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**Conference papers: Invited papers on achievements and developments in
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Geodesy for Sustainable Development *

International Association of Geodesy (IAG)

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Geodesy for Sustainable Development

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Executive Summary

Geodesy is the science of determining the geometry, gravity field, and rotation of the Earth, and their evolution in time. Geodesy underpins all satellite positioning technology which is a key enabler of spatial data interoperability and increasingly a requirement for sustainable development. However, geodesy requires ongoing investment by government in the establishment of the global geodetic network infrastructure necessary to support the 'Global Geodetic Observing System' (GGOS). The network must include a global distribution of modern ground stations with collocated space geodetic techniques that will provide the spatial and temporal coverage required for the maintenance of GGOS data products. This ambitious undertaking can be achieved if a substantive intergovernmental underpinning is established. Towards this end, the establishment of the UN-GGIM provides an opportunity to improve the sustainability of GGOS, the IAG Services and the supporting agencies to provide the long-term coverage of the in-situ space geodetic networks in time and geographic distribution.

Introduction

Geodesy is both part of the geosciences and is an engineering science (including surveying, mapping and navigation). Hence geodesy is concerned with:

- Monitoring of the solid Earth e.g., displacement, subsidence or deformation of the ground and structures, due to tectonic, volcanic and other natural phenomena, as well as human activity;
- Monitoring of variations in the liquid Earth e.g., sea level rise, ice sheets, mesoscale surface topography features, mass transport;
- Monitoring variations in the Earth's rotation i.e. polar motion, the length of the day
- Monitoring the atmosphere with satellite geodetic techniques e.g., ionosphere and troposphere composition and physical state;
- Monitoring the temporal variations in the gravity field of the Earth;
- Determining satellite orbits, including earth observation and navigation satellites;
- Determining positions, and their changes with time, of points on or above the

surface of the Earth with the utmost accuracy.

In providing these capabilities, geodesy increasingly underpins all sustainable development.

The Global Geodetic Observing System (GGOS)

Under the banner of GGOS, the International Association of Geodesy (IAG) has sought to integrate the services for all the major satellite geodesy techniques: International Global Navigation Satellite System (GNSS) Service (IGS – <http://igs.org>); International Laser Ranging Service (ILRS – <http://ilrs.gsfc.nasa.gov>); International Very Long Baseline Interferometry Service (IVS – <http://ivscc.gsfc.nasa.gov>); International Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) Service (IDS – <http://ids.cls.fr>); International Earth Rotation and Reference Systems Service (IERS – <http://www.iers.org>); and the International Gravity Field Service (IGFS – <http://www.igfs.net>). These services generate a wide range of products, including precise satellite orbits, ground station coordinates, Earth rotation and orientation values, gravity field quantities and atmospheric parameters.

The mission of GGOS is:

- to provide the observations needed to monitor, map and understand changes in the Earth's shape, rotation and mass distribution;
- to provide the global 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.

GGOS integrates different geodetic techniques, different models, and different approaches in order to ensure a long-term, precise monitoring of the geodetic observables to support the most demanding scientific and societal applications.

GGOS provides the observational basis to maintain a stable, accurate and global reference frame and in this function is crucial for all Earth observation and many practical applications. GGOS contributes to the Global Earth Observing System of Systems (GEOSS) not only with the accurate reference frame required for many components of GEOSS but also with observations related to the global hydrological cycle, the dynamics of atmosphere and oceans, and natural hazards and disasters.

GGOS acts as the interface between the geodetic services and external users such as the Group on Earth Observation (GEO) and various United Nations authorities. A major goal is to ensure the interoperability of the services and GEOSS. With this the geodetic community can provide the global geosciences community with a powerful tool consisting mainly of high quality services, standards and references, and theoretical and observational innovations.

GGOS Strengths

The IAG Services, as the backbone of the GGOS, are characterised by:

- Delivery of the products related to the high precision reference frames (geometry, Earth rotation, gravity field). These products provide:
 - Metrological basis for other geosciences;
 - Dynamics of the Earth;
 - Accurate foundation for Positioning and Navigation applications.
- Fundamental science and infrastructure for global geodetic tasks which form the basis for regional and national geodetic systems.
- A functional community of international voluntary cooperation.
- Provision of openly available, operational products for societal benefit areas and the geosciences.
- Science foundation for operational geodesy.
- A scientifically-based strategic plan for the enhancement of the geodetic products (GGOS2020).

GGOS Weaknesses

- The products of IAG Services are currently “best effort” which is not ideal given the heavy societal reliance on them.
- Infrastructure custodians are lacking long-term stable financial resources for the operation of current infrastructure.
- The global observing networks are not optimal (inhomogeneous global distribution of observatories, insufficient data, and variable data quality).
- Replacement of aging infrastructure to allow for new technical challenges and developments is rarely planned and budgeted in a uniform way.

- In the last few years the global geodesy network has suffered several debilitating closures and reductions due to budgetary cutbacks and equipment failure which has led to a degradation of the network. In the late 1990s, more than 20 core station existed, as demonstrated by the larger number of core stations used for the determination of ITRF2000. However, at present there are only 9 stations with collocated permanent GNSS, SLR and VLBI observations.

GGOS Opportunities

- A stabilisation of the permanent global geodetic infrastructure may be possible under the umbrella of an intergovernmental arrangement.
- The products of the IAG Services, including the accuracy of the International Terrestrial Reference Frame (ITRF), can be improved. This will require more observations, instrumental improvements so as to ensure better data, better network design and better analysis strategies.
- The existing networks can be densified at the regional level, especially in remote or lesser developed areas (southern hemisphere, Africa, etc.).
- Internationally coordinated decisions on the operation of geodetic infrastructure and analysis centres will advance the GGOS goals.
- New contributors from countries with small or no current contribution to IAG Services may be attracted by the GGOS so that the observing activities will be extended.
- Participation in the GGOS will facilitate capacity building through the transfer of geodetic science and technology to less developed regions.
- Involvement in the GGOS may appear to be easier to developing countries if an intergovernmental umbrella exists.

GGOS Threats

- Demands from the user community can't be met fully by the existing infrastructure.
- Lack of recognition of geodetic products by the end user community results in a corresponding lack of recognition of the need for ongoing operational funding for network infrastructure and IAG Services at a governmental level.
- Financing the activities of the GGOS from research funds as a short-term scientific project does not lead to sustainable products. In particular it will not lead to a refined ITRF. This could result in the world lacking a robust coordinate reference

system that underpins much of its commerce and industry, especially those sectors that rely on accurate GPS-based positioning. It could also impact, directly or indirectly, on the safety of people.

- The leadership currently claimed by IAG/GGOS in the derivation of the global reference frame could be lost to a commercial consortium(s).

Summary

The sustained and long-term provision of the GGOS products including the reference frame requires a globally distributed network of modern collocated space geodetic stations. This is an ambitious undertaking, but it is essential if we wish to better understand many of the processes that influence global change. The establishment of this network will require support and cooperation from government agencies that presently provide the geodetic infrastructure and means to attract additional governmental agencies (in other countries) as the network is expanded. This cooperation would be greatly facilitated and more likely secured by an agreement at intergovernmental level among those nations whose agencies/institutions provide the necessary geodetic station infrastructure. Through the agreement, these institutions would make a commitment to participate, and this participation could grow as time goes on.

Recommendations

- Recognise the need for sustainability and improvement of the global network of geodetic infrastructure and IAG/GGOS Services.
- Recognise the need for intergovernmental recognition of, and representation to, GGOS as one of the key global observing systems.
- Recognise the benefits that GGOS provides to science and society as a core capability, providing the fundamental underpinning of global Earth observations for monitoring of global change, environment, natural hazards, etc.
- Support the international geodetic services that are the main source of key parameters needed to realise a stable global frame of reference, and to observe and study changes in the dynamic Earth system.
- Actively promote, sustain, improve and evolve the global geodetic infrastructure needed to meet Earth science and societal requirements.
- Actively encourage improved data sharing and access between Member States, including GNSS, gravity, tide gauge and heighting datasets.