Global Geodetic Observing System (GGOS)

Chair of the GGOS Coordinating Board: **H. Kutterer** (Germany)
Vice-Chair of the GGOS Coordinating Board: **R. Neilan** (USA)

http://www.ggos.org

GGOS Terms of Reference

Preamble

The proposal for the Global Geodetic Observing System (GGOS) was developed by the GGOS planning group between 2001 and 2003 according to the Bylaws of the International Association of Geodesy (IAG). The proposal was accepted by the IAG Executive Committee and the IAG Council at their meetings during the XXIII IUGG General Assembly in Sapporo in July 2003. GGOS was there endorsed by the IUGG through Resolution No. 3.

Changes in the IAG Bylaws in 2007 resulted in GGOS being recognized as an integral component of IAG along with Services and Commissions. This transformed the status of GGOS from that of an IAG Project to an IAG component. Specific to the GGOS are IAG Bylaws §1(d) and §15. During 2013-2015, revisions to the structure of GGOS were discussed leading to the Terms of Reference 2015, primarily to streamline its organizational structure. According to the IAG Bylaws §1(d) "The Global Geodetic Observing System works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research".

GGOS Vision

Advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time.

GGOS Mission

- 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.
- To benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built.

We live on a dynamic planet in constant motion that requires long-term continuous quantification of its changes in a truly stable frame of reference. GGOS and its related research and services will address the relevant science issues related to geodesy and geodynamics in the 21st century, but also issues relevant to society (global risk management, geo-hazards, natural resources, climate change, severe storm forecasting, sea level estimations and ocean forecasting, space weather, and others). It is an ambitious program of a dimension that goes beyond IAG, requiring a strong cooperation within the geodetic, geodynamic and geophysical communities, and externally, to related endeavours and communities. GGOS will provide this integration at the highest level, in service to the technical community and society as a whole.

GGOS Strategic Direction

Overarching Strategic Areas of GGOS

The GGOS Goals, Objectives, and Outcomes are built around four strategic areas that are directly attributable to the established GGOS goals. These areas were established in the 2011 Strategic Plan, and continue to be relevant to the activities and future efforts of GGOS in subsequent strategic plans. The strategies 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.

1. 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.
2. 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
3. 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.
4. 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 GGOS organizational fabric.

IAG Services, Commissions, and Inter-Commission Committees in Support of GGOS

In order to accomplish its mission and goals, GGOS depends on the IAG Services, Commissions and Inter-Commission Committees. The Services provide the infrastructure and products on which all contributions of GGOS are based. The IAG Commissions and Inter-Commission Committees provide expertise and support for the scientific development within GGOS. In summary, GGOS is IAG's central interface to the scientific community and to society in general.

IAG is a Participating Organization of the Group on Earth Observations (GEO). GGOS acts on behalf of the IAG in GEO and actively contributes to the Global Earth Observation System of Systems (GEOSS).

GGOS addresses relevant science issues related to geodesy and geodynamics in the 21st century, but also issues relevant to society (including but not limited to management of natural resources, natural hazards, global risk management, monitoring of climate change and related phenomena, ocean forecasting and sea level projections, early warning of severe storms, tsunamis, other hazards, and space weather). It is an ambitious program of a dimension that goes beyond IAG, requiring a strong cooperation within the geodetic and Earth science communities, and externally, to related endeavours and communities.

The GGOS 2020 Book (Global Geodetic Observing System: Meeting the Requirements of a Global Society on an Changing Planet in 2020", H.-P. Plag and M. Pearlman (editors) , Springer, 2009) serves as the initial basis for the implementation of GGOS, as the observing system of IAG, and is used to derive work plans based on its recommendations.

GGOS Structure

Overview of Key GGOS Elements

The organizational structure of GGOS is comprised of the following key elements which are depicted in Fig. 1:

- *GGOS Consortium* – is the collective voice for all GGOS matters. It will meet annually as possible. The elements of GGOS have the flexibility to determine and designate two representatives to the GGOS Consortium as each (Service, Commission and Inter-Commission Committees, or other entity) decides. The Consortium is to be comprised of the Chairs of Services and the Directors of the Service's central offices or Central Bureaus; Presidents and Vice-Presidents of IAG Commissions, Inter-Commission Committees, and other entities essential to GGOS as determined by the Consortium. The GGOS Consortium is the nominating and electing body of elected positions on the GGOS Coordinating Board as noted below. The Chair of GGOS shall act as the Chair of the GGOS Consortium.
- *GGOS Coordinating Board* – is the central oversight and decision-making body of GGOS, and represents the IAG Services, Commissions, Inter-Commission Committees, and other entities. For a comprehensive list of represented entities, see below.
- *GGOS Executive Committee* – serves at the direction of the Coordinating Board to accomplish day-to-day activities of GGOS tasks.
- *GGOS Science Panel* – advises and provides recommendations relating to the scientific content of the GGOS 2020 book to the Coordinating Board; and represents the geodetic and geoscience community at GGOS meetings. *GGOS Coordinating Office* – coordinates the work within GGOS and supports the Chairs, the Executive Committee and the Coordinating Board.
- *GGOS Bureau of Products and Standards* – tracks, reviews, examines, evaluates all actual standards, constants, resolutions and products adopted by IAG or its components and recommends their further use or proposes the necessary updates.

- *GGOS Bureau of Networks and Observations* – develops a strategy to design, integrate and maintain the fundamental geodetic infrastructure including communication and data flow; monitors the status of the networks and advocates for implementation of core and other co-located network sites and improved network performance.
- *GGOS Committees, Working Groups and Focus Areas (formerly known as Themes)* – address overarching issues common to several or all IAG components, and are a mechanism to bring the various activities of the Services, Commissions and Inter-Commission Committees together, or to link GGOS to external organizations. Focus Areas are cross-disciplinary and address specific focus areas where GGOS contributors work together to address broader and critical issues.

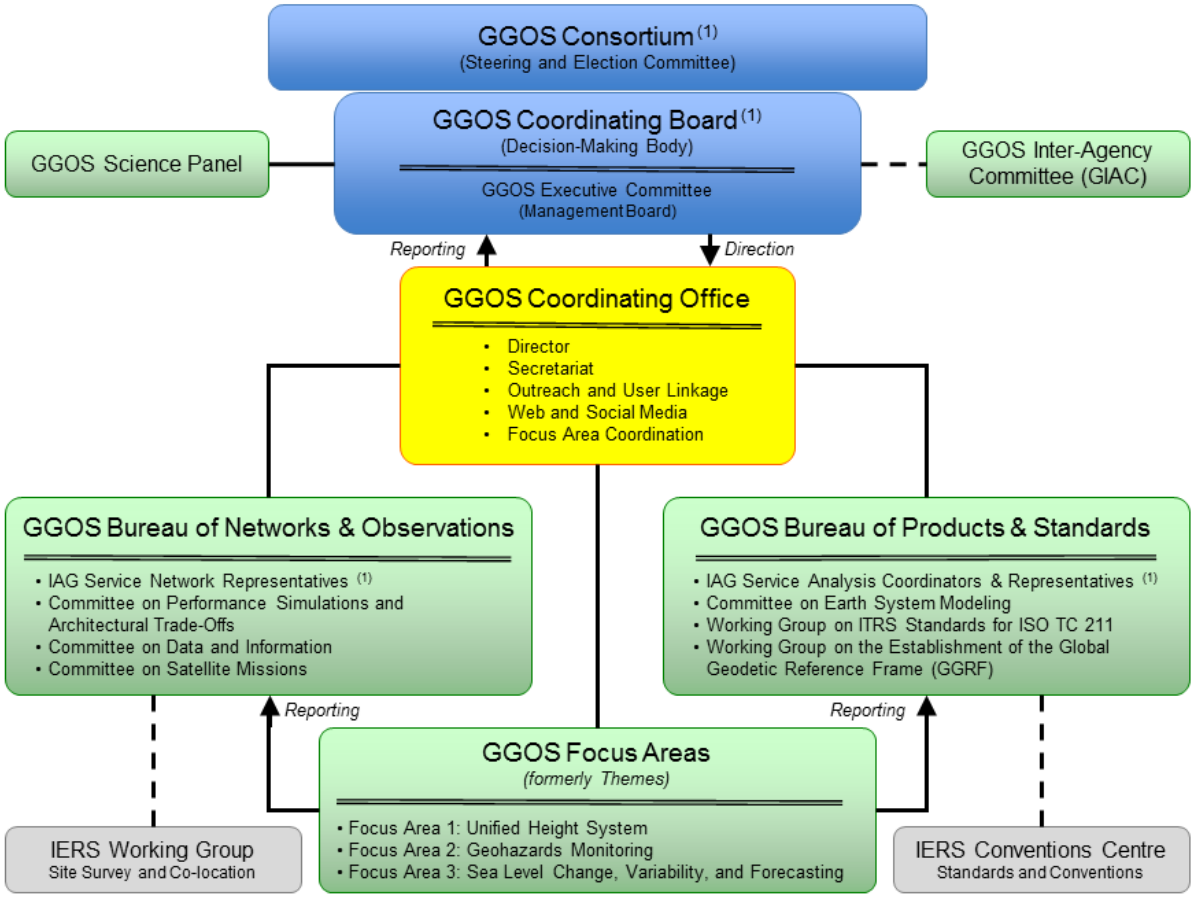

Fig. 1 GGOS organizational chart 2016

Fundamental Supporting Elements of GGOS

- *IAG* promotes scientific cooperation and research in geodesy on a global scale and contributes to it through its various research bodies. GGOS is the Observing System of the IAG.
- *IAG Services, Commissions and Inter-Commission Committees* are the fundamental supporting elements of GGOS.
- *GGOS Inter-Agency Committee (GIAC)* – a forum that seeks to generate a unified voice to communicate with Governments and Intergovernmental organizations (GEO, UN bodies) in all matters of global and regional spatial reference frames and research and applications.

Details of the Structure of GGOS

GGOS Consortium

The GGOS Consortium is the voice and essentially the large steering committee of GGOS. It reviews the GGOS progress, activities, and nominates and votes for the candidates for the elected positions on the GGOS Coordinating Board.

The GGOS Consortium is comprised of two designated representatives from each IAG component. The Chair of an IAG Service Governing or Directing Board, and the Director of the Central Bureau or Coordinating Office, as well as Commission and Inter-Commission Committee Presidents and Vice Presidents may be those designated members. However, no person may represent two or more components, and no one may have more than one vote. The presiding Chair of the GGOS is, by default, the Chair of the Consortium. GGOS Consortium decisions are based on consensus. Decisions requiring a vote are decided by simple majority of the votes cast. The quorum is met when at least fifty percent of members are present, but electronic voting is acceptable provided a quorum responds.

The Consortium is the electing body for the GGOS Coordinating Board. The Consortium will meet at least once a year.

GGOS Coordinating Board

The Coordinating Board (CB) is the decision making body of GGOS. Decisions are based upon consensus, whenever possible. Decisions requiring a vote are decided by simple majority of the votes cast. The quorum for a valid vote is participation of fifty percent of the voting members of the Coordinating Board. Votes may be held in person at meetings, or by appropriate electronic means at the discretion of the GGOS Executive Committee. The Coordinating Board will meet at least once yearly, although twice yearly is preferable.

Coordinating Board Members

Voting Coordinating Board members:

GGOS Chair (votes in case of a tie)	1
GGOS Vice-Chair	1
Chair of GGOS Science Panel (ex-officio)	1
Director of Coordinating Office (ex-officio)	1
Directors of GGOS Bureaus (ex-officio)	2
IAG President or designated representative (ex-officio)	1
Service Representatives (elected by the Consortium)	4
IAG Commission, and Inter-Commission Committee Representatives (elected by the Consortium)	2
Members-at-Large (elected by the GGOS CB)	3
Total voting members	**16**

Non-Voting Coordinating Board Members:

Chairs of GGOS Committees / Working Groups (ex-officio)	n
Focus Area Leads (ex-officio)	3
GGOS Web and Social Media Manager (ex-officio)	1
Immediate Past Chair of the GGOS CB (ex-officio)	1
Representative of the GIAC (ex-officio)	1

Approved observers may also participate at the discretion of the Chair.

Chair

The chair of the GGOS Coordinating Board is determined according to the IAG Bylaws [IAG Bylaw 15(d): "The GGOS Chair is appointed by the IAG Executive committee in consultation with the GGOS Coordinating Board for one four-year period, which may be renewed once."]. The Chair of the GGOS CB is, by default, also known as the GGOS Chair.

Members-at-Large

Members-at-Large are invited to join the Coordinating Board in order to provide balance in representation of geographical regions or unique capabilities. The Chair, with the assistance of the Coordinating Office, appoints an Election Committee to organize the voting process and to ensure availability of the nominated candidates. The Election Committee then presents the final list of Members-at-Large candidates to the CB for a vote.

Appointment of the Chair and Election of Coordinating Board Members

The process for elections to the GGOS Coordinating Board will follow the four-year IAG General Assembly, which takes place during the IUGG General Assembly (see IAG Bylaws for more detail). Candidates nominated to serve on the Coordinating Board must be members of the GGOS Consortium. The CB elects the Vice-Chair of the GGOS CB by a vote. However, the GGOS Chair is appointed by the IAG Executive Committee in consultation with the GGOS Coordinating Board.

GGOS Executive Committee

The GGOS Executive Committee (EC) is comprised of the following members:

GGOS Chair	1
GGOS Vice-Chair	1
Director of Coordinating Office	1
Directors of the Bureaus	2
Members of the CB selected for EC membership	2
Total	**7**

Every other year, the GGOS Chair submits a list of his or her candidates for the two open member spaces to the CB for approval. These candidates must be voting members of the CB in order to be nominated to the EC.

The GGOS Chair may nominate an EC member to serve as primary GGOS representative to all GGOS stakeholders, including but not limited to: IAG and its Services, CEOS, GEO, space agencies, the United Nations, university partners, and national mapping agencies. This position will be filled by the GGOS Vice-Chair or other EC member, depending on Chair nomination and CB approval. A secondary or stakeholder-specific GGOS representative may also be nominated, if necessary.

The Immediate Past Chair of GGOS, the Chair of the GGOS Science Panel, and the President of IAG are all permanently invited guests at meetings of the Executive Committee. Other observers may be invited to attend EC meetings (or teleconferences) as needed.

GGOS Science Panel

The GGOS Science Panel is an independent and multi-disciplinary advisory board that provides scientific support and guidance to the GGOS steering and coordination entities as requested. This support may include organization of relevant scientific sessions at conferences, workshops, and other events.

The IAG Commissions and Inter-Commission Committees each nominate two candidates to the Science Panel subject to approval by the CB. The CB may appoint additional Members-at-Large to the Science Panel in order to provide balance in representation of geographical regions or unique capabilities. The immediate past Chair of the Science Panel is a Member of the Science Panel. The Science Panel will elect its own Chair to be approved by the CB.

IAG Services, Commissions and Inter-Commission Committees

GGOS works with these IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research. GGOS respects the bylaws and terms of reference for these essential components. GGOS is built on the existing IAG Services and their products. GGOS is not taking over tasks of the existing, and well working IAG Services. GGOS will provide a framework for existing or future Services and strive to ensure their long-term stability.

GGOS Committees, Working Groups and Focus Areas

GGOS Committees and Working Groups (WG) are established by the Coordinating Board as needed. Working Groups are set up for one 4-year period, Committees for longer periods of time. The Coordinating Board appoints their chairs and prepares and approves their charters. The members of Committees and WGs are nominated by their chairs and confirmed by the Coordinating Board.

Focus Areas are cross-disciplinary focus areas and meant to consider gaps and needed future products. The GGOS CB approves the Focus Areas. The CB appoints theme leads. Focus Areas outline their purpose and propose a work plan to address any noted gap to be addressed by the particular theme focus.

GGOS Coordinating Office

The GGOS Coordinating Office (CO) performs the day-to-day activities in support of GGOS, the Executive Committee, the Coordinating Board, and the Science Panel, and ensures coordination of the activities of the various components. The CO ensures information flow, maintains documentation of the GGOS activities, and manages specific assistance functions that enhance the coordination across all areas of GGOS, including inter-services coordination and support for workshops. The CO in its long-term coordination role ensures that the GGOS components contribute to GGOS in a consistent and continuous manner. The CO also maintains, manages, and coordinates the GGOS web presence and outreach.

Bureau of Products and Standards

The Bureau of Products and Standards keeps track of the strict observations of adopted geodetic standards, standardized units, fundamental physical constants, resolutions and conventions in all official products provided by the geodetic community. It reviews, examines and evaluates all actual standards, constants, resolutions and conventions adopted by IAG or its components, and recommends further use or proposes the necessary updates. It identifies eventual gaps in standards and products, and initiates steps to close them with, e.g., resolutions by the IUGG and/or IAG Councils.

Bureau of Networks and Observations

The Bureau of Networks and Observations develops a strategy to design, integrate and maintain the fundamental infrastructure in a sustainable way to satisfy the long-term (10-20 years) requirements identified by the GGOS Science Panel. 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. Coordinating and implementing the GGOS co-located station network is a key focus for 2010-2020.

GGOS Bureau of Networks and Observations

Director: Michael Pearlman (USA)
Members: Erricos C. Pavlis (USA), Carey Noll (USA), Hayo Hase (Germany), Chopo Ma (USA), Giuseppe Bianco (Italy), Wu Bin (China), Ruth Neilan (USA), Steve Fisher (USA), Jérôme Saunier (France), Pascale Ferrage (France), Riccardo Barzaghi (Italy), Mark Tamisiea (UK), Tilo Schöne (Germany), Daniela Thaller (Germany), Richard Gross (USA), Bernd Richter (Germany), Jürgen Müller (Germany), Roland Pail (Germany), Sten Bergstrand (Sweden), John Dawson (Australia).

Introduction and Background

The Bureau of Networks and Observations (BN&O) is a redefinition of the GGOS Bureau for Networks and Communication (BN&C) which was established in 2003 to develop a strategy to design, integrate, implement and maintain the fundamental geodetic network of co-located instruments (VLBI, SLR, GNSS, and DORIS) and the supporting infrastructure in a sustainable way to satisfy the long-term (10 - 20 years) GGOS requirements (GGOS 2020, 2009). The BN&O advocates for implementation of the global space geodesy network of sufficient capability and geographic coverage to achieve data products essential for GGOS and serves as a coordinating point for the Services to meet, discuss status and plans, and examine common paths for meeting GGOS requirements. Committees and working groups are included in the Bureau in recognition of their synergistic role with Bureau activities.

The new Bureau has been restructured to:

- Expand its role with the inclusion of other than the geometric Services and techniques (gravity, tide gauges, etc.);
- Improve communication and information exchange and coordination with the space missions;
- Include simulation and network analysis activities;
- Include the site-tie component at co-located sites; and
- Include the meta-data development activities.

These expanded activities are being implemented by incorporating the non-geometric measurement Services and the pertinent GGOS committees (Missions, Simulations, Data and Information Systems) and working groups (IERS Working Group on Survey and Co-location) that have a very synergistic role with the Bureau. The Bureau plays a very fundamental role in the GGOS Focus areas: Geohazards Monitoring, Sea Level Monitoring, and Unified Height System.

Objectives

The Objectives of the Bureau are to:

- Provide a forum for the Services, committees and working groups to share and discuss plans, progress, and issues, and to develop and monitor multi-entity efforts to address GGOS requirements;
- Actively promote, design and coordinate the global geodetic ground-based infrastructure needed to meet requirements for Earth science and societal benefits;
- Lead efforts for the integration of various ground observation networks under the GGOS umbrella; and
- Coordinate the international geodetic Services' activities that are the main source of key data and products needed to realize stable global reference frames and other data products essential to study changes in the dynamic Earth System and characterize key Earth science parameters for the benefit of society.

Tasks

In its role to support the Services and better serve the users, the activities of the Bureau are:

- Advocate for implementation of the global space geodesy network of sufficient capability to achieve data products essential for GGOS;
  - Update the Bureau website for public use;
  - Provide status and plans on network development from the Bureaus;
  - Continue to oversee the Bureau's "Call for Participation in the Global Geodetic Core Network: Foundation for Monitoring the Earth System" and work with new groups interested in participating;
  - Meet with interested parties and encourage partnerships.
- Provide a forum for the Services, committees and working groups to meet, discuss status and plans, and examine common interests and requirements;
- Maintain and update the "Site Requirements for GGOS Core Sites" document;
- Monitor and project the status and evolution of the GGOS space geodesy network in terms of location and performance (with the IAG Services);
- Coordinate the effort of the Services to implement procedures to provide test-based estimates of their data quality and report;
- Facilitate efforts to integrate relevant parameters from other ground networks (gravity field, tide gauges, etc.) into the GGOS network to support GGOS requirements including the reference frame, a unified height system, etc.; advocate for installation of GNSS receivers at appropriate tide gauges;

- Support the technique Services on the promotion of recommended technologies/configurations and procedures in the establishment of new sites and the upgrading of current sites, and in the evaluation of performance of new stations and new capabilities after they become operational;

The evolution of the networks will be a long-term endeavor, but the evolution in the networks, including both the core and participating co-location sites, new technology and legacy sites, and the associated modeling and analyses, will provide steady and very useful improvements in the data products. The evolving data and data products will be a major driver for developing and validating the new models and analysis techniques.

Committees of the Bureau of Networks and Observations

BNO C1: Committee on Performance Simulations and Architectural Trade-Offs
(joint with IAG Sub-Commission 1.1)

Chair: Daniela Thaller (Germany)
Vice-Chair: Richard Gross (USA)

Objectives

Project future network capability and examine trade-off options for station deployment and closure, technology upgrades, impact of site ties, additional space missions, etc. to maximize the utility of the GGOS assets:

- Use simulation techniques to assess the impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties, space ties (added spacecraft, etc.), analysis and modeling techniques, etc.;
- Use and developing improved analysis methods for reference frame products by including all existing data and available co-locations (i.e., include all satellites and use all data types on all satellites);
- Make recommendations on network configuration and strategies based on the simulation and trade-off studies.

The PLATO Committee / Working Group has 20+ member groups working on simulations and data analysis covering the full range of existing ground and space assets, including VLBI, SLR, GNSS, and DORIS. The main focus is how do we use existing resources including co-location in space with existing and new dedicated satellites to best support GGOS planning and implementation.

Investigations that are being included in the PLATO activity include studying the impact of:

- The full range of existing ground and space assets:
  - GNSS assets (ground and space)
  - SLR (beyond Lageos-1 and -2) including ranging to GNSS satellites;
  - LLR assets
  - VLBI assets including tracking of GNSS satellites;
  - Co-located assets in space (e.g. GRACE, OSTM)
  - Mixture of existing legacy stations and simulated next generation stations
  - Improved GNSS antenna calibrations and clock estimation strategies (GNSS alone or when in combination with SLR, VLBI, and DORIS)
- Anticipated improved performance of current systems:
  - Simulate impact of upgrading existing stations and their procedures
  - Simulate impact of additional ground surveys at co-location sites (site ties)
- Potential future space assets:
  - Co-locate all four techniques in space on a dedicated satellite (e.g., GRASP)

Tasks

- Define proper GGOS-related tasks with priorities;
- Develop a plan with tasks and task assignments (task teams) in concert with the PLATO participants;

At the suggestion of Xavier Collilieux (new chair of IAG Sub-commission 1.2, on global reference frame), GGOS has agreed that the PLATO Committee become a Joint (Sub-Commission 1.2) Working Group between GGOS and IAG Commission 1, with special interest in studies related to space co-locations.

BNO C2: Committee on Data and Information

Chair: Bernd Richter (Germany)
Vice-Chair: Carey Noll (USA)

Objectives

Develop a metadata strategy for all ground-based measurement techniques:

- Promote the use of metadata standards and conventions and recommend implementations of metadata management in the pursuit of a metadata policy;
- Promote interoperability among participating data centers with other databases and services;
- Develop strategies to protect the intellectual properties on data and products;
- Align metadata standards with the GEOSS approach and methodology, interface on data standards with GEO and ICSU.

GGOS is seeking a metadata schema that can be used by its elements for standardized metadata communication, archiving, and retrieval. First applications would be the automated distribution of up-to-date station configuration and operational information, data archives and catalogues, and procedures and central bureau communication. One particular plan of great interest is a site metadata schema underway within the IGS Data Center Working Group. This work is being done in collaboration with the IGS, UNAVCO, SIO, CDDIS, and other GNSS data centers. The current activity is toward a means of exchange of IGS site log metadata utilizing machine-to-machine methods, such as XML and web services, but it is expected that this will be expanded to the other Services to help manage site-related metadata and to other data related products and information. Schema for the metadata should follow international standards, like ISO 19xxx or DIF, but should be extendable for technique-specific information, which would then be accessible through the GGOS Portal.

Tasks

- Organize meetings to address a GGOS meta-data plan;
- Identify members of all of the involved Services who will be in the Meta-Data Committee (MDC);
- Decide the extent of the information that is necessary to fulfill catalogue services.
- Develop a proposal with examples of techniques with filled schema for review by the MDC and the Services;
- Develop a spreadsheet of collection-level metadata for review by the Services;
- Identify gravity-affiliated and tide-gauge affiliated people to be added to the MDC;

BNO C3: Committee on Satellite Missions

Chair: Jürgen Müller (Germany)
Vice-Chair: Roland Pail (Germany)

Objectives

Improve coordination and information exchange with the missions for better ground-based network response to mission requirements and space-segment adequacy for the realization of GGOS goals

Goals

Advocating, coordinating, and exchanging information with satellite missions as part of the GGOS space infrastructure, for a better ground-based network response to mission requirements and space-segment adequacy for the realization of the GGOS goals.

- Assess current and near-future satellite infrastructure, and their compliance with GGOS 2020 goals;
- Support proposals for new mission concepts and advocate for needed missions;
- Interfacing and outreach. These tasks will require interfacing with other components of the Bureau; especially the ground networks component, the simulation activity (PLATO), as well as the Bureau of Standards and Products.

Tasks

- Work with the Coordinating Office to set up and maintain a Satellite Missions Committee section on the GGOS website;
- Set-up and maintain an inventory/repository (accessible through the GGOS website and/or portal) of current and near-future satellite missions relevant to GGOS;
- Evaluate the contribution of current and near term satellite missions to the GGOS 2020 goals;
- Work with the Focus Areas and the Science Committee to establish the required mission roles and to identify the critical gaps in mission infrastructure;
- Work with GGOS Executive Committee, Focus Areas, and data product development activities (e.g., ITRF) to advocate for new missions to support GGOS goals;
- Support the Executive Committee and the Science Committee in the GGOS Interface with space agencies;
- Finalize and publish (outreach) of Science and User Requirements Document for future gravity field missions.

GGOS Bureau of Products and Standards

Director: Detlef Angermann (Germany)
Vice-Director: Thomas Gruber (Germany)
Members: M. Gerstl (Germany), R. Heinkelmann (Germany), U. Hugentobler (Germany), L. Sánchez (Germany), P. Steigenberger (Germany)

Associated Members and Representatives:
J. Ádám (Hungary), F. Barthelmes (Germany), R. Barzaghi (Italy), S. Bonvalot (France), C. Boucher (France), H. Capdeville (France), M. Craymer (Canada), J. Gipson (USA), T. Herring (USA), L. Hothem (USA), J. Ihde (Germany), J. Kusche (Germany), F.G. Lemoine (USA), J.M. Lemoine (France), U. Marti (Switzerland), E. Pavlis (USA), G. Pétit (France), J. Ries (USA), M. Thomas (Germany)

The Bureau of Products and Standards (BPS) is a redefinition of the former Bureau for Standards and Conventions (BSC), due to restructuring of the GGOS organization in 2014. The BPS supports the IAG in its goal to obtain products of highest possible accuracy, consistency, and temporal and spatial resolution, which should refer to a consistent reference frame, stable over decades in time. To achieve this important goal, it is a fundamental requirement that common standards and conventions are used by all IAG components for the analysis of the different space geodetic observations. The BPS also concentrates on the integration of geometric and gravimetric parameters and the development of new products, required to address important geophysical questions and societal needs. Associated with the BPS are the GGOS Committee "Contributions to Earth System Modeling" and the Working Groups "ITRS Standards for ISO TC 211" and "Establishment of the Global Geodetic Reference Frame (GGRF)" (see below).

Objectives

The key objective of the BPS is to keep track of adopted geodetic standards and conventions across all IAG components as a fundamental basis for the generation of consistent geometric and gravimetric products. The work is primarily build on the IAG Service activities in the field of data analysis and combinations. The BPS shall act as contact and coordinating point regarding homogenization of standards and IAG/GGOS products. More specifically the objectives of the BPS may be divided into two major topics/activities:

(1) Standards: This includes the compilation of an inventory regarding standards, constants, resolutions and conventions adopted by IAG and its components and a regular update of such a document. Steps shall be initiated to close gaps and deficiencies in standards and conventions. Based on the recommendations given in this inventory priorities should be defined together with dedicated experts in the field. An action plan shall be compiled, including the definition of tasks, responsibilities and a time schedule. Finally, the BPS shall propose the adoption of new standards where necessary and propagate standards and conventions to the wider scientific community and promote their use.

(2) Products: The BPS shall review and evaluate the present status regarding IAG Service products, including analysis and combination procedures, as well as accuracy assessment with respect to GGOS requirements. The Bureau shall initiate steps to identify user needs and requirements for geodetic products and shall contribute to develop new products based on the integration of geometric and gravimetric observations.

Activities

- The BPS has compiled an inventory based on the standards and conventions currently in use by IAG and its components. The resulting publication "*GGOS Bureau of Products and Standards: Inventory of Standards and Conventions used for the Generation of IAG Products*" has been reviewed by an external board and the revised version shall be published in the IAG Geodesist's Handbook 2016 and on the GGOS web site as a *living document*.
- As a major outcome this inventory presents the current status regarding standards and conventions, identifies gaps and inconsistencies and provides recommendations for improvements.
- The transition of the former BSC to the BPS, as a consequence of restructuring of the GGOS organization, has been accomplished, including the compilation of an implementation plan for the BPS and the associated GGOS components and the revision of its charter.
- The interaction between the BPS and the IAG Services as well as with other entities involved in standards and conventions has been strengthened by including representatives of these entities in the BPS board and by compiling a management plan.

In-progress activities and planned efforts

- Publication of the inventory on standards and conventions in the IAG Geodesist's Handbook and on the GGOS web site as a *living document;*

- Discussion of recommendations given in the inventory and compilation of an action plan, including a task description, specification of responsibilities and time schedule;
- Evaluation of the current status of IAG/GGOS products, including an accuracy assessment with respect to the GGOS requirements;
- Initiation of efforts to identify user needs and requirements for products that are currently not provided by the IAG services;
- Supporting the GGOS Portal to provide the relevant information for IAG/GGOS products and contribute to promote geodetic products to the wider user community.

Committees and Working Groups of the Bureau of Products and Standards

BPS C1: Committee on Contributions to Earth System Modeling

Chair: Maik Thomas (Germany)

The GGOS BPS Committee on "Contributions to Earth System Modeling" was established in 2011 in order to promote the development of an integrated Earth system model that is simultaneously applicable to all geodetic parameter types, i.e., Earth rotation, gravity and surface geometry, and observation techniques. Hereby, the working group contributes to:

- a deeper understanding of dynamical processes in the Earth system integrally reflected in geodetic monitoring data;
- the establishment of a link between the global time series of geodetic parameters delivered by GGOS and relevant process models;
- a consistent integration and interpretation of observed geodetic parameters derived from various observation techniques;
- the utilization of geodetic observations for the interdisciplinary scientific community (in cooperation with GGOS WG on Data and Information Systems).

Objectives

The overall long-term goal is the development of a physically consistent modular numerical Earth system model for homogeneous processing, interpretation and prediction of geodetic parameters with interfaces allowing the introduction of constraints provided by geodetic time series of global surface processes, rotation parameters and gravity variations. This ultimate goal implicates the following objectives:

- promotion of homogeneous processing of geodetic monitoring data (de-aliasing, reduction) by process modeling to improve analysis of geodetic parameter sets;
- contributions to the interpretation of geodetic parameters derived from different observation techniques by developing strategies to separate underlying physical processes;
- contributions to the integration of geodetic observations based on different techniques in order to promote validation and consistency tests of various geodetic products.

Activities

Current activities focus on

- the development of consistent standards, parameters, analysis strategies and formats for all components of the unconstrained modular system model approach;
- the identification of relevant interactions among subsystems and appropriate parameterizations, in particular to represent the dynamic links between near-surface fluids and the "solid" Earth;
- the development of strategies for the separation of temporal variations of Earth rotation, gravity and geoid into individual causative physical processes.

Important in-progress activities and future efforts focus on

- feasibility studies for the provision of error estimates of model-based predictions of geodetic quantities (EOP, deformation, gravity variations);
- application of forward modeling and inversion methods in order to predict geodetic quantities and to invert geodetic observations for the underlying causative processes;
- the preparation of numerical algorithms for the assimilation of geodetic products into the numerical system model approach in order to provide a tool for validation and consistency tests of various monitoring products.

BPS WG1: Working Group on ITRS Standards for ISO TC 211

Chair: Claude Boucher (France)

Purpose and Activities

This group was initially established to investigate the strategy to obtain the adoption by the International Standardization Organization (ISO) of a standardization document related to ITRS. Following the initial work done by the group, a proposal was submitted to ISO by France. This proposal was a New Work Item Proposal (NWIP) related to ITRS submitted to the ISO TC 211 on Geographical information/Geomatics, to which IAG is a liaison. A new NWIP on ITRS has been officially re-submitted by France to ISO TC211 which is presently under the formal approval channel.

ISO finally decided that a preliminary study demonstrating the importance of geodetic references at large was necessary before going further in the direction of the initial proposal. A project (19161) was therefore established within ISO TC211 WG4 and chaired by Claude Boucher. The project report was finalized in January 2015, reviewed and finally submitted to WG4 for approval and decision of further actions.

Recommendations and planned efforts

The report ends with some recommendations:

- To develop a standard related to ITRS
- To make further studies about the interest and feasibility of a standard on vertical references
- To make similar action for universal identification of geodetic stations
- To work to improve geodetic terminology, including update of existing standards

The GGOS WG was in stand-by during this time. But assuming that the proposal about ITRS will be ultimately approved by ISO TC211, it seems opportune to reactivate this WG with a new mandate, namely drafting the document related to ITRS, and to update the membership of this WG.

BPS WG2: Establishment of the Global Geodetic Reference Frame (GGRF)

Chair: Urs Marti (Switzerland)

Terms of Reference

The United Nations General Assembly adopted the resolution on a Global Geodetic Reference Frame for Sustainable Development (A/RES/69/266) on February 26, 2015.

IAG, as the responsible scientific organization for the establishment and maintenance of global reference systems and reference frames establishes a joint working group (JWG) for the realization of this UN resolution under the umbrella of the Bureau of Products and Standards (BPS) of the Global Geodetic Observing System (GGOS). This JWG works together with representatives of IAG Commissions 1 and 2, the Inter-Commission-Committee on Theory (ICCT) the International Earth Rotation and Reference Systems Service (IERS) and the International Gravity Field Service (IGFS).

Besides the UN resolution, the following two IAG resolutions adopted at the IUGG General Assembly 2015 in Prague are the basis of the actions of this working group:

- Resolution 1 for the definition and realization of an International Height Reference System (IHRS)
- Resolution 2 for the establishment of a Global Absolute Gravity Reference System

A preparatory paper "Description of the Global Geodetic Reference Frame" has been prepared by IAG in 2015.
This JWG will work on the establishment and coordination of the geometric reference frame, the global height system, the global gravity network and their temporal changes. The application of Earth orientation parameters and tidal models and the underlying standard and reference models has to be brought into consistency.

Objectives and activities

Main objectives and activities of the Working Group are:

- Assist GGOS in defining the fundamental network and observing systems for the realization of the global geometric reference frame
- Assist the working group for establishing the International Height Reference System (IHRS) in the realization
- Integrating and combining the global gravity network with other techniques
- Advance the realization of a conventional global reference gravity field model
- Study the influence of earth orientation parameters and tidal models on the realization of a consistent global reference frame in geometry, height and gravity
- Study the necessity to replace / update the global reference system GRS80
- Foster the free exchange of geodetic data and products
- Organize and assist sessions and symposia on the global reference frame at conferences
- Development of a roadmap for the definition and realization of a Global Geodetic Reference System

Members

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Jonas Ågren (Sweden), Commission 2
Detlef Angermann (Germany), Chair of GGOS BPS
Riccardo Barzaghi (Italy), IGFS
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Harald Schuh (Germany), IAG President
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Corresponding Member

Gary Johnston (Australia), Commission 1

Focus Area 1: Unified Height System

Chair: Laura Sánchez (Germany)

The objective of Focus Area 1 is the unification of the existing vertical reference systems around the world. This should be achieved through the definition and realization of a global vertical reference system that

- supports geometrical (ellipsoidal) and physical (normal, orthometric, geoidal) heights world-wide with centimetre precision in a global frame;
- enables the unification of all existing physical height systems (i.e., all geopotential differences shall be referred to one and the same reference equipotential surface with potential W_0); and
- provides high-accuracy and long-term stability of the vertical coordinates.

A first step towards the establishment of a worldwide unified (standardized) height system was the release of an IAG resolution for the definition and realization of an International Height Reference System (IHRS) that was issued during the 2015 IUGG General Assembly. This resolution outlines the conventions for the definition of the IHRS in terms of potential parameters: the vertical coordinates are geopotential numbers referring to an equipotential surface of the Earth's gravity field realized by a conventional W_0 value. At present, the main challenge is the realization of the IHRS, i.e., the establishment of the International Height Reference Frame (IHRF). It is expected that the IHRF follows the same structure as the ITRF: a global network with regional and national densifications, with known geopotential numbers referring to the global IHRS. To guarantee a precise combination of physical and geometric parameters and to support the vertical datum unification worldwide, this reference network should be collocated with fundamental geodetic observatories, geometrical reference stations, reference tide gauges, local levelling networks, and gravity reference stations. For this purpose, it will use contributions from all IAG Commissions, and the available databases, standards and infrastructure of the IAG/GGOS Services.

Planned activities

- Refinement of standards and conventions for the definition and realization of the IHRS, including unification of standards and conventions that are used by the geometric and gravity Services of the IAG.
- Develop GGOS products for realizing the IHRS.
- Recommendation for a global vertical reference frame; i.e. the IHRF.
- Guidelines/procedures for height system unification.
- Development of a registry (metadata) containing the existing local/regional height systems and their connections to the global one.
- Strategies for the maintenance and use in practice of the IHRS.
- Determination and modelling of the temporal changes of the IHRF.
- Update the IHRS definition and realization as needed, based on future improvements in geodetic theory and observations.
- Servicing the vertical datum needs of other geosciences such as, e.g., hydrography and oceanography.

Efforts are currently underway to establish working groups and processing centres that will focus on one or more of the action items above. One such group is the already established JWG 0.1.2, whose objectives are outlined below.

Joint Working Group of Focus Area 1

JWG 0.1.2: Strategy for the Realization of the International Height Reference System (IHRS)
(joint with Commissions 1 and 2, ICCT, and the International Gravity Field Service)

Chair: L. Sánchez (Germany)

The IAG Resolution No. 1 released during the IUGG 2015 General Assembly outlines five conventions for the definition of the International Height Reference System (IHRS). The definition is given in terms of potential parameters: the vertical coordinates are geopotential numbers ($-\Delta W_P = C_P = W_0 - W_P$) referring to an equipotential surface of the Earth's gravity field realized by the conventional value $W_0 = 62\ 636\ 853.4\ m^2s^{-2}$. The spatial reference of the position P for the potential $W_P = W(X)$ is given by coordinates X of the International Terrestrial Reference Frame (ITRF). This Resolution also states that parameters, observations, and data shall be related to the mean tidal system/mean crust.

At present, the main challenge is the realization of the IHRS; i.e., the establishment of the International Height Reference Frame (IHRF): a global network with regional and national densifications, whose geopotential numbers referred to the global IHRS are known. According to the GGOS objectives, the target accuracy of these global geopotential numbers is $1 \times 10^{-2}\ m^2s^{-2}$. In practice, the precise realization of the IHRS is limited by different aspects; for instance, there are no unified standards for the determination of the potential values W_P, the gravity field modelling and the estimation of the position vectors X follow different conventions, the geodetic infrastructure is not homogeneously distributed globally, etc. This may restrict the expected accuracy of $1 \times 10^{-2}\ m^2s^{-2}$ to some orders lower (from $10 \times 10^{-2}\ m^2s^{-2}$ to $100 \times 10^{-2}\ m^2s^{-2}$). Consequently, the next step is to outline the minimum set of fundamentals needed for a reliable and sustainable realization of the IHRS.

According to this, the objectives of the JWG 0.0.2 are:

- To define the standards and conventions required to establish an IHRF consistent with the IHRS definition. A main issue is the high-precise modelling of the time-dependent changes of the vertical coordinate (which also reflect time variations of X and W).
- To formulate minimum requirements for the IHRF reference stations.
- To develop a strategy for collocation of IHRF reference stations with existing geometrical reference stations at different densification levels.
- To identify the geodetic products associated to the IHRF and to describe the elements to be considered in the corresponding metadata.
- To review the processing strategies for the determination of the potential values W_P and to recommend an appropriate computation procedure based on the accuracy level offered by those strategies.
- To review different approaches for the vertical datum unification and to provide guidance for the integration of the existing local height systems into the global IHRS/IHRF.
- To make a proposal about the organizational and operational infrastructure required to maintain the IHRF and to ensure its sustainability.

The main result of this JWG should be a document similar to the IERS conventions; i.e., a sequence of chapters describing the different components to be consider for the precise and sustainable realization of the IHRS and its practical utilization.

The activities of this JWG are based on the results presented by previous work, in particular those of the IAG Inter-Commission Project 1.2: Vertical Reference Frames (conventions for the definition of World Height System, 2003 – 2011); GGOS Focus Area 1 (former Theme 1): Unified Height System (action Items for the unification height reference systems, since 2011); the ESA project "GOCE+ Height System Unification with GOCE" (2011-2014); the GGOS-BPS (inventory of standards and conventions used for the generation of IAG/GGOS products, since 2011); and the Joint Working Group 0.1.1 on Vertical Datum Standardisation (2011-2015).

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Focus Area 2: Geohazards Monitoring

Chair: J. Labrecque (USA)

The Geohazards Monitoring Focus Area of the Global Geodetic Observing System (GGOS) seeks to apply geodetic science and technology in support of global and regional resiliency to environmental hazards.

The GGOS and its associated IAG services (International GNSS Service (IGS), International VLBI Service for Geodesy and Astrometry (IVS), International DORIS Service (IDS), International Laser Ranging Service (ILRS), International Earth Rotation and Reference Systems Service (IERS), and International Gravity Field Service (IGFS)) provide products that serve as the fundamental geodetic references for science, governments, and industry. The most notable of these products serve as the basic reference for positioning and timing information associated with the Global Navigation Satellite Systems (GNSS) including the International Terrestrial Reference Frame (ITRF), precision orbit and time information and continuing scientific and technical advancements to the utilization of the GNSS data.

These and other GGOS products achieved wide global recognition and acceptance because of their accuracy, timeliness, and continuing technical improvements. These are the very qualities needed for effective environmental warning. In some cases the acceptance of geodetic applications have been immediate and widespread such as the application of GNSS to understanding and modeling earthquake faults.

However, in other cases geodetic technology has advanced faster than nations can utilize this new capability. The Geohazards Monitoring Focus Area seeks to accelerate and guide the acceptance of new geodetic capability to improve resilience to environmental hazards. The Focus Area will establish working groups comprised of GGOS members and the responsible agencies of participating nations. The Focus Area encourages the sharing of intellectual, financial and physical resources as recommended by the UN-GGIM (http://ggim.un.org).

As its first initiative, the Geohazards Monitoring Focus Area has issued a Call for Participation (CfP) to research scientists, geodetic research groups and national agencies in support of the implementation of the IUGG 2015 Resolution 4: Global Navigation Satellite System (GNSS) Augmentation to Tsunami Early Warning Systems (http://www.iugg.org/resolutions/IUGGResolutions2015.pdf). The CfP responders will comprise a working group to be a catalyst and a motivating force through the definition of requirements, identification of resources, and the encouragement of international cooperation in the establishment, advancement, and utilization of GNSS for Tsunami Early Warning, The initiative will have early focus upon the Indo-Pacific region following the IUGG 2015 Resolution 4.

Future working groups of the Geohazards Monitoring Focus Area will support compelling initiatives that improve the resiliency of global and regional societies through the application of geodetic science and technology. The working groups mandate will be to develop an attainable and valuable goal as recommended by the GGOS Science panel. Each working group will define a work-plan with an estimated time line that will be subject to periodic review by the GGOS Coordinating Board.

Focus Area 3: Sea Level Change, Variability and Forecasting

Chair: T. Schöne (Germany)

Sea level rise and its impact on human habitats and economic well being is one of the key issues in the climate change discussion. In recent years this topic has received considerable and growing attention by the general public, engineers, researchers, and policy makers and calls for multi-disciplinary research. In 2010 GGOS has identified sea level change as one of the cross-cutting themes for geodesy and established this topic as one of its Focus Areas. The primary task of Focus Area 3 is to demonstrate the value of different geodetic techniques available under the umbrella of GGOS to the mitigation of sea level rise including studies of the impacts of its change over the world's coastal regions and islands, and to support practical applications such as sustainability.

Focus Area 3 interacts with the other two Focus Areas as well as with the related Committees and Working Groups of the GGOS Bureaus. Close cooperation is established and will be intensified with groups and organizations working in related fields. One major topic is the identification of gaps and their closure in geodetic observing techniques and networks and to advocate additions in the GGOS monitoring network and Services where necessary.

Activities

Through the projects accepted ongoing Call for Participation Focus Area 3 will progress with the following tasks:

- Identification or (re)-definition of the requirements for a roper understanding of global and regional/local sea level rise and its variability especially in so far as they elate to geodetic monitoring provided by the GGOS Infrastructure, and their current links to external organizations (e.g., GEO, CEOS, and other observing systems).
- Identification of gaps in geodetic observing techniques contributing to sea level research and advocate improvements and additions in the GGOS monitoring network and Services where necessary
- Establishing Focus Area 3 as the interface and point-of-contact between GGOS and organizations concerned with sea level research aspects
- In the long-term, the aim is to support forecasting of global and regional sea level for the 21st century. Special emphasis will be given to local and regional projects which re relevant to coastal communities, and which depend on the global perspective of GGOS.