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Call for Participation
The Global Geodetic Core Network: Foundation for Monitoring the Earth System

A Project of the Global Geodetic Observing System (GGOS) as a contribution to the Global Earth Observation System of Systems (GEOSS)

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This is a Call for Participation in the development, implementation, and operation of the GGOS geodetic core network. The Call is being issued by the GGOS Bureau for Networks and Communication.

Background

The GEO Task AR-07-03 "Global Geodetic Reference Frames" (now Sub-TaskDA-09-02c) carried out a detailed assessment of the requirements that the nine Societal Benefit Areas (SBA) of Earth Observations addressed by the Group on Earth Observations (GEO) have in terms of geodetic observations and products. This process focused especially on the requirements concerning the geodetic terrestrial reference frame (TRF). The outcome of the assessment is summarized in the "GGOS 2020 Book" (Plag and Pearlman, 2009). In summary, the most demanding requirements for the Terrestrial Reference Frame (TRF) stem from two application: (1) monitoring the water cycle at global to regional scales and (2) monitoring and modeling sea-level and ice-mass changes in order to detect global change signals in the Earth system. Quantitatively, the assessment finds that the terrestrial reference frame should be accurate at a level of 1 mm and be stable at a level of 0.1 mm/yr. Likewise, the static geoid should be accurate at a level of 1 mm and be stable at a level of 0.1 mm/yr, consistent with the accuracy and stability of the terrestrial reference frame (Gross et al., 2009).

A number of satellite missions (ENVISAT, ERS-2, ICESat, Jason 1 and 2) are currently observing sea and ice surfaces, and mass transport in the water cycle is being determined from satellite gravity missions (GRACE A and B), while the static geoid will soon benefit from GOCE observations. Future sea surface topography and satellite gravity missions will add valuable observations for the detection and monitoring of global change signals if properly referenced in the same frame as the observations from current and legacy missions. Synthetic Aperture Radar (SAR) missions provide measurements of land surface displacements that help to detect, for example, active volcanoes, unstable slopes, and areas of coastal subsidence, and Interferometric SAR (InSAR) provides surface displacements induced by earthquakes, groundwater extraction, volcano eruptions, and melting ice loads as crucial input for science and research. Emerging technologies such as GNSS reflectometry and Light Detection and Ranging (LIDAR) will increase spatial and temporal coverage of these observations and improve spatial resolution. Full utilization of the potential of these observations for research and practical applications will only be possible if the geodetic terrestrial reference frame meets or exceeds the accuracy and stability levels summarized in Gross et al., (2009). Only then will we be able to close the mass balance in the global water cycle and constrain, with small uncertainties, changes in ice sheets and glaciers, land water storage, ocean mass and volume, and sea level. Likewise, full utilization of the satellite observations for studies of geohazards and the prevention and mitigation of disasters depends on a reliable reference frame, allowing for the combination and integration of different technologies and data sets.

In order to achieve the required accuracy and stability levels in the TRF, integration of the whole suite of space-geodetic techniques is required. The assessment of the required global geodetic infrastructure, carried out within the frame of GEO Task AR-07-03, emphasizes the importance of geodetic core sites for the successful integration of the space geodetic techniques. It further identifies the current large geographical gaps in the global network of core sites as a major limitation for improvements in reference frame accuracy and stability. Core sites are defined as those sites where all four of the space-geodetic techniques are co-located, and where the ties between the individual techniques (GNSS, SLR, VLBI, DORIS) at the site are known to the same accuracy as the targeted reference frame accuracy.

Based on that, the “GGOS 2020” assessment in Recommendation 9.1 recommends “that *the global geodetic infrastructure not only be maintained at the current level but also be augmented, in order to close major spatial and technological gaps, with: (1) a global network of core sites on all continents,(2) absolute and superconducting gravimeters at a global network of reference sites, in particular the core sites, and (3) two additional dedicated SLR satellites, that an operational core system be built up and maintained with the necessary infrastructure for an operational geodetic Earth system service providing quantitative information on changes in ice sheets, sea level, water cycle, and climate, as well as for hazards, disasters, and resource management application, and that the operational core include at least: (i) the global geodetic networks for the determination and monitoring of the geodetic reference frames, including Earth rotation, (ii) continuous gravity satellite missions for the monitoring of mass transport, (iii) continuous satellite missions for the monitoring of ice sheets, sea surface height, and lake level variations, and (iv) continuous satellite missions for imaging of the solid Earth’s surface.”*

This recommendation is made even more urgent with the recognition that many of the current network instruments are decades old, seriously degrading, and built from parts that can no longer be purchased.

THE BUREAU

The GGOS Bureau for Networks and Communication will provide oversight, coordination, and guidance for the development, implementation and operation of the GGOS Network of Core Sites. The Bureau Charter is:

- Develop a strategy to design, integrate and maintain the fundamental geodetic network of co-located instruments and supporting infrastructure in a sustainable way to satisfy the long term (10 - 20 years) requirements identified by the GGOS Science Council.

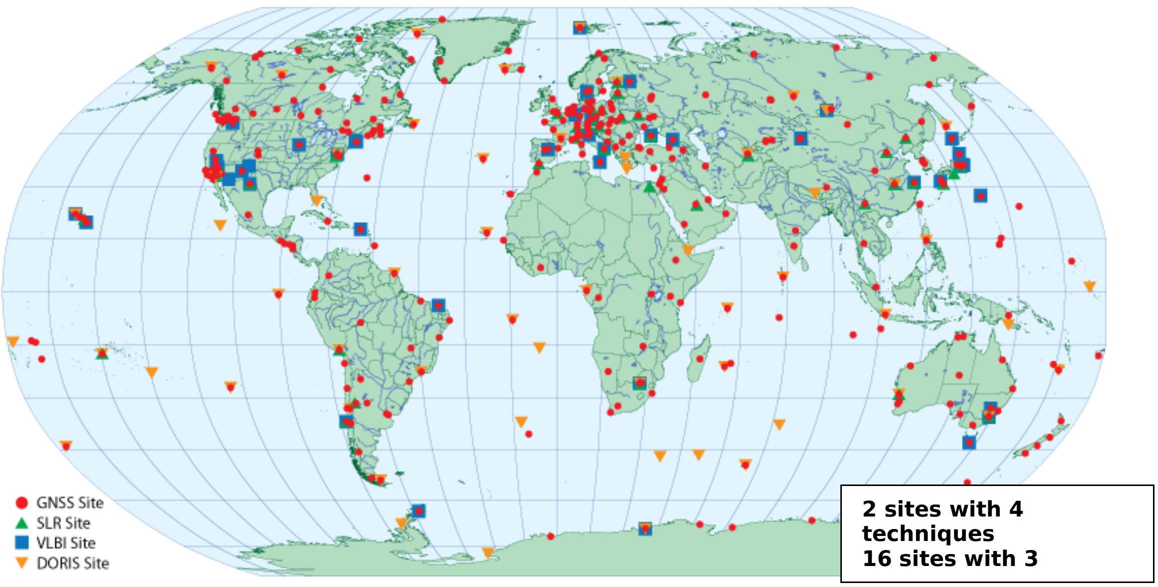
- At the base of GGOS are the sensors and the observatories situated around the world providing the timely, precise, and fundamental data essential for creating space geodesy products.
- Primary emphasis must be on sustaining the infrastructure needed to maintain the evolving global reference frames, while at the same time ensuring the broader support of the scientific applications of the collected data.

Synergistic opportunities to better integrate or co-locate with the infrastructure and communications networks of the many other Earth Observation disciplines organized under GEOSS should be considered and exploited.

State of the Current Network

Currently there are 415 GNSS stations in the International GNSS Service (IGS) network; 40 SLR stations in the International Laser Ranging Service (ILRS) network, 40 stations in the International VLBI Service (IVS) network, and 57 stations in the International DORIS Service (IDS) network. However, there are only two stations that have all four techniques and sixteen stations with three techniques (see Figure 1). Although all of the Services have gaps in geographic coverage, the gaps in SLR and VLBI are of particular concern. All of the networks are an anachronistic mix of legacy systems (in some cases decades old) and modern systems. Performance differences between stations and system deterioration over time have seriously compromised overall network performance.

Fig. 1 Global Space Geodesy Networks



Design of the Future Network

Initial results of a NASA-funded simulation activity to design the optimal next generation ITRF, shows that a globally well distributed network of 25 – 30 stations with the next generation SLR and VLBI technology will be sufficient to meet GGOS goals. The addition of GNSS and DORIS will strengthen the network, improve coverage, and provide the essential capability of distributing the ITRF to any location on Earth. Each of the techniques (GNSS, SLR, VLBI, and DORIS) has identified the next generation technology and each is in the process of implementing prototypes and testing out those new technologies at network sites (Plag and Pearlman, 2009, Chapter 9).

The GGOS Global Geodetic Core Network sites will include VLBI, SLR, GNSS and where possible DORIS, with proper inter-technique vector monitoring.

New Generation Systems

Each of the ground techniques is in the midst of upgrade.

The new generation VLBI, VLBI2010, will use a broadband signal acquisition chain (2 – 12 GHz) with up to four RF bands, digital electronics and fast, small antennas. This design will reduce RFI problems and provide higher temporal and spatial resolution for improved estimation of the tropospheric correction. The system is being developed to be minimally staffed, remotely operated, broadband, RFI avoiding, fully digital, fast slewing, and capable of producing VLBI delays with uncertainties of 4 ps.

The next generation SLR systems operate with (1) higher repetition rate (100 Hz to 2 kHz) lasers to increase data yield and improve normal point precision; (2) photon-counting detectors to reduce the emitted laser energies by orders of magnitude and reduce optical hazards on the ground and at aircraft (some are totally eye-safe); (3) multi-stop event timers with few ps resolutions to improve low energy performance in a high solar-noise environment; and (4) considerably more automation to permit remote and even autonomous operation. Many systems are working at single photon levels with Single Photon Avalanche Diode (SPAD) detectors or MicroChannel Plate PhotoMultiplier Tubes (MCP/PMIs). Some systems are experimenting with two-wavelength operations to test atmospheric refraction models and/or to provide unambiguous calibration of the atmospheric delay.

The next generation GNSS system network will be based on commercially available receivers that will include technology to track the full GNSS satellite complex (GPS, GLONASS, COMPASS, Galileo) with modernization to include the additional GPS signals (L2C, L5). This will require a substantial update of processing software and multi-technique network analysis.

The next generation DORIS ground system will be an extension of the current second-generation network as implemented by the CNES and IGN. The most modern of the receivers (the DGXX on board Jason-2) can track up to seven DORIS beacons simultaneously. Future satellite missions that will carry the DGXX DORIS receivers include altimeter missions such as CRYOSAT-2, Jason-3, SWOT, AltiKA, HY2A, and SENTINEL-3A. Most of the stations use third generation beacons. A station renovation program was initiated in 2000 in order to improve the long-term stability of the DORIS support and it is almost complete.

A vital aspect of the next generation network station will be the measurement of the vector between the invariant reference points (e.g. intersection of SLR telescope or VLBI antenna mount axes, GPS antenna phase centers, etc.) on each of the co-located space geodetic instruments in order to provide closure. As discussed in Ray and Altamimi (2005), survey measurements must be extrapolated to the aforementioned reference points. Current ground survey techniques can provide closure to properly configured ground monuments to mm accuracies, but these measurements tend to be very expensive and infrequent. The task at hand is to develop an economical approach that will measure, or even continuously monitor the inter-system vectors with sufficient spatial accuracy and temporal resolution to support the aforementioned reference frame requirements of 1 mm accuracy and 0.1 mm/year stability.

Objectives of the Project

Working with the IAG Services within this project, GGOS aims to facilitate closure of the major geographical and technological gaps in the current global network of geodetic core sites. The project will scope a network of core sites that will have the requisite geographical coverage to allow the targeted reference frame accuracy to be achieved with the projected capability of the next generation space geodetic instruments. The technology for the new space geodetic instruments already exists; the performance of the essential components has already been demonstrated and/or is being integrated into prototype instruments now. A challenging technical aspect at the moment is the measurement, and ultimately the monitoring, of the inter-systems vectors at the core sites. When completed, the Global Geodetic Core Network will be a major step in the implementation of Recommendation 9.1, which resulted from GEO Task AR-07-03. It is recognized that the core network will not materialize overnight, but will evolve as stations are either upgraded or replaced with more modern and accurate versions and as new stations are built. As the network improves, so will the geodetic data products.

Mode of implementation

The GGOS Call for Participation is being issued to all GEO Member Countries, Participating Organizations, and other organizations that may be interested. It requests participation in the planning and implementation of the GGOS Global Geodetic Core Network. Participation can be in many forms including: research and planning in the development and implementation of individual core sites, technological developments of the components of the core sites; establishment and/or operation of core sites; and provision of suitable locations for the core sites.

We seek proposals from organizations that would participate in the development, implementation and maintenance of the GGOS Global Geodetic Core Network. We seek proposals from:

1. Organizations that would actively support the network design and planning activity with analysis, simulations, site research (geology, weather, logistics, personnel, etc). A working group will be formed from those selected to help select the sites and encourage new participants in areas needing coverage.
2. Organizations that would help design and develop the inter-technique vector systems and operational procedures.

3. Organizations that currently operate a space geodetic site and would implement and operate core stations including:
    a. existing stations that already have the four techniques implemented and plan for upgrade to the next generation systems;
    b. existing stations that have one or more techniques operational, are planning for upgrade to the next generation systems and for the implementation of the remaining techniques;
4. Organizations that have no operational space geodetic sites, but would implement and operate core stations;
5. Organizations that have space geodetic instruments or are developing space geodetic instruments that they are willing to relocate to a GGOS Global Geodetic Core Site in cooperation with a local organization.

Many of the stations will require cooperative arrangements to fulfill the Core Network Station requirements (site, logistics, communications, full systems, hardware components, etc.). We encourage preformed teams to propose to implement/upgrade and operate these stations. We will also encourage team formation from among organizations that submit proposals and with new groups whose participation would benefit the Core Network.

With regard to proposal teams, one organization must be identified as the lead. An organizational structure to carry out the proposed activity must be provided in the proposal. Proposers must provide their own financial resources in carrying out their proposed duties. The proposal should clearly address the capabilities being offered by the institution (or institutions), its financial ability to carry them out, and appropriate points of contact. Each of the participating organizations should provide an institutional support form signed by the appropriate level authority (e.g. director, minister, etc.) to demonstrate the national or institutional commitment (whichever is appropriate) for the proposed effort.

Data Policy

All data provided by the Stations in the GGOS Core Network for GGOS activities will be submitted to the CCDIS and EDC for access by those participating in GGOS and other international space geodesy activities.

Linkage to GEO Committees and Tasks

GGOS represents IAG as a Participating Organization in GEO. GGOS contributes substantially to a number of GEO Work Plan Tasks and participates in GEO Committee activities. The CfP will be integrated in the GEO Work Plan activities and the results and progress will be reported to relevant GEO Committees and Task Teams.

Initial Time Schedule

It is very unlikely that the proposals in immediate response to the CfP will satisfy the full network requirement. This call will be repeated as necessary to encourage new participation and formation of new teams to bring stations to fruition. The initial time schedule is;

September 1, 2009: Completion of Call for Participation (CfP)
September 15, 2009: Publication of the CfP
January 15, 2010: Deadline for submission for the first round of proposals
March 1, 2010: Announcement of selected Proposals from the first round.

The first round of proposals is due on January 15, 2010. The proposals will be evaluated and responses sent out by March 1, 2010. Additional proposals will be evaluated on a 6-monthly period cycle until completion of the network or announcement of a closing. The Bureau will work with responding organizations to help form complete teams for future submission.

RESOURCES

The funds required for this activity must be provided by the proposing institution(s) and agencies. Proposers may also solicit support from external entities in terms of financial contributions and expertise. From the proposal, it should become clear that the proposing institution(s) has/have the expertise, capabilities and financial resources to perform the proposed tasks.

TERM

We encourage organizations to propose for long-term participation. The value of the Core Network depends upon its long term stability in configuration and performance. We request the proposals cover a period of at least 5 years, with the recognition that conditions beyond one's control may dictate a shorter period. Station commitment will be made by the proposing organization to GGOS. The agreement may be terminated by either party with 6 months notice. The term will be automatically renewed, unless either party gives notice 6 months prior to the end of the term.

PROPOSAL STRUCTURE, DEADLINE AND SUBMISSION

The proposal should contain the following parts: title, proposing institution(s) with its/their address(es), designated Head of the new component, other participants, abstract, goals, expertise, facilities and capabilities that currently exist, work still needed to bring the facility up to a full Core Network site if appropriate, work plan (work and schedule), responsibilities (if more than one institution involved), and allocated resources.

Proposals should be concise, i.e. 4 – 5 pages in length. The first closure date is January 15, 2010. Proposals should be submitted electronically; signed by the responsible head(s) of the proposing institution(s) with the authority for the commitment of human and financial resources, to the Chair of the GGOS Bureau for Ground Networks and Communications:

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PROPOSAL REVIEW

The proposals will be evaluated and ranked by the GGOS Bureau for Networks and Communications and final decisions will be made by the GGOS Steering Committee. Where appropriate, the Bureau will work with the proposing teams to help organize full support for the implementation and operation of stations. Successful proposers will be notified by March 1, 2010. Proposals submitted after January 15 will be evaluated on 6-monthly cycles.

References

Gross, R., Beutler, G., Plag, H.-P., 2009. Integrated scientific and societal user requirements and functional specifications for the GGOS. In Plag, H.-P. and Pearlman M., (eds): *The Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020*, 209-224, Springer Berlin.

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Ray, J., Altamimi, Z., 2005. Evaluation of co-location ties relating the VLBI and GPS reference frames, *Journal of Geodesy,* 79, 189-195.