Global Geodetic Observing System (GGOS)

Chair of the GGOS Coordinating Board: Basara Miyahara (Japan)
Vice-Chair of the GGOS Coordinating Board: Laura Sanchez (Germany)
Director of the Coordinating Office: Martin Schnal (Austria)

http://www.ggos.org

GGOS Background

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 endorsed by the IUGG through Resolution No. 3 at the same General Assembly.

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 GGOS are IAG Bylaw numbers 1(d) and 15. During 2009-2016, and again in 2017, revisions to the structure of GGOS were discussed leading in 2018 to the Terms of Reference, primarily to update changes to the organizational structure of GGOS.

According to the IAG Bylaws 1(d): “The Global Geodetic Observing System (GGOS) works with the IAG Services to provide the geodetic expertise and infrastructure necessary for the monitoring of 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 IAG 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 requires strong cooperation within the geodetic, geodynamic and geophysical communities, and the establishment of strong links to other international organizations. 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 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 organizational fabric of GGOS.

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).

The GGOS 2020 Book\(^1\) 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

Structural 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.

**GGOS Coordinating Board** – is the central oversight and decision-making body of GGOS.

**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 to the Coordinating Board relating to the scientific content of the GGOS 2020 book and its updates; and represents the geodetic and geoscience community at GGOS meetings.

**GGOS Coordinating Office** – coordinates the work within GGOS and supports the Chair, the Executive Committee and the Coordinating Board; and coordinates GGOS external relations.

**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 Affiliates** – are national or regional organizations that coordinate geodetic activities in that country or region. GGOS Affiliates allow increased participation in GGOS, especially by organizations in under-represented areas of Africa, Asia-Pacific, and South and Central America.

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**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.

**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 works with these IAG components to provide the geodetic infrastructure that is necessary for monitoring the Earth system and for global change research. GGOS, built upon the existing IAG Services and their products, will provide a framework for existing or future Services and will strive to ensure their long-term stability.

**GGOS Inter-Agency Committee (GIAC)** — was a forum that sought to generate a unified voice to communicate with Governments and Intergovernmental organizations (GEO, CEOS, UN bodies) in all matters of global and regional spatial reference frames and geodetic research and applications. GIAC was dissolved when the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) Working Group on the Global Geodetic Reference Frame (GGRF) was elevated to the permanent Subcommittee on Geodesy of the UN-GGIM.

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(1) GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

**Fig. 1** Organization structure of GGOS (December 2019)
United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) – led by United Nations Member States, UN-GGIM aims to address global challenges regarding the use of geospatial information and to serve as a body for global policymaking in the field of geospatial information management.

UN-GGIM Subcommittee on Geodesy (SCoG) – provides an intergovernmental forum for cooperation and exchange of dialogue on issues relating to the maintenance, sustainability and enhancement of the Global Geodetic Reference Frame (GGRF).

Details of the Structure of GGOS

GGOS Consortium
The GGOS Consortium is the voice and essentially the large steering committee of GGOS. It reviews GGOS progress and activities and nominates and votes for the candidates for the elected positions on the GGOS Coordinating Board. The GGOS Consortium is comprised of up to two designated representatives from each IAG Service, Commission, and Inter-Commission Committee and one representative from each GGOS Affiliate. 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 and Chairs of GGOS Affiliates 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 GGOS is ex-officio 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 nominating and electing body for the GGOS Coordinating Board. The Consortium will meet at least once a year. Observers may participate in meetings of the Consortium at the discretion of the Chair.

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. Observers may participate in meetings of the Coordinating Board at the discretion of the Chair.

Coordinating Board Members

Voting members:
GGOS Chair (votes in case of a tie)  1
GGOS Vice-Chair  1
GGOS Science Panel Chair (ex-officio)  1
GGOS Coordinating Office Director (ex-officio)  1
GGOS Manager of External Relations (ex-officio)  1
GGOS Bureau Directors (ex-officio)  2
GGOS Affiliate Representatives (elected by the Consortium)  2
IAG President or designated representative (ex-officio)  1
IAG 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  19

Non-voting members:
GGOS Committee and Working Group Chairs (ex-officio)  6
GGOS Focus Area Leads (ex-officio)  4
GGOS Web and Social Media Manager (ex-officio)  1
Immediate Past Chair of GGOS (ex officio)  1

Total Non-Voting Members  12

Total membership of Coordinating Board
19 Voting Members
12 Non-Voting Members
31 Total members

Chair

The Chair of the GGOS Coordinating Board is determined according to the IAG Bylaws. The Chair of the GGOS Coordinating Board is also known as the GGOS Chair. The GGOS Chair presides over meetings of the GGOS Consortium, Coordinating Board, and Executive Committee. The Chair is the principal spokesperson and representative of GGOS to the IAG and outside organizations.

Vice Chair

The Vice Chair of the GGOS Coordinating Board is elected by the Coordinating Board. The Vice Chair assists the Chair and serves as the Chair in the absence of the Chair or when a motion involving the Chair is being discussed.
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 as IAG Service, Commission, and Inter-Commission Committee representatives must be members of the GGOS Consortium. Candidates nominated to serve on the Coordinating Board as GGOS Affiliate representatives must be members of the GGOS Affiliates. The CB elects the Vice-Chair of the GGOS CB by a vote. However, the GGOS Chair is elected by the IAG 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
- GGOS Coordinating Office Director 1
- GGOS Manager of External Relations 1
- GGOS Bureau Directors 2
- Voting Members of the CB selected for EC membership 2
Total 8

Every other year, the GGOS Chair submits a list of his or her candidates for the two open EC 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 Immediate Past Chair of GGOS, the Chair of the GGOS Science Panel, and the President of IAG or designated representative 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 and the GGOS Focus Areas each nominate one candidate 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 established 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 Working Groups are nominated by their Chairs and confirmed by the Coordinating Board.

Focus Areas are cross-disciplinary and are meant to consider gaps and needed future products. The GGOS CB approves the Focus Areas. The CB appoints Focus Area leads. Focus Areas outline their charter and propose plans to address the work that they will undertake.

GGOS Coordinating Office
The GGOS Coordinating Office (CO) performs the day-to-day activities in support of GGOS, the Executive Commit-
The Geodesist’s Handbook 2020

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.

The position of Manager of External Relations resides within the Coordinating Office. The GGOS Manager of External Relations coordinates GGOS engagement with external organizations such as the Group on Earth Observations (GEO), the Committee on Earth Observation Satellites (CEOS), and the International Science Council (ISC) World Data System (WDS). The CB elects the Manager of External Relations by a vote.

**Bureau of Products and Standards**

The Bureau of Products and Standards keeps track of the strict observations of adopted resolutions, geodetic standards, standardized units, fundamental physical constants 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 ISO, ISC, IUGG, IAU, IAG and 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. The Bureau advocates for implementation of core and other co-located network sites to satisfy GGOS requirements, monitors the present state of the networks and projects future status, and supports and encourages infrastructure critical for the development of data products essential to GGOS. 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 of the Bureau.

**GGOS Affiliates**

A GGOS Affiliate is a national or regional organization that coordinates geodetic activities in that country or region. GGOS Affiliates provide a forum for multi-technique, space-geodetic discussions, work to improve the quality of space-geodetic observations, and encourages the different agencies in that country or region that own, operate, and maintain the space-geodetic infrastructure there to collaborate with each other. To become a GGOS Affiliate, interested organizations submit an application to GGOS which is approved by the GGOS CB by a vote.

**GGOS Coordinating Board (Voting Members):**

GGOS President/Chair: Basara Miyahara (Japan)
Vice-President/Chair: Laura Sánchez (Germany)
Chair of GGOS Science Panel: Kosuke Heki (Japan)
Director of Coordinating Office: Martin Sehnal (Austria)
Manager of External Relations: Allison Craddock (USA)
Directors of Bureaus of Networks and Observations: Michael Pearlman (USA)
Director of Bureau of Products and Standards: Detlef Angerman (Germany)
GGOS Japan Affiliate Representatives: Toshimichi Otsubo (Japan)
IAG President: Zuheir Altamimi (France)
IAG Service Representative: Riccardo Barzaghi (Italy)
IAG Service Representative: Daniela Thaller (Germany)
IAG Service Representative: Sean Bruinsma (France)
IAG Service Representative: Robert Heinkelmann (Germany)
IAG Commissions and ICC Representative: Tonie Van Dam (Luxemburg)
IAG Commissions and ICC Representative: Adrian Jäggi (Switzerland)
Member-at-Large: Maria Cristina Pacino (Argentina)
Member-at-Large: Nicholas Brown (Australia)
Member-at-Large: Ludwig Combrinck (South Africa)
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 the Bureau.

In addition, the IERS Working Group on Site Survey and Co-location also participates in the BN&O activities; this Working group is now in the process of reorganization with Ryan Hippenstiel / NOAA as Chair.

Objectives

The Bureau of Networks and Observations (BNO) supports the networks capability available to the IAG in its goal to provide geodetic data products of sufficient quantity, quality and temporal and spatial resolution to improve our understanding of the dynamic Earth for both scientific understanding and societal needs. Fundamental to achieving reaching this goal is the maintenance and further development of the globally available terrestrial and celestial reference frames, which are the basis for our metric measurements over space, time, and evolving technology.

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 role of the BNO is to:

- Advocate for the expansion and upgrade of the space geodesy network for the maintenance and improvement of the reference frame and other GGOS priorities; Main focus will be on the Reference Frame; but the other applications need to be accommodated;
- Encourage partnerships to build and upgrade network infrastructure;
- Organize and expand the GGOS affiliated network;
- Monitor network status; projected network evolution based on input from current and expected future participants, estimate performance capability 5 and 10 years ahead;
- Conduct simulation studies and analyses to assess impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties, and network trade of options (PLATO);
- Develop Metadata Systems for a wide range of users including GGOS; near term strategy for data products (Carey Noll at GSFC) and a more comprehensive longer-term plan for an all-inclusive system (Nick Brown at GA) (Committee on Data and Information);
- Provide the opportunity for representatives from the Services and the Standing Committees to meet and share progress and plans; discuss issues of common interest; meetings at EGU, AGU, GGOS Days, etc.;
- Talks and posters on the Bureau at EGU, AGU, JPGU-AGU, AOGS meetings, etc.;
- Letters/documentation to support stations, current/new missions, and analysis centers;

Tasks

- Continue recruiting station membership in the GGOS Network through the CfP; issue membership certificates (great response);
- Continue monitoring network status and plans; develop next network projection status for 5 and 10 years ahead;
- Provide next update of the "Guideline for GGOS Core Sites and Co-locations Sites" document;
- Work with the IGFS and IHRF, the PSMSL and the other services 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; Global Geodetic Observing System (GGOS);
- 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;
- Continue simulation and trade-off studies for network options (PLATO Committee);
- Continue metadata systems development; target phase 1 (data products) for 2020 (Committee on Data and Information);
- Improve communication and information exchange and coordination with the space missions; (Committee on Satellite Missions);
- Work with the IERS Working Group on Site Survey and Co-location to improve the quality of site ties and instrument reference points;
- Continue BNO meetings to meet, discuss status and plans, and examine common interests and requirements;
- Continue presentation at international meetings in BNO activities and plans;
- Continue providing letters and documentation support
- Update the Bureau web pages for public use (to be compatible with the new GGOS website in process;
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: Benjamin Maennel (Germany)

Objective

The PLATO Committee / Working Group has currently 12-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 on how do we use existing observation capabilities (stations, observation concepts, tracking performance, etc.) including co-location in space with existing and new dedicated satellites to best support GGOS planning and implementation.

Project future network capability and examine trade-off options for station deployment and closure, technology upgrades, the 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, colocation 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.

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/Jason-2)
  - 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 the impact of upgrading existing stations and their procedures
  - Simulate the impact of additional ground surveys at colocation sites (site ties)
- Potential future space assets: - Co-locate all four techniques in space on a dedicated satellite

Tasks

- Examining trade-off options for station deployment and closure, technology upgrades, the impact of site ties, etc. and project future network capability based on network configuration projected by the BNO or relevant IAG services (IGS, ILRS, IVS, IDS);
- Investigating the impact of improved SLR tracking scenarios including spherical satellites, LEOs, and GNSS satellites and VLBI satellite tracking on reference frame products;
- Identifying technique systematics by analyzing short baselines, data from new observation concepts, and available co-locations (e.g., consistent processing of LEO and ground-based observations);
- Investigating the best-practice methods for co-location in space and assessing the impact of co-location in space on reference frame products based on existing satellites and by simulation studies for proposed missions.
BNO C2: Committee on Data and Information

Chair: Nicholas Brown (Austria)
Vice-Chair: Carey Noll (USA)

Objectives
The Committee on Data and Information had two GGOS objective areas:
- Development and implementation of a portal;
- Development and implementation of a metadata scheme

Initial work on the portal was done by Bernd Richter. When he retired, the task was transferred to the GGOS Coordinating Office.

Near term Metadata activity (Carey Noll/CDDIS)
CDDIS is implementing collection-level metadata through the Earth Observation System Data and Information System (EOSDIS) Common Metadata Repository (CMR). CDDIS is an EOSDIS Distributed Active Archive Centers (DAACs) and thus utilizes the EOSDIS infrastructure to manage collection and granule level metadata describing CDDIS archive holdings; these metadata include DOIs associated with the CDDIS archive contents. The CMR is accessible through APIs and can be used in the future by GGOS to find geodetic data and products available through the CDDIS.

Longer-Term Metadata activity (Nick Brown / Geoscience Australia)
Development of a Geodesy Markup Language (GeodesyML), for the GNSS community; potential for expansion to the other space geodesy techniques and GGOS. The current study is identifying metadata standards and requirements, assessing critical gaps and the how these might be filled, what changes are needed in the current standards, and who are the key people who should work on it (more comprehensive scheme). The schema that would 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:
Activities underway at CDDIS:
1. Complete collection level metadata related to CDDIS data and product holdings in the EOSDIS Common Metadata Repository (CMR)
2. Re-ingest CDDIS data holdings in order to extract granule level metadata linked to new collection level records

Activities underway in Geodesy Markup Language (GeodesyML) System
1. Review and document the metadata and standards requirements of precise positioning users in expected high use sectors (e.g. precision agriculture, intelligent transport, marine, location-based services etc.).
2. Assess and document the critical gaps in standards which restrict how Findable Accessible Interoperable and Reusable (FAIR) precise positioning data is for the expected high use sectors.
3. Record use cases of standards being applied well and the benefits it provides to users.
4. Review the “use cases” of geodetic data developed by Geoscience Australia and the IGS Data Center Working Group and document what work and time would be required to ensure these use cases can be met in international standards. This could be:
   - Identify which gaps can be filled by GeodesyML
   - Identify which components of GeodesyML would be better, handled by / integrated with, existing standards (such as TimeSeriesML, SensorML, Observations and Measurements) where possible.
   - Identify which components of already existing international geospatial infrastructure can be approached (such as the European Inspire initiative)
   - Advise on who we should engage with from the OGC/ISO community to facilitate a change to a standard to meet our requirements.
5. Work with Project Partners to develop and test other use cases (e.g. integration of geodetic data with geophysics data (e.g. tilt meters), Intelligent Transport Sector data, mobile applications). Then, document what work and time would be required to ensure these use cases can be met in international standards.
6. Provide advice on how to best engage with the right communities to learn from their experiences, test their tools and influence the development of required standards.
BNO C3: Committee on Satellite Missions

Chair: Roland Pail (Germany)
Vice-Chair: C.K. Shum (USA)

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

- Advocate, coordinate, and exchange 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 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

- Continue the regular activities, i.e. updating the two central lists, supporting future satellite missions, etc.
- Work with the Coordinating Office to set up and maintain a Satellite Missions Committee section on the GGOS website;
- Evaluate the contribution of current and near-term satellite missions to the GGOS 2020 goals;
- 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.
- Increase the exchange and collaboration with PLATO; set up a more formal procedure of collaboration; discuss needs and run simulations to study the impact of future satellite missions, identify gaps for fulfilling the GGOS goals, etc.
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, Representatives of IAG Services and other entities involved:

R. Barzaghi (Italy)  
S. Bonvalot (France)  
H. Capdeville (France)  
M. Craymer (Canada)  
J. Gipson (USA)  
T. Herring (USA)  
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K. Kelly (USA)  
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F. Lemoine (USA)  
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M. Reguzzoni (USA)  
J. Ries (USA)  
N. Stamatakis (USA)  
H. Wziontek (Germany)  

GGOS components associated to the BPS:

- Committee Earth System Modelling (Chair: M. Thomas)  
- Committee Essential Geodetic Variables (Chair: R. Gross)  
- BPS Working Group Towards a consistent set of parameters for the definition of a new GRS (Chair: U. Martí)

Objectives

- The Bureau of Products and Standards (BPS) supports GGOS in its goal to obtain consistent products describing the geometry, rotation and gravity field of the Earth. A 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 products. Moreover the BPS interacts with external stakeholders that are involved in standards and conventions, such as the International Organization for Standardization (ISO), the Committee on Data for Science and Technology (CODATA), the International Astronomical Union (IAU) and the UN GGIM Subcommittee on Geodesy (SCoG). 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. The BPS has compiled an inventory “GGOS Bureau of Products and Standards: Inventory of Standards and Conventions used for the Generation of IAG Products” (see IAG Geodesist's Handbook 2016). This inventory provides an assessment of the present status, identifies gaps and shortcomings concerning the generation of the IAG products, as well as recommendations. This inventory needs to be regularly updated since the IAG standards and products are evolving over time. 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. In this context, the BPS recommends the development of a new Geodetic Reference System GRS20XX based on the best estimates of the major parameters related to a geocentric level ellipsoid.
  2. Products: The BPS shall take over a coordinating role regarding the homogenization of standards and geodetic products. The present status regarding IAG Service products shall be evaluated, including analysis
and combination procedures, accuracy assessment with respect to GGOS requirements, documentation and IAG metadata information for IAG products. The Bureau shall initiate steps to identify user needs and requirements for geodetic products and shall contribute to develop new and integrated products. The BPS shall also contribute to the development of the GGOS Portal (as central access point for geodetic products), to ensure interoperability with IAG Service data products and external portals (e.g., GEO, EOSDIS, EPOS, GFZ Data Services).

Tasks
- The tasks of the Bureau of Products and Standards are to:
  - act as contact & coordinating point for homogenization of IAG standards and products
  - keep track of adopted geodetic standards and conventions across all IAG components, and initiate steps to close gaps and deficiencies
  - interact with external stakeholders in the field of standards and conventions (e.g., IAU, ISO, BIPM, CODATA, UN-GGIM, …), the BPS director has been nominated as IAG representative to ISO/TC 211 and as IAG representative in the UN-GGIM GGRF Working Group “Data Sharing and Development of Geodetic Standards”
  - update the inventory on standards and conventions used for the generation of IAG products
  - contribute to the re-writing/revising of the IERS Conventions, the BPS director has been nominated as Chapter Expert for Chapter 1 “General definitions and numerical standards”
  - focus on the integration of geometric and gravimetric observations and to support the development of integrated products (e.g., GGRF, IHRF, atmosphere products)
  - contribute to the UN GGIM Subcommittee on Geodesy (SCoG)
  - contribute to the Committee on Essential Geodetic Variables (EGVs)
  - contribute to the GGOS DOI Working Group

Committees and Working Groups of the Bureau of Products and Standards

GGOS Committee on Earth System Modeling

Chair: Maik Thomas (Germany)

The GGOS Committee on “Earth System Modeling” tends to promote the development of physically consistent modular Earth system modeling tools that are simultaneously applicable to all geodetic parameter types (i.e., Earth rotation, gravity field and surface geometry) and observation techniques. Hereby, the committee contributes to:
- the interpretation of geodetic monitoring data and, thus, to a deeper understanding of dynamical and complex interacting processes in the Earth system responsible for the observed variations;
- the establishment of a link between the geodetic products delivered by GGOS and numerical process models;
- a consistent combination and integration of observed geodetic parameters derived from various monitoring systems and techniques;
- the utilization of geodetic products for the interdisciplinary scientific community.

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:
- development of Earth system model components considering interactions and relationships between surface deformation, Earth rotation and gravity field variations as well as interactions and physical fluxes between relevant compartments of the Earth system;
- promotion of homogeneous processing of geodetic monitoring data (de-aliasing, reduction) by process modeling to improve analyses 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**

Major current activities focus on:

- the implementation of generalized modules for the realistic consideration of interactions of near-surface fluids with the geosphere arising, e.g., from surface-loading and self-attraction;

- implementation of interfaces to geodetic monitoring data based on Kalman and particle filter approaches in order to constrain and improve stand-alone model approaches and to prove consistency of various geodetic monitoring products;

- feasibility studies for the provision of error and uncertainty estimates of model predictions of geodetic parameters (Earth rotation, gravity field, surface deformation) due to imperfect model physics, initialization, and external forcing.

Important in-progress activities and future efforts focus on:

- evaluation of opportunities to constrain dynamically coupled model systems with geodetic data products by applying Kalman filter and inversion techniques;

- application of forward modeling and inversion methods in order to improve model-based predictions of geodetic quantities and to invert geodetic observations for the underlying causative processes.

**Committee on Essential Geodetic Variables**

Chair: Richard Gross (USA)

The GGOS BPS Committee on Essential Geodetic Variables was established in 2018 in order to define a list of Essential Geodetic Variables and to assign requirements to them. Essential Geodetic Variables (EGVs) are observed variables that are crucial (essential) to characterizing the geodetic properties of the Earth and that are key to sustainable geodetic observations. Examples of EGVs might be the positions of reference objects (ground stations, radio sources), Earth orientation parameters, ground- and space-based gravity measurements, etc. Once a list of EGVs has been determined, requirements can be assigned to them. Examples of requirements might be accuracy, spatial and temporal resolution, latency, etc. These requirements on the EGVs can then be used to assign requirements to EGV-dependent products like the terrestrial and celestial reference frames. The EGV requirements can also be used to derive requirements on the observing systems that are used to observe the EGVs. And the list of EGVs can serve as the basis for a gap analysis to identify observations needed to fully characterize the geodetic properties of the Earth. During GGOS Days 2017 it was agreed that a Committee within the GGOS Bureau of Products and Standards should be established in order to define the list of Essential Geodetic Variables and to assign requirements to them. This Committee was subsequently established in 2018 and consists of representatives of the IAG Services, Commissions, Inter-Commission Committees, and GGOS Focus Areas.

**Tasks**

The tasks of the Committee on Essential Geodetic Variables are to:

- Develop criteria for choosing from the set of all geodetic variables those that are considered essential
- Develop a scheme for classifying EGVs
- Within each class, define a list of EGVs
- Assign requirements to each EGV
- Document each EGV including its requirements, techniques by which it is observed, and point-of-contact for further information about the EGV
- Perform a gap analysis to identify potential new EGVs
- Define a list of geodetic products that depend on each EGV
- Assign requirements to the EGV-dependent products
- Hold workshops to engage the geodetic community in the process of defining EGVs, determining their dependent products, and assigning requirements to them

**GGOS Working Group: Towards a consistent set of parameters for the definition of a new GRS**

Chair: Urs Marti (Switzerland)

**Terms of Reference**

The Geodetic Reference System 1980 GRS80 is still the conventional system for most applications in Geodesy and other Earth sciences. It was defined through the four parameters a (semi-major axis), J2 (Dynamical Form Factor), GM (geocentric Gravitational Constant) and ω (Angular Rotation Velocity). It represents the scientific status of the 1970ies and in its concept, the tidal systems and relativistic theories are not considered. Since its adaptation, various inconsistencies have been introduced into geodetic standards and applications, such as new values for GM or a in the IERS conventions. In 2015, a conventional value for the gravitational potential at sea level W0 was adopted in an IAG resolution, which is in contradiction to the definition of GRS80.
This WG will publish a new set of defining parameters for a modern GRS based on today's knowledge and calculate all the necessary derived parameters in a consistent way. It will study the necessity to work towards an IAG resolution to replace GRS80 as the conventional system and provide transformation procedures between the two systems. It will study as well the necessity to define and adopt a conventional global gravity field model for standard applications in geodesy, navigation and related topics.

This JWG is assigned to the GGOS Bureau of Products and Standards (BPS) and works together with representatives of IAG Commissions 1 and 2, the Inter-Commission-Committee on Theory (ICCT), the International Gravity Field Service (IGFS), the International Earth Rotation and Reference Systems Service (IERS) and the Committee on Essential Geodetic Variables (EGV).

This JWG will focus its activities on the 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**

The main objectives and activities of this working group are:

- Calculate consistent parameters of a new mean Earth ellipsoid and derived quantities
- Study the necessity to replace the global reference system GRS80 as the conventional system
- Advance the realization of a conventional global reference gravity field model (combined and satellite only)
- 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
- Study the influence of Earth orientation parameters, tidal models and relativistic effects on the realization of a consistent global reference frame in geometry, height and gravity
- Foster the free exchange of geodetic data and products

**Members**

*Urs Marti* (Switzerland), Chair
*Detlef Angermann* (Germany), Chair of GGOS BPS, IERS
*Richard Gross* (USA) IAG Vice President, Committee on EGV
*Ilya Oshchepkov* (Russia), GRS, Gravity Networks and Height Systems
*Christopher Kotsakis* (Greece), Commission 1
*Jonas Ågren* (Sweden), Commission 2
*Ulrich Meyer* (Switzerland) COST-G
*Riccardo Barzaghi* (Italy), IGFS
*Jaakko Mäkinen* (Finland), Tidal Systems
*Pavel Novak* (Czech Republic), ICCT
*Laura Sánchez* (Germany), IHRF
*Hartmut Wziontek* (Germany), IGRF
*John Nolton* (USA), GRS
*Robert Heinkelmann* (Germany), IAU
*Sergei Kopeikin* (USA), relativistic effects
*Erricos Pavlis* (USA), ILRS

*
Focus Area: Unified Height System

Chair: Laura Sánchez (Germany)

The present objective of Focus Area Unified Height System is the implementation of the IAG resolution for the definition and realization of an International Height Reference System (IHRF) issued during the 2015 IUGG General Assembly. This resolution outlines the conventions for the definition of the IHRS in terms of potential parameters: 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 \(W(X)\) is given by coordinates \(X\) of the International Terrestrial Reference Frame (ITRF). This Resolution also states that the IHRS coordinates should be related to the mean-tide system/mean crust.

At present, a 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, whose geopotential numbers referring to the global IHRS are known. According to the GGOS objectives, the desired 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. Therefore, the achievable accuracy may be restricted to \(10 \times 10^{-2} m^2s^{-2}\) ... \(100 \times 10^{-2} m^2s^{-2}\), which is one or two orders of magnitude lower than the desired accuracy.

During the term 2015 – 2019, important advances were achieved: a global core reference network for the IHRF was defined and, within the Colorado experiment, it was possible to compare different methodologies for the determination of the reference coordinates \(W_p\). The results are very promising and these activities will be continued in term 2019 – 2023 by the Joint Working Group (JWG) 0.1.3 “Implementation of the International Reference Frame – IHRF”. This working group is a joint initiative of Joint Working Group (JWG) of the GGOS Focus Area Unified Height System, the International Gravity Field Service (IGFS), the IAG Inter-commission Committee on Theory (ICCT) and the IAG Commissions 2 (Gravity field) and 1 (Reference Frames). The corresponding terms of reference are describe in the following.

Joint Working Group 0.1.3: Implementation of the International Height Reference Frame (IHRF)

Chair: Laura Sánchez (Germany), Lead of the GGOS Focus Area Unified Height System
Vice-chair: Riccardo Barzaghi (Italy), Chair of the International Gravity Field Service

Major objectives of the JWG 0.1.3 are:

- Based on the Colorado experiment outcomes, to elaborate a document with detailed standards and conventions for the realization and maintenance of the IHRS.
- To compute a first static solution for the IHRF core network, to evaluate the achievable accuracy under the present conditions (data availability, computation methods, etc.) and to identify key actions to improve the determination of the IHRS/IHRF coordinates.
- With the support of the IAG Commission 2, the IGFS and the ICCT to promote the study of
  - quality assessment in the determination of potential values,
  - determination of potential changes with time \(W\),
  - realization of the IHRS in marine areas.
- In agreement with the IGFS and the IAG Commission 2, to design a strategy to install an operational infrastructure within the IGFS to ensure the maintenance and availability of the IHRF in a long-term basis. Aspects to be considered are
  - Updates of the IHRS definition and realization according to future improvements in geodetic theory and observations.
  - Regular updates of the IHRF (e.g. IHRFyyyy) according to new stations, coordinate changes with time, improvements in the estimation of reference coordinates and modelling of the Earth’s gravity field, etc.
  - Support in the realisation and utilisation of the IHRS/IHRF at regional and national level.
  - To guarantee an organizational and operational infrastructure to ensure the sustainability of the IHRF.

A strong joint work is planned with

- International Gravity Field Service – IGFS, chair: R. Barzaghi (Italy), vice-chair: G. Vergos (Greece).
- ICCT JSG: Geoid/quasi-geoid modelling for realization of the geopotential height datum, chairs: J Huang (Canada), YM Wang (USA).
- IAG SC 2.2: Methodology for geoid and physical height systems, chair: G. Vergos (Greece).
• IAG Commission 2.2 WG: Error assessment of the 1 cm geoid experiment, chairs: M. Willberg (Germany), T. Jiang (China).
• IAG Commission 2 JWG: On the realization of the International Gravity Reference Frame, chairs: H. Wziontek (Germany), S. Bonvalot (France)
• GGOS-BPS WG: Towards a consistent set of parameters for a new GRS, chair U. Marti (Switzerland).

Members

H.A. Abd-Elmotaal (Egypt) M. Varga (Croatia)
J. Agren (Sweden) G. Vergos (Greece)
H. Denker (Germany) M. Véronneau (Canada)
W. Featherstone (Australia) Y. Wang (USA)
R. Forsberg (Denmark) M. Willberg (Germany)
V.N. Grigoriadis (Greece) M. Amos (New Zealand)
T. Gruber (Germany) D. Avalos (Mexico)
G. Guimarães (Brazil) M. Bilker-Koivula (Finland)
J. Huang (Canada) D. Blitzkow (Brazil)
T. Jiang (China) S. Claessens (Australia)
Q. Liu (Germany) X. Collilieux (France)
J. Mäkinen (Finland) M. Filmer (Australia)
U. Marti (Switzerland) A.C.O.C. Matos (Brazil)
K. Matsuo (Japan) J. McCubbine (Australia)
P. Novák (Czech Republic) R. Pail (Germany)
I. Oshchepkov (Russia) D. Roman (USA)
M. Sideris (Canada) C. Tocho (Argentina)
D. Smith (USA) H. Wziontek (Germany)

Focus Area: Geohazards

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 resilience 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 continuous 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 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 https://office.iag-aig.org/iag-and-iugg-resolutions). The CfP responders 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 is initially focused upon the Indo-Pacific region following the IUGG 2015 Resolution 4.

Present Status and Progress:

• The Geohazards Focus Area (GFA) is focused upon the implementation of the IUGG 2015 General Assembly Resolution #4. The GFA summarized its previous activities in a 2015 to 2019 quadrennial report to the IAG. (https://www.dropbox.com/s/9ivbaqju798y2f9/IGA-Geohazards%20Report%202015-2019.pdf?dl=0).
• Since the establishment of GATEW working group, the working group has grown to 18 members from 12 nations (chart) with the recent inclusion of the Indian National Centre for Ocean Information (INCOIS). As listed in the attached membership chart.
<table>
<thead>
<tr>
<th>Country</th>
<th>Organization</th>
<th>Resources</th>
<th>Contact</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Geoscience Australia</td>
<td>Large National Real Time GNSS Network</td>
<td>John Dawson</td>
<td><a href="mailto:John.Dawson@ga.gov.au">John.Dawson@ga.gov.au</a></td>
</tr>
<tr>
<td>Chile</td>
<td>U. Chile, Department of Geophysics, CSN</td>
<td>Large National Real time Geodetic and Seismic Network</td>
<td>Sergio Barrientos, Sebastián Riquelme, Juan Baez</td>
<td><a href="mailto:sbarrien@dgf.uachile.cl">sbarrien@dgf.uachile.cl</a>, <a href="mailto:sebastian@dgf.uachile.cl">sebastian@dgf.uachile.cl</a>, <a href="mailto:jcbaez@csn.uc">jcbaez@csn.uc</a> Nhiel.cl</td>
</tr>
<tr>
<td>China</td>
<td>GNSS Research Center, Wuhan University</td>
<td>First Real Time Asian Analysis Center</td>
<td>Jianghui Geng</td>
<td><a href="mailto:jgeng@whu.edu.cn">jgeng@whu.edu.cn</a></td>
</tr>
<tr>
<td>China</td>
<td>Shanghai Observatory</td>
<td>Eminent geodetic research organization with strong experience in geodetic infrastructure, analysis and applications</td>
<td>Shuanggen Jin</td>
<td><a href="mailto:sgjin@shao.ac.cn">sgjin@shao.ac.cn</a></td>
</tr>
<tr>
<td>Colombia</td>
<td>Geological Survey Colombia</td>
<td>Large Real Time GNSS Network, Regional Data Sharing with Brazil, Peru, Panama, Venezuela, COCONet Data Center</td>
<td>Hector Mora</td>
<td><a href="mailto:hmora@sgc.gov.co">hmora@sgc.gov.co</a></td>
</tr>
<tr>
<td>France</td>
<td>Institut de Physique du Globe de Paris</td>
<td>Strong research in tsunami coupled ionospheric waves and tracking</td>
<td>Giovanni Ochijiini</td>
<td><a href="mailto:ninto.a.paris@gmail.com">ninto.a.paris@gmail.com</a></td>
</tr>
<tr>
<td>Germany</td>
<td>GeoForschung Zentrum, Department Geoservices</td>
<td>Strong research and development of GNSS Early Warning including Indonesia and Oman projects</td>
<td>Harald Shuh, Jörm Lauterjung</td>
<td><a href="mailto:schuh@gfz-potsdam.de">schuh@gfz-potsdam.de</a>, <a href="mailto:lau@gfz-potsdam.de">lau@gfz-potsdam.de</a></td>
</tr>
<tr>
<td>India</td>
<td>Indian National Centre for Ocean Information Services (INCOIS)</td>
<td>INCOIS operates Tsunami Warning Center ESSO and a large array of seismic, tidal gauges buoy, GNSS and strong motion accelerometers at sites including the Andaman and Nicobar Islands.</td>
<td>Mrs. Vijaya Sunanda Manneela</td>
<td><a href="mailto:sheno@incois.gov.in">sheno@incois.gov.in</a>, <a href="mailto:sunanda@incois.gov.in">sunanda@incois.gov.in</a></td>
</tr>
<tr>
<td>Italy</td>
<td>University of Rome Geodesy and Geomatics</td>
<td>Initiating research in GNSS Tsunami Warning</td>
<td>Mattia Crespi, Augusto Mazzoni</td>
<td><a href="mailto:mattia.crespi@uniroma1.it">mattia.crespi@uniroma1.it</a>, <a href="mailto:augusto.mazzoni@uniroma1.it">augusto.mazzoni@uniroma1.it</a></td>
</tr>
<tr>
<td>Mexico</td>
<td>Instituto de Geofisica, UNAM</td>
<td>Large National GNSS network and analysis system, COCONet Data Center</td>
<td>Enrique Cabral</td>
<td><a href="mailto:ecabral@geofisica.unam.mx">ecabral@geofisica.unam.mx</a></td>
</tr>
<tr>
<td>New Zealand</td>
<td>GNS Science</td>
<td>Large National Network</td>
<td>Elisabetta D'Anastasion</td>
<td><a href="mailto:E.DAnastasio@gns.cri.nz">E.DAnastasio@gns.cri.nz</a></td>
</tr>
<tr>
<td>New Zealand</td>
<td>Land Information New Zealand</td>
<td>Large National Network</td>
<td>Dion Hansen</td>
<td><a href="mailto:DHansen@linz.govt.nz">DHansen@linz.govt.nz</a></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Survey Department of Sri Lanka</td>
<td>Strong interest in developing Tsunami Early Warning</td>
<td>P. Sangakkara, Mr A. Dissanyake</td>
<td><a href="mailto:sangakkara@yahoo.com">sangakkara@yahoo.com</a>, <a href="mailto:addsgc@survey.gov.lk">addsgc@survey.gov.lk</a></td>
</tr>
<tr>
<td>USA</td>
<td>Georgia Tech</td>
<td>Significant focus on subduction zone activity and the generation of tsunamis</td>
<td>Andrew V. Newman</td>
<td><a href="mailto:anewman@gatech.edu">anewman@gatech.edu</a></td>
</tr>
<tr>
<td>USA</td>
<td>Jet Propulsion Laboratory</td>
<td>Real time expertise, ionospheric mapping, global and operations, earthquake and tsunami warning</td>
<td>Attila Komjathy</td>
<td><a href="mailto:attila.komjathy@jpl.nasa.gov">attila.komjathy@jpl.nasa.gov</a></td>
</tr>
<tr>
<td>USA</td>
<td>UNAVCO</td>
<td>Global GNSS networks, real time data systems, Global GNSS support</td>
<td>Linda Rowan</td>
<td><a href="mailto:rowan@unavco.org">rowan@unavco.org</a></td>
</tr>
<tr>
<td>USA</td>
<td>READI Working Group</td>
<td>NASA-GOAA working group developing GNSS Based Tsunami Warning</td>
<td>Yehuda Bock, Timothy Melbourne</td>
<td><a href="mailto:ybock@ucsd.edu">ybock@ucsd.edu</a>, <a href="mailto:tim@Geology.cwru.edu">tim@Geology.cwru.edu</a></td>
</tr>
<tr>
<td>USA</td>
<td>NASA</td>
<td>NASA Solid Earth Science. Provides funding from GNSS Tsunami Warning development. Cooperating with NOAA in this effort.</td>
<td>Gerald Bawden</td>
<td><a href="mailto:gerald.w.bawden@nasa.gov">gerald.w.bawden@nasa.gov</a></td>
</tr>
</tbody>
</table>
The GATEW worked with other organizations to publish a report on GTEWS 2017 in the UNDRR GAR19 report in May 2019 [https://www.prevention-web.net/publications/view/66779]. The GAR 19 paper reports on the deliberations and recommendations of the GTEWS 2017 workshop that GGOS GFA cosponsored. The GAR 19 white paper articulates the role of GTEWS technology and the GTEWS 2017 recommendations in the implementation of the Sendai Framework.

The strong participation exemplified by the GATEW membership now serves as the basis of a GEO community activity Geodesy4Sendai. See page 92 of the GAR19 report of the GTEWS 2017 workshop [https://www.earthobservations.org/documents/gwp20_22/gwp2020_summary_document.pdf].

- The Geodesy4Sendai activity raises the recommendation of the GTEWS 2017 workshop to ministerial level discussions.

**Planned Actions and Milestones**

- 2020 election of a Chair for the GATEW working group/
- Establish the GNSS Shield Consortium as recommended by the GTEWS 2017 workshop.
- Organize the GATEW activities to align with the GEO Geodesy4Sendai community activity
- GTEWS 2020: The GFA is engaged with partnering organization in the planning and fund raising is underway for GTEWS 2020 workshop with a focus upon implementation of the GTEWS 2017 workshop.

**Develop Support for GNSS Consortium:**

- A proposal to be re-submitted to the US National Science Foundation by members of the READI Group (a member of the GATEW working group) is viewed as a US contribution to GNSS Shield Consortium as recommended by the GTEWS 2017 workshop. Similar efforts by other GATEW is solicited.
- G. Occhipinti (IPGP, France) and M. Crespi (Sapienza University of Rome, Italy) are preparing a proposal to the European Commission to apply ionospheric imaging to the estimation of earthquake and tsunami risk and their resulting disasters.
- If they are successful, these efforts by the European and US membership will be the first contributions to the implementation of the GTEWS 2017 recommendations. Please review the recommendations of the GTEWS 2017 and consider how you might support these recommendations.

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 on Geodetic Space Weather Research**

Chair: Michael Schmidt (Germany)

Space weather means today an own, very up-to-date and interdisciplinary field of research. It describes physical processes in space mainly caused by the Sun’s radiation of energy. The manifestations of space weather are multiple, for instance, the variations of the Earth’s magnetic field or the changing states of the upper atmosphere, in particular the ionosphere and the thermosphere.

The most extreme known space weather event happened at September 1, 1859 – the Carrington storm. Other prominent recent, but much weaker events have been the Halloween storm at October 28 – 30, 2003, or the St. Patrick’s storm at March 17, 2015. The strength of these events, their impacts on modern society and the possibility of much stronger future events have brought several countries such as US, UK, Japan, Canada and China to recognize the necessity of studying these impacts scientifically, of developing protection strategies and procedures and to establish space weather data centres and space weather services. As a consequence of these activities the Focus Area on Geodetic Space Weather Research (FA GSWR) was initiated and finally implemented into the GGOS structure. The following statements summarize the necessity of geodesy to deal with the topic space weather: Geodesy has

- to deal with the ionosphere, since the measurements of most of the space-geodetic observation techniques are depending on the properties of the ionosphere along the ray path of an electro-magnetic wave between transmitter and receiver,
- to deal with the thermosphere, since the thermospheric drag is the most important deceleration effect on Low-Earth Orbiting (LEO) satellites below 1000 km and objects in the re-entry stage,
- a long history and large experience in developing and using sophisticated analysis techniques and modelling approaches.

To put the aforementioned issues in a nutshell, the **main objectives** of the FA GSWR are (1) the improvement of positioning and navigation (PPP), (2) the improvement of pre-
cise orbit determination (POD) and (3) the study of the coupled processes between magnetosphere, ionosphere and thermosphere (MIT).

Objective (1) aims at the high-precision and the high-resolution (spatial and temporal) modelling of the electron density. This allows to compute a signal propagation delay, which will be used in many geodetic applications, in particular in positioning, navigation and timing (PNT). Moreover, it is also important for other techniques using electromagnetic waves, such as satellite- or radio-communications. Concerning objective (2), satellite geodesy will obviously benefit when working on POD, but there are further technical matters like collision analysis or re-entry calculation, which will become more reliable when using high-precision and high-resolution thermospheric drag models. Objective (3) links the magnetosphere with the first two objectives by introducing physical laws and principles such as continuity, energy and momentum equations and solving partial differential equations.

For a long time geodesists looked at the atmosphere just as a disturbing factor whose impacts on electromagnetic signal propagation, i.e. the signal delay and the bending of the ray path, have to be corrected by applying atmospheric correction models of sufficient accuracy. On the other hand, as already mentioned before, the observation data of various geodetic measurement techniques that are influenced by the atmosphere in different ways provide valuable information on state and dynamics of the ionosphere. These are of great interest also for other disciplines such as meteorology. Today, for Geodetic Space Weather Research geodesy has to go another step forward by introducing physics. To be more specific, we have to take into account the complete chain of cause and effect. This means the research has (1) to start with processes and events on the Sun, (2) to be continued with the effects on the magnetosphere, the ionosphere, the thermosphere and their coupling processes down to the Earth’s surface and finally (3) to end by the consideration of the impact of space weather on (geodetic) applications and measurement systems.

Geodetic Space Weather Research is fundamental research, particularly when intending to detect and to survey structures of the ionosphere, e.g. bubbles, or when studying special phenomena like electro-jets. Summarizing, geodetic space weather research has to be based on (a) the use and combination of all space geodetic observation methods, (b) the use of Sun (solar) observations, (c) real-time modelling, (d) the development of deterministic and stochastic forecast approaches and (e) assimilation strategies.

### Planned activities of the FA GSWR

- extensive simulation studies which have to be performed in order to assess the impact of space weather on technical systems and to define – as a consequence – necessary actions in case of severe space weather events,
- the development of ionosphere and thermosphere models as stated above as GGOS products for direct application,
- the establishment of recommendations for applications of the models, e.g. in satellite orbit determination, collision analysis and re-entry computations,
- updates of the models as needed and based on the future improvements of modelling strategies, observing systems, etc., and
- the establishment of roadmaps for improving the models by including future satellite measurement systems and missions such as the Formosat-7/COSMIC-2 mission.

To arrive at the above described aims of the FA GSWR one new Joint Study Groups (JSG) and three Joint Working Groups (JWG) have to be installed. In detail, these groups are titled as

- **JSG 1**: Coupling processes between magnetosphere, thermosphere and ionosphere (implemented at IAG ICCT and joint with GGOS, Focus Area on Geodetic Space Weather Research and IAG Commission 4, Subcommission 4.3)
- **JWG 1**: Electron density modelling (joint with IAG Commission 4, Sub-commission 4.3)
- **JWG 2**: Improvement of thermospheric models (joint with IAG Commission 4, Sub-commission 4.3 and ICCC)
- **JWG 3**: Improved understanding of space weather events and their monitoring by satellite missions (joint with IAG Commission 4, Sub-commission 4.3);

For more details see the terms of Reference (ToR) and the descriptions of the JSG and the JWG presented below. There will be a strong connection and cooperation between the four groups. Since the first is covering the coupling processes, i.e. it has to be dealt with many physical problems, we will install it as JSG at the IAG ICCT.

Other implemented IAG Study Groups (SG) and Working Groups (WG) within the IAG programme will provide valuable input for the FA GSWR, in particular from the Commission 4, Sub-commission 4.3. Finally, it should be mentioned that the work within the FA GSWR will be carried out in close relation to the International Association of Geomagnetism and Aeronomy (IAGA), since this organisation is also concerned with the understanding of properties related, e.g. to the ionosphere and magnetosphere as well as the Sun and the solar wind. Partly, the work will be related to the International Association of Meteorology and Atmospheric Sciences (IAMAS), too.
Overview on one Joint Study Group (JSG) and three Joint Working Groups (JWG):

The running time of these groups is not restricted to the 4-year IAG-period from 2019 to 2023, but could last significantly longer.

JSG 1: Coupling processes between magnetosphere, thermosphere and ionosphere

Implemented at IAG ICCT; joint with GGOS, Focus Area on Geodetic Space Weather Research and Commission 4, Sub-Commission 4.3

Chair: Andres Calabia Aibar (China, andres@calabia.com)
Vice-Chair: vacant

Terms of Reference (ToR) / Description:

Consequences of upper-atmosphere conditions on human activity underscore the necessity to better understand and predict the effects of Magnetosphere-Ionosphere-Thermosphere (MIT) processes and coupling, and prevent from potential detrimental effects on orbiting, aerial, and ground-based technologies. For instance, major concerns include the perturbation of electromagnetic signals passing through the ionosphere for accurate and secure use of Global Navigation Systems (GNSS), and the lack of accurate aerodynamic-drag models required for accurate tracking, decay, and re-entry calculations of Low Earth Orbit (LEO) objects, including manned and unmanned artificial satellites. In addition, ground power grids and electronics of satellites could be influenced, e.g., by the magnetic field generated by sudden changes in the current system due to solar storms. Figure 1 illustrates the proposed new structure of the Focus Area on Geodetic Space Weather Research (FA GSWR) as a double tetrahedron.

Monitoring and predicting the Earth’s upper atmosphere processes driven by solar activity is highly relevant to science, industry and defence. These communities emphasize the need to increment the research efforts for better understanding of the MIT responses to highly variable solar conditions, as well as detrimental space weather effects on our life and society. On the one hand, the electron-density variation produces the perturbation in speed and direction of electromagnetic signals propagated through the ionosphere, and reflects as a time-delay in the arrival of the modulated components from which pseudo-range measurements of Global Navigation Satellite Systems are made, and an advance in the phases of the signal’s carrier waves which affects carrier-phase measurements. On the other hand, aerodynamic-drag associated with neutral-density fluctuations resulting from upper atmospheric expansion/contraction in response to variable solar and geomagnetic activity, increases drag and decelerates Low Earth Orbits, dwindling lifespan of space-assets, and making tracking difficult.

Through the interrelations, dependencies, and coupling patterns between ionosphere, thermosphere, and magnetosphere variability, the JSG 1 aims to improve the understanding of the coupled processes in the MIT system, and considerations of the solar contribution. In addition, tides from the lower atmosphere forcing can feed into the electrodynamics, and have a composition effect leading to changes in the MIT system. In this scheme, our tasks are addressed to exploit the knowledge of the tight MIT coupling by investigating multiple types of magnetosphere, ionosphere, and thermosphere observations. The final outcome will help to enhance the predictive capability of empirical and physics-based models through interrelations, dependencies, and coupled patterns of variability between the essential geodetic variables.

Objectives:

- Characterize and parameterize the global modes of MIT variations associated with diurnal, seasonal, and space weather drivers, as well as the lower atmosphere forcing.
- Determine and parameterize the mechanisms responsible for discrepancies between observables and the present models.
- Detect and investigate coupled processes in the MIT system for the deciphering of physical laws and principles such as continuity, energy and momentum equations and solving partial differential equations.

Members:

1. Piyush M. Metha (Department of Aerospace Engineering and Mechanics, University of Minnesota, USA, piyushmukeshmehta@gmail.com)
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4. Gang Lu (High Altitude Observatory, National Center for Atmospheric, ganglu@ucar.edu)
5. TBC
JWG 1: Electron density modelling

Joint with Commission 4, Sub-Commission 4.3

Chair: Fabricio dos Santos Prol (Germany) Fabricio.DosSantosProl@dlr.de
Vice-Chair: Alberto Garcia-Rigo (Spain) garciarigo@ieec.cat

Terms of Reference (ToR)/Description:

The main goal of this group is to disseminate and evaluate established methods of 3-D electron density estimation in terms of electron density, peak height, Total Electron Content (TEC), or other derived products that can be effectively used for GNSS positioning or for analyzing perturbed conditions due to representative space weather events. It is planned to generate products, showing the general error given by such 3-D electron density estimations and, also, distribute information regarding to space weather conditions. To achieve this main goal, the following objectives are defined.

Objectives:

- Develop a database, where the methods from the group members will be able to be evaluated in terms of GNSS, radio-occultation, DORIS, in-situ data, altimeters, among other electron density and TEC measurements.
- Evaluate established methods for 3-D electron density estimation in order to define their accuracy related to specific parameters of great importance for Space Weather and Geodesy.
- Generate products indicating the space weather conditions and expected errors of the methods.
- Carry out surveys in order to detect if the products are linked to the user’s specific needs. Based on an analysis of the user needs, re-adaptations will be identified in order to improve the products in an iterative process. It is planned to define which parameters are of interest for the users and to detect additional information that may be required.

Members:

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JWG 2: Improvement of thermosphere models

Joint with IAG Commission 4, Sub-Commission 4.3 and ICCC

Chair: Christian Siemes (The Netherlands) C.Siemes@tudelft.nl
Vice-Chair: Kristin Vielberg (Germany) vielberg@geod.uni-bonn.de

Terms of Reference (ToR) / Description:

Mass density, temperature, composition and winds are important state parameters of the thermosphere that affect drag and lift forces on satellites. Since these significantly influence the orbits of space objects flying at altitudes below 700 km, accurate knowledge of the state of the thermosphere is important for applications such as orbit prediction, collision avoidance, evolution of space debris, and mission lifetime predictions. Drag and lift forces can be inferred from space geodetic observations of accelerometers, which complement other positioning techniques such as GNSS, satellite laser ranging or radar tracking of space objects. The objective of the working group is to improve thermosphere models through providing relevant space geodetic observations.
and increasing consistency between datasets by advancing processing methods. Broadening the observational data basis with geodetic space observations, which are available now for a time span of 20 years, will also benefit climatological studies of the thermosphere.

**Objectives:**

- Review space geodetic observations and state-of-the-art processing methods
- Advance processing methods to increase consistency between observational datasets
- Improve thermosphere models through providing accurate and consistent space geodetic observations
- Study the impact of improved observational datasets and advanced processing methods on orbit determination and prediction
- Use of improved thermosphere models and observational data sets to forward the investigation of thermosphere variations in the context of climate change

**Members:**

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**JWG 3: Improved understanding of space weather events and their monitoring by satellite missions**

Joint with IAG Commission 4, Sub-Commission 4.3

Chair: Alberto Garcia-Rigo (Spain) garciarigo@ieec.cat
Vice-Chair: Benedikt Soja (USA) benedikt.s.soja@jpl.nasa.gov

**Terms of Reference (ToR) / Description:**

Space weather events cause ionospheric disturbances that can be detected and monitored thanks to estimates of the vertical total electron content (VTEC) and the electron density (Ne) of the ionosphere. Various space geodetic observation techniques, in particular GNSS, satellite altimetry, DORIS, radio occultations (RO) and VLBI are capable of determining such ionospheric key parameters. For the monitoring of space weather events, low latency data availability is of great importance, ideally real time, to enable triggering alerts. At present, however, only GNSS is suited for this task. The use of the other techniques is still limited due latencies of hours (altimetry) or even days (RO, DORIS, VLBI).

The JWG 3 will investigate different approaches to monitor space weather events using the data from different space geodetic techniques and, in particular, combinations thereof. Simulations will be beneficial to identify the contribution of different techniques and prepare for the analysis of real data. Different strategies for the combination of data will be investigated.

Furthermore, the geodetic measurements of the ionospheric parameters will be complemented by direct observations of the solar corona, where solar storms originate, as well as of the interplanetary medium. Spacecrafts like SOHO or ACE have monitored the solar corona and the solar wind for decades and will be beneficial, together with data from other spacecrafts like SDO, in assessing the performance of geodetic observations of space weather events. Data from Parker Solar Probe, which will allow even greater insights, has just recently been made publicly available.

Geodetic VLBI is also capable of measuring the electron density of the solar corona when observing targets angularly close to the Sun and will be useful for comparisons. Other solar-related satellite missions such as Stereo, DSCOVR, GOES, etc. provide valuable information such as solar radiation, particle precipitation and magnetic field variations. Other indications for solar activity - such as the F10.7 index on solar radio flux, SOLERA as EUV proxy or rate of Global Electron Content (dGEC), will also be investigated. The combination and joint evaluation of these data sets with the measurements of space geodetic observation techniques
is still a great challenge. Through these investigations, we will gain a better understanding of space weather events and their effect on Earth’s atmosphere and near-Earth environment.

**Objectives**

- Selection of a set of historical representative space weather events to be analysed.
- Determination of key parameters and products affected by the selected space weather events.
- Identification of the main parameters to improve real time determination and the prediction of ionospheric/plasmaspheric VTEC and Ne estimates as well as ionospheric perturbations in case of extreme solar weather conditions.
- Improving the (near) real time determination of the electron density within the ionosphere and plasmasphere to detect space weather events.
- Combination of measurements and estimates derived from space geodetic observation techniques by conducting extensive simulations, combining different data sets and testing different algorithms.
- Comparison and validation using external data, in particular data from spacecraft dedicated to monitoring the solar corona.
- Interpretation of the results. Correlate acquired data/products with space weather events’ impact on geodetic applications (e.g. GNSS positioning, EGNOS performance degradation).

**Members:**

TBD