOS Consortium, the GGOS Coordinating Board (CB), the GGOS Science Panel and the GGOS Executive Committee (EC). The operational level consists of the GGOS Coordinating Office (CO), the GGOS Bureau of Networks and Observations, the GGOS Bureau of Products and Standards as well as the GGOS Focus Areas on Unified Height System, Geohazards and Sea Level Change. The work of these components is supported and promoted by committees and working groups addressing issues such as satellite missions which are highly relevant for the work of GGOS.

The GGOS Consortium is the large steering body of GGOS. Its members represent all IAG components (commissions, services, inter-commission committees). The GGOS Chair is one of the voting members of the IAG Executive Committee, the highest body of the IAG. The GGOS CB is the decision-making body, supported by the GGOS EC and the GGOS CO for day-to-day operations. In addition, the IAG commissions are represented in the GGOS Science Panel which acts as an advisory board. The IAG services are represented at the operational level as well through participation in the work of the two GGOS Bureaus. Hence, there are strong and close links from and to GGOS within the IAG structure.

As an organization, GGOS develops and maintains an overall strategic plan and biannual implementation plans of the GGOS components. The GGOS goals and objectives are built around four strategic areas that are directly attributable to the established GGOS goals. These areas are relevant to the activities and future efforts of GGOS. The strategic areas are related to each goal, but are overarching in nature – just as each goal acts in support of other goals, each strategy has a role in all of the goals. Here, due to space limitations, only an overview is given on this issue. The following strategic areas are fundamental:

- Geodetic Information and Expertise (intangible assets):
  GGOS outcomes will support the development and maintenance of organizational intangible assets, including geodetic information and expertise. The development of this strategic focus area will benefit all other goals and objectives.
- Global Geodetic Infrastructure (advocacy for, and sustenance of, tangible assets): Development of, advocacy for, and maintenance of existing global geodetic infrastructure is in direct support of each GGOS goal.
- Services, Standardization, and Support (internal and external coordination): Optimal coordination, support, and utilization of IAG services, as well as leveraging existing IAG resources, are critical to the progress of all GGOS goals and objectives.
- Communication, Education, and Outreach (public relations, external education and outreach, internal continuing education and training): Marketing, outreach, and engagement are critical elements for sustaining the organizational fabric of GGOS.

Looking at the governance and operation of GGOS (including the IAG Scientific Services) from the viewpoint of sustainability they strongly rely on resources provided by space and national mapping agencies. Up to now, the operational IAG components depend on voluntary contributions on a best-effort basis. In terms of long-term operation this implies a high risk for example for the derivation and provision of a highly precise global geodetic reference frame. Recent activities of the

Committee on Global Geospatial Information Management (GGIM) of the United Nations (UN) try to overcome and finally solve this problem based on high-level political commitment. More information on the UN GGIM Sub-Committee on Geodesy, on the UN General Assembly Resolution on Global Geodetic Reference Frames and on the respective roadmap can be found on www.unggrf.org.

4. CONCLUSIONS

GGOS is the global observing system of the International Association of Geodesy. It integrates the three pillars of Geodesy by combining all relevant geodetic observations and numerical Earth system models. Like all IAG Scientific Services it strongly relies on the long-term availability of global geodetic infrastructure and on adequate resources to run, foster and promote its operations. The outstanding tasks are one the one hand the GGOS accuracy goals which challenge science and technology and on the other hand the warranty for long-term operation and development based on international cooperation.

REFERENCES

Plag, H.-P. und M. Pearlman (Eds.). 2009: Global Geodetic Observing System – Meeting the Requirements of a Global Society on a Changing Planet in 2020. Springer: Dordrecht, Heidelberg, London, New York.

Rothacher, M. 2008. Global Geodetic Observing System (GGOS): Status and Future. AOGS 5th Annual Meeting 2008, June 16-20, 2008, Busan, Korea.

Rothacher, M., G. Beutler, D. Behrend, A. Donnellan, J. Hinderer, C. Ma, C. Noll, J. Oberst, M. Pearlman, H.-P. Plag, B. Richter, T. Schöne, G. Tavernier, P.L. Woodworth. 2009. Chapter 9 – The future Global Geodetic Observing System. In: Plag, H.-P. und M. Pearlman (Eds.). 2009, pp. 237-272.

BIOGRAPHICAL NOTES

Hansjörg Kutterer is Director General of BKG, the German Federal Agency for Cartography and Geodesy. He received his Dipl.-Ing. degree and Doctor degree in Geodesy at the University of Karlsruhe. After 20 years of an academic career including the position of the Head of Geodetic Institute of the Leibniz University Hannover he moved to BKG in 2011. He holds (and held) positions in various committees and organizations such as Vice President of EuroGeographics and Chair of GGOS. In addition, he is President of DVW, the German member organization of FIG.

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