Global Geodetic Observing System

http://www.ggos.org

Chair: Hansjörg Kutterer (Germany)
Vice Chair: Ruth Neilan (USA)

Introduction

As the observing system of the IAG, GGOS facilitates a unique and essential combination of roles centering upon advocacy, integration, and international relations. GGOS also promotes high-level outcomes, such as the realization of the International Terrestrial Reference Frame through developing and maintaining working relationships among a variety of internal and external groups and organizations.

GGOS Structure

The GGOS structure is illustrated in Figure 1, below. The decision-making entities are the Consortium, the Coordinating Board and the Executive Committee. Standing Committees, the thematic working bodies of GGOS, are distributed over two bureaus, the Science Panel and the Focus Areas as well as affiliated organizations. Communications and outreach, including the new unified GGOS website are managed by the Coordinating Office. Recent changes in GGOS organizational nomenclature were implemented at the advice of the IAG, specifically the former items called “Themes” have been renamed to “Focus Areas,” and similarly, the former “Working Groups” were re-titled to “Standard Committees” in 2016. In 2017 a new Focus Area “Geodetic Space Weather Research” was added.

Figure 1. Organization chart of GGOS, as of mid-2017.
Overview

The period from 2015-2017 was an active time of growth and organization within GGOS. A summary of these activities, by component, is below. A key element touching on all elements of this overview was the revision and update of the GGOS Terms of Reference (ToR) in 2015 to reflect developments and strategic direction since the original ToR publication in 2011.

Consortium

The GGOS Consortium functions as the large steering committee and collective voice of GGOS, and is comprised of two members from each IAG service, commission, and inter-commission committee. According to the GGOS ToR, the Consortium membership is reviewed and refreshed every four years, which took place coincident to the 2015 IUGG General Assembly. The current members of the GGOS Consortium as result of this nomination procedure are compiled in the following table. According to the ToR, only the GGOS Consortium is allowed to accept new members. Because of retirement and changes in the services the table must be revised in September 2017.

The presiding chair of GGOS is also the chair of the GGOS Consortium. As the GGOS Consortium is supposed to meet annually, the meetings took place at the GGOS Days 2015 (Frankfurt am Main, Germany), 2016 (Boston, Massachusetts, USA) and will take place September 2017 (Jeju, South Korea).

Table 1: Members of the GGOS Consortium, as of May 2017

<table>
<thead>
<tr>
<th>Services</th>
<th>Name</th>
<th>Title</th>
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<tbody>
<tr>
<td>GGOS</td>
<td>Hansjörg Kutterer</td>
<td>GGOS Chair</td>
</tr>
<tr>
<td>International Gravimetric Bureau (BGI)</td>
<td>Sylvain Bonvalot</td>
<td>Director</td>
</tr>
<tr>
<td>International Gravimetric Bureau (BGI)</td>
<td>Sean Bruinsma</td>
<td>Designated GGOS Representative</td>
</tr>
<tr>
<td>Bureau international des poids et mesures, BIPM</td>
<td>Felicitas Arias</td>
<td>Director BIPM Time Department</td>
</tr>
<tr>
<td>Bureau international des poids et mesures, BIPM</td>
<td>Gérard Petit</td>
<td>Principal Physicist BIPM Time Department</td>
</tr>
<tr>
<td>International Centre for Global Earth Models (ICGEM)</td>
<td>Franz Barthelmes</td>
<td>Director</td>
</tr>
<tr>
<td>International Doris Service (IDS)</td>
<td>Laurent Soudarin</td>
<td>Director</td>
</tr>
<tr>
<td>International Doris Service (IDS)</td>
<td>Pascal Willis</td>
<td>Chair</td>
</tr>
<tr>
<td>International Earth Rotation and Reference Systems Service (IERS)</td>
<td>Daniela Thaller</td>
<td>Director of the Central Bureau</td>
</tr>
<tr>
<td>International Geoid Service (IGeS)</td>
<td>Mirko Reguzzoni</td>
<td>President</td>
</tr>
<tr>
<td>International Geoid Service (IGeS)</td>
<td>Giovanna Sona</td>
<td>Director</td>
</tr>
<tr>
<td>International Geoid Service (IGeS)</td>
<td>Urs Marti</td>
<td>Designated GGOS Representative</td>
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<tr>
<td>International Geoid Service (IGeS)</td>
<td>Jianliang Huang</td>
<td>Designated GGOS Representative</td>
</tr>
<tr>
<td>International Gravity Field Service (IGFS)</td>
<td>Riccardo Barzaghi</td>
<td>Chair</td>
</tr>
<tr>
<td>International Gravity Field Service (IGFS)</td>
<td>Steve Kenyon</td>
<td>Director of the Central Bureau</td>
</tr>
<tr>
<td>International GNSS Service (IGS)</td>
<td>Ruth Neilan</td>
<td>Director</td>
</tr>
<tr>
<td>International GNSS Service (IGS)</td>
<td>Gary Johnston</td>
<td>Chair</td>
</tr>
</tbody>
</table>
After finalizing the composition of the GGOS Consortium the members of the GGOS Coordinating Board (CB) were elected, also on a four-year cycle. The GGOS CB acts as the decision-making body of GGOS. The present members of the GGOS CB are indicated in the following table.

A new Focus Area in “Geodetic Space Weather Research” was added in 2017. The GGOS CB meets twice a year on the occasion of the EGU meeting in Vienna and the GGOS Days at several locations, Frankfurt 2015 and Cambridge/Boston 2016 as well as Jeju 2017 in September.
<table>
<thead>
<tr>
<th>Role</th>
<th>Voting Status</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service representative</td>
<td>voting</td>
<td>Riccardo Barzaghi</td>
</tr>
<tr>
<td>Service representative</td>
<td>voting</td>
<td>Ruth Neilan</td>
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<tr>
<td>Service representative</td>
<td>voting</td>
<td>Christoph Foerste</td>
</tr>
<tr>
<td>Service representative</td>
<td>voting</td>
<td>Urs Marti</td>
</tr>
<tr>
<td>IAG Commissions Representative</td>
<td>voting</td>
<td>Pavel Novák</td>
</tr>
<tr>
<td>IAG Commissions Representative</td>
<td>voting</td>
<td>Roland Pail</td>
</tr>
<tr>
<td>Member-at-Large</td>
<td>voting</td>
<td>Ludwig Combrinck</td>
</tr>
<tr>
<td>Member-at-Large</td>
<td>voting</td>
<td>Luiz Poulo Souto Fortes</td>
</tr>
<tr>
<td>Member-at-Large</td>
<td>voting</td>
<td>Gary Johnston</td>
</tr>
<tr>
<td>Chair of GGOS Standard Committee on Satellite and Space Missions (SI)</td>
<td>non-voting</td>
<td>Roland Pail</td>
</tr>
<tr>
<td>Chair of GGOS Standard Committee on Data and Information Systems (DM)</td>
<td>non-voting</td>
<td>Guenter Stangl</td>
</tr>
<tr>
<td>Chair of GGOS Standard Committee on Contribution to Earth System Modelling (EM)</td>
<td>non-voting</td>
<td>Maik Thomas</td>
</tr>
<tr>
<td>Chair of GGOS Standard Committee on Performance Simulations and Architectural Trade-Offs (PLATO), a Joint Working Group with IAG Sub-Commission 1.2</td>
<td>non-voting</td>
<td>Daniela Thaller</td>
</tr>
<tr>
<td>Chair of GGOS Standard Committee on ITRS Standards</td>
<td>non-voting</td>
<td>Claude Boucher</td>
</tr>
<tr>
<td>Chair of Joint Working Group: &quot;Establishment of the Global Geodetic Reference Frame (GGRF)&quot;</td>
<td>non-voting</td>
<td>Urs Marti</td>
</tr>
<tr>
<td>Lead of Focus Area Unified Height System [UH]</td>
<td>non-voting</td>
<td>Laura Sanchez</td>
</tr>
<tr>
<td>Lead of Focus Area Natural Hazards [NH]</td>
<td>non-voting</td>
<td>John LaBrecque</td>
</tr>
<tr>
<td>Lead of Focus Area Understanding and Forecasting Sea-Level Rise and Variability [SL]</td>
<td>non-voting</td>
<td>Tilo Schöne</td>
</tr>
<tr>
<td>Lead of Focus Area Geodetic Space Weather Research</td>
<td>non-voting</td>
<td>Michael Schmidt</td>
</tr>
<tr>
<td>GGOS Portal Manager</td>
<td>non-voting</td>
<td>Guenter Stangl</td>
</tr>
<tr>
<td>Immediate Past Chair of the CB</td>
<td>non-voting</td>
<td>---</td>
</tr>
<tr>
<td>Representative of the GIAC/GIC*</td>
<td>non-voting</td>
<td>Per Erik Opseth</td>
</tr>
</tbody>
</table>

*Please note that GIAC was terminated end of 2016, so all references to GIAC or GIC are purely for historical purposes.

**Executive Committee**

Based on the members of the GGOS CB the members of the GGOS Executive Committee (EC) were nominated by the GGOS chair and approved by the GGOS CB. The present members of the GGOS EC are compiled in the following list. The role of the GGOS EC is to serve at the direction of the CB to accomplish day-to-day activities of GGOS tasks. The GGOS EC has had regular telecons on an approximately monthly basis since July 2011, continuing the sequence of telecons under the previous structure.

<table>
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<th>Name</th>
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<tr>
<td>Hansjörg Kutterer</td>
<td>GGOS Chair</td>
</tr>
<tr>
<td>Ruth Neilan</td>
<td>GGOS Vice-Chair</td>
</tr>
<tr>
<td>Guenter Stangl</td>
<td>Director of Coordinating Office</td>
</tr>
<tr>
<td>Michael Pearlman</td>
<td>Director of Bureau of Networks and Communication</td>
</tr>
</tbody>
</table>
Leadership of the GGOS Coordinating Office transitioned from Giuseppe Bianco of Agenzia Spaziale Italiana (Italian Space Agency, ASI), Italy, to Allison Craddock of Bundesamt für Kartographie und Geodäsie (Federal Agency for Cartography and Geodesy, BKG), Germany, in 2015. In 2016, Günter Stangl of Bundesamt für Eich- und Vermessungswesen, (Federal Agency for Metrology and Surveying, BEV), Austria assumed the role and oversaw the complete transition of the CO to BEV. An overview of the main contacts is shown in the figure below.

A regular presence at the major conferences of geosciences, AGU and EGU, as well as GEO, was established. There was also a presence with presentations, posters and exhibition at the IUGG 2015, and will be at IAG/IASPEI in July 2017. Starting in May 2017, a GGOS page will be included in the IAG newsletter at least once a year.

The website http://www.ggos.org was shifted in May 2017 from ASI to BEV. The new GGOS website will be built from scratch, while maintaining key items and historical resources. This was agreed upon in August 2016 between the former GGOS CO director and the new one. The webpages are checked and renewed, partially by the different GGOS components, and partially by the GGOS CO. The next steps planned are to add online access to GGOS metadata as well as links to observations and products. The GGOS social media presence was initiated, with a twitter account @IAG_GGOS.

Figure 2. Organizational chart of GGOS external relations.
GGOS Science Panel

Chair: R. Gross (USA)

Members:
- G. Blewitt (USA)
- J. Bogusz (Poland)
- R. Gross (USA)
- T. Gruber (Germany)
- B. Heck (Germany)
- K. Heki (Japan)
- J. LaBrecque (USA)
- U. Marti (Switzerland)
- M. Merrifield (USA)
- M. Rothacher (Switzerland)
- Z.-K. Shen (China)
- J. Wickert (Germany)
- P. Wielgosz (Poland)

Purpose and Scope

The GGOS Science Panel is a multi-disciplinary group of experts representing the geodetic and relevant geophysical communities that provides scientific advice to GGOS in order to help focus and prioritize its scientific goals. The Chair of the Science Panel is a member of the Coordinating Board and a permanent guest at meetings of the Executive Committee. This close working relationship between the Science Panel and the governance entities of GGOS ensures that the scientific expertise and advice required by GGOS is readily available.

Activities and Actions

The objectives and tasks of the GGOS Science Panel are given in its 2017-2018 Implementation Plan. The Science Panel provides support to GGOS. During 2015-2017, this support included participation in Consortium, Coordinating Board, and Executive Committee meetings and conference calls. The Science Panel has been actively promoting the goals of GGOS by helping to organize GGOS sessions at major scientific conferences. During 2015-2017, GGOS sessions have been organized at:

- 2015 Asia Oceania Geosciences Society Annual Meeting in Singapore
- 2015 European Geosciences Union General Assembly in Vienna
- 2016 European Geosciences Union General Assembly in Vienna
- 2017 European Geosciences Union General Assembly in Vienna
- 2015 American Geophysical Union Fall Meeting in San Francisco
- 2016 American Geophysical Union Fall Meeting in San Francisco
- 2017 Japan Geophysical Union – American Geophysical Union Joint Meeting in Chiba, Japan

In addition to helping organize sessions at scientific conferences, the GGOS Science Panel also organizes topical science workshops in order to foster discussion about the geodetic observations and infrastructure required by different scientific disciplines. One such workshop was organized during 2015-2017:
The rotation of the Earth varies continuously, in both its rate of rotation and in the orientation of its axis with respect to either crust-fixed or space-fixed reference frames. Its study links together the fields of Geodesy, Astronomy and Geophysics. In this Symposium, over 50 participants from Asia, Europe, and the Americas met in Wuhan, China to assess our current ability to observe the Earth’s time varying rotation, to assess our current understanding of the causes of the observed variations, to assess the consistency of Earth rotation observations with global gravity and shape observations, to explore methods of combining Earth rotation, gravity, and shape observations, and to identify improvements in the global geodetic observing system needed to further our understanding of the Earth’s variable rotation. Peer-reviewed proceedings of the Symposium will be published as a special issue of *Geodesy and Geodynamics*.

**Objectives and Planned Efforts for 2017-2019 and Beyond**

During 2017-2019 the Science Panel will continue to participate in Consortium, Coordinating Board, and Executive Committee meetings and conference calls. In addition, the Science Panel will continue to help organize GGOS sessions at conferences and symposia including:

- American Geophysical Union Fall Meetings
- Asia Oceania Geosciences Society Annual Meetings
- European Geosciences Union General Assemblies
- International Association of Geodesy General and Scientific Assemblies

The Science Panel will also continue to organize topical science workshops in order to determine the requirements that different scientific disciplines have for geodetic data and products.

With the GGOS Bureau of Products and Standards, the Science Panel will help conduct a Gap Analysis to identify the gap between the data and products provided by the IAG and the needs of the user community. As part of this analysis, a list of Essential Geodetic Variables (EGVs) will be compiled along with observational requirements on those variables. This list of EGVs and their observational requirements can then be used to determine requirements on derived products like the terrestrial reference frame. This activity is part of the Science Panel’s contribution to updating the GGOS2020 book.
GGOS Bureau of Networks and Observations

Director: Mike Pearlman (USA)

Prepared by: Michael Pearlman, Carey Noll, Erricos C. Pavlis, Chopo Ma, Ruth Neilan, Frank Lemoine, Daniela Thaller, Guenter Stangl, Jürgen Müller, and Sten Bergstrand

Membership

Standing Committees affiliated with this Bureau:
- GGOS Standing Committee on Satellite Missions
- GGOS Standing Committee on Data and Information Systems
- GGOS Standing Committee on Performance Simulations and Architectural Trade-Offs (PLATO)
- IERS Working Group on Survey and Co-location

Associated Members and Representatives:
- Director (Mike Pearlman/CfA USA)
- Secretary (Carey Noll/NASA USA)
- Analysis Specialist (Erricos Pavlis/UMBC USA)
- IERS Representative (Sten Bergstrand/SP Sweden)
- A representative from each of the member Services:
  - IGS (Ruth Neilan/JPL USA, Steve Fisher/JPL USA)
  - ILRS (Giuseppe Bianco/ASI Italy, Wu Bin/SHAO China)
  - IDS (Jérôme Saunier/IGN France, Pascale Ferrage/CNES France)
  - IVS (Hayo Hase/BKG Germany, Chopo Ma/NASA USA)
  - IGFS (Riccardo Barzaghi/PM Italy, George Vergos/UT Greece)
  - PSMSL (Lesley Rickards/BODC UK, Tilo Schone/GFZ Germany)
- A representative from each of the member Standing Committees:
  - PLATO (Daniela Thaller/BKG Germany, Benjamin Maennel/GFZ Germany)
  - Data and Information (Günter Stangl/OEAW Austria, Carey Noll/NASA USA)
  - Satellite Missions (Jürgen Müller/IfE Germany, Roland Pail/TUM Germany)
  - IERS Working Group on Survey Ties and Co-location (Sten Bergstrand/SP Sweden, John Dawson/GA Australia)

Activities, Actions, and Publications during 2015-2017

The Bureau

- Continued to provide a forum for the Services and Standing Committees/Working Groups to share and discuss plans, progress, and issues, and to develop and monitor multi-entity efforts to address GGOS requirements; meetings are held in conjunction with AGU and EGU each year; material from the meetings are posted on the GGOS website (http://www.ggos.org/Components/BNC/BNChome.html).
- Continued the Bureau’s “Call for Participation in the Global Geodetic Core Network: Foundation for Monitoring the Earth System” and work with new potential groups interested in participating; a total of 19 submissions have been received covering 114 sites that included legacy core sites, legacy/new technology co-location sites, core and co-location sites under development, and sites offered for future participation; a summary of the CfP responses is available on the Bureau’s website: (http://192.106.234.28/Components/BNC/update%20Apr2013/GGOS_CfPResponseSummaries_20150106.pdf). A number of other new stations will join once they are operational.
Continued to advocate for new and increased network participation, encouraging formation of new partnerships to develop new sites, monitored the status of the networks; held meetings and communications with representatives from Russia, Italy, Brazil, Japan, Spain, France, and Saudi Arabia to discuss implementation of new stations and upgrade of legacy stations.

Supported efforts for the integration of various ground observation networks within the GGOS affiliated Network; continued to maintain and update the “Site Requirements for GGOS Core Sites” document (with the IAG Services); the next major step will be to include the requirements for the gravity field once it is fully documented by the IGFS and the IGRF working group; Work with the IGFS in the definition of its requirements.

Continued to promote and advocate for GGOS and the GGOS integrated global geodetic ground-based infrastructure through talks and posters at AGU, EGU, AOGS, APSG (China), JpGU-AGU, IAG, etc. and meetings and special presentations at GSI (Japan), IMPE (Brazil), IAP (Russia) etc.; supported efforts to integrate relevant parameters from other ground networks (gravity field, tide gauges, etc.) into the GGOS network to support GGOS requirements.

Continued to maintain and update the inventory/repository of current and near-future satellite missions, highlighting those of most interest to GGOS; The current version should be online in mid-2017; continued advocating for new advocating new missions; wrote letters of support for the E-GRASP/Eratosthenes proposals; Need to stress greater cooperation between the PLATO and Missions Standing Committees. More details are provided in the Missions Standing Committee section below.

Provided simulations and analyses to estimate how the data products will improve over time as the infrastructure improves. The next survey of current and projected network station capabilities will be undertaken in the second half of 2017. The results from the survey will be used to project network data quality capability 5 and 10 years ahead. Simulations on the e-GRASP/Eratosthenes mission and other co-location missions to strengthen the case for support and for network planning. More detail is provided in the Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO) section below.

Continued development and implementation of a GGOS metadata system in two stages: a stage-one scheme (hosted by CDDIS) for GGOS and GGOS-relevant data products planned for demonstration by the end of 2017, and a longer term, stage-two implementation, for the full GGOS requirements including site and instrument information, based on an XML metadata scheme under development by the Geoscience Australia, UNAVCO, and the IAG. Additional details are provided in the Data and Information Standing Committee section below.

Continued working on the establishment of a common terminology for all space geodesy techniques, a terminology that is also valid outside the space geodetic community; the DORIS community has adapted a common terminology, and improved its surveying procedures as well as communication of the results. The IGS terminology has done the same, but there are differences among the techniques; continued working on outreach to increase local survey participation and standardization. More details are provided in the IERS Working Group on Survey Ties and Co-Location section below.

**Related Bureau Documentation**

As part of the network activity, the Bureau has facilitated the creation of several key documents:

- “GGOS Site Requirements for Fundamental Stations” document:
  

A plan to define the process by which GGOS determines the extent of the needed infrastructure, including the scope and specification of the network, conditioned on the existing or plausible technology available, “GGOS Infrastructure Implementation Plan”: http://192.106.234.28/Components/BNC/GGOS_Infrastructure_Plan_V3_130321.pdf

A plan to assess the current and future plans for a GGOS core network, including projections five to ten years in the future, “Space Geodesy Network Model”: http://192.106.234.28/Components/BNC/candidatesites_130122.pdf

Documents developed within the context of NASA’s Space Geodesy Project, evaluating several sites as potential core sites; these documents are available from the SGP website at: http://space-geodesy.gsfc.nasa.gov/publications/papers.html

A summary report issued from the TLS (Terrestrial Laser Scanner) Workshop that was held at NASA GSFC, September 08-10, 2008: http://192.106.234.28/Components/BNC/Summary%20report%20from%20the%20TLS%20(Terrestrial%20Laser%20Scanner).pdf

Websites

http://www.ggos.org/Components/BNC/BNChome.html

Publications and Presentations


GGOS Standing Committee on Satellite Missions

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

Members

Besides Chair and Co-Chair, CSM has quite an open team of members, associate members and guests to work on the various CSM tasks and to provide material for the website, presentation material, and other documentation. CSM has 1 or 2 meetings per year. The main work, however, is done via email exchange.

Purpose and Scope

The Committee on Satellite Missions (CSM), formerly GGOS Satellite Mission Working Group, was established in December 2008, under the lead of C.K. Shum. In December 2010, Isabelle Panet was appointed as new Chair, in December 2013 Roland Pail took over the role of the CSM Chair, followed by Jürgen Müller in December 2015.

The purpose and scope of CSM is the information exchange 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. New space missions shall be advocated and supported, if appropriate.

CSM has been set-up as an international panel of experts, with consultants of national and international space agencies.

Satellite missions are a prerequisite for realizing a global reference for any kind of Earth observation. They are the key for monitoring change processes in the Earth system on a global scale with high temporal and spatial resolution. Therefore, beyond purely scientific objectives they meet a number of societal challenges, and they are an integral part of the GGOS infrastructure and essential to realize the GGOS goals. The role of CSM is to monitor the availability of satellite infrastructure, to propose and to advocate new missions or mission concepts, especially in case that a gap in the infrastructure is.

Activities and Actions

- New chair (Jürgen Müller) took over in December 2015.
- In 2016, the number of active committee members has been revised.
- An inventory of the GGOS satellite infrastructure has been collected, including some missions that only touch the GGOS needs. The list will be refined and updated in the 2017/2018 timeframe.
- A preliminary list of satellite contributions to fulfill the GGOS 2020 goals has been prepared. The list will be refined and updated in the 2017/2018 timeframe.
- In 2015 chaired by CSM (Roland Pail), the "Science and user requirements document for future gravity field missions" has been finalized and published, see www.dgk.badw.de/fileadmin/docs/b-320.pdf
- In 2016, CSM has contributed to ESA’s Earth Explorer 9 call by providing support letters (from GGOS chair) and by actively acting in the proposers’ teams (individual CSM members) of the two planned geodetic missions
  - E-GRASP/Eratosthenes (co-location of geodetic transmitters in space)
  - E.motion2 (gravity field mission)
Close cooperation exists with the Bureau of Standards and Products, and the Sub-Commissions 2.3 and 2.6 of IAG. Additionally, there are strong interfaces to national and international space agencies.

Objectives and Planned Efforts for 2015-2017 and Beyond

1. Contribute to a CSM section on the GGOS website. A new website is available since early 2017. Here, close exchange with the GGOS Communication Office is planned.
2. Revise and maintain the inventory/repository of current and near-future satellite missions. A reduced list with the most important missions has been prepared in spring 2017 and is revised now by the CSM members. It shall continuously be extended and updated.
3. Evaluate and refine contributions of current and near-future missions to the GGOS 2020 goals. A revised version with the most important contents has been prepared in spring 2017 and is revised now by the CSM members. It shall continuously be extended and updated.
5. Interface with other GGOS components to identify critical gaps in the satellite infrastructure and advocating new missions. Here, regular exchange is planned with PLATO, e.g., to stimulate dedicated simulations to better understand and overcome shortcomings with respect to the GGOS 2020 goals.
7. Support the Executive Committee and the Science Committee in the GGOS Interface with space agencies.

Most of the CSM tasks are ongoing activities. 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.

Website


Publications and Presentations

GGOS Standing Committee on Data and Information Systems

Chair: Guenter Stangl (Austria)  
Co-Chair: Carey Noll (USA)

Purpose and Scope

Develop a metadata strategy for all ground-based measurement techniques and data products that provides discoverability and interoperability, is easily transferable via web services, and is based on internationally recognized data exchange methods; the plan is to implement a metadata scheme in two stages: a stage-one scheme for GGOS and GGOS relevant data products and a longer term, stage-two scheme for the full GGOS requirements.

The current focus of the WG is on developing standards for metadata that can be utilized by the space geodesy community. Metadata typically encompass critical information about the measurements that are required to turn these measurements into usable scientific data. Metadata also includes information that supports data management and provides a foundation for data discovery. Data centers extract metadata from incoming data sources and also augment that metadata with information from other sources. It is typical for data centers to store the metadata in databases in order to manage the data in their archives and to distribute both data and metadata to data users. Metadata can further be utilized by data discovery applications to allow users to find datasets of interest. In order to be effective, metadata need to be simple to generate and maintain. They must be consistent and informative for the archivist and the user.

GGOS is seeking a metadata schema that can be used by all of its elements for standardized metadata communication, archiving, and retrieval. First applications would be automated distribution of up-to-date stations configuration and operational information, data archives and catalogues, and procedures and central bureau communication. Several schemas that show promise have been under development by SOPAC (Scripps), GML (Australia/NZ), etc. The intent is that data need be entered only from an initial source (a station, a Data Center, an Operations Center, data products, etc.) and would then flow to and be integrated into those metadata files where users would have access. The plan is to organize a meeting, probably in early August at UNAVCO in Boulder, for representatives from the Services, the Data Centers, the Science Community, etc. to give each of the schema developers an opportunity to preach his wears and allow discussion on the pros and cons of each.

The objective is to try to come to closure on a schema that we could as a community adopt for general implementation. Groups would not be obligated to a rapid implementation schedule, but would commit to the agreed schema when they are ready to begin the process.

Activities and Actions

- CDDIS continues to construct collection-level metadata records for implementation in NASA EOSDIS (CMR)
- IGS continues development of Site Log XML metadata (lead: Fran Boler/UNAVCO)
  - Geosciences Australia (GA) has released GeodesyML
  - Implements an application schema for the Site Log XML metadata
  - Several IGS data centers and groups have worked with this schema and are implementing/refining
  - Use Cases are slowly being assembled
  - Software tools for text site log to XML site log conversion are being developed and will be available to all
Objectives and Planned Efforts for 2015-2017 and Beyond

- Adopt and implement a metadata system to provide access to GGOS relevant data products (December 30, 2017)
  - Define the data product requirements for the GGOS relevant metadata (February 15, 2017)
  - Present concept and plan for implementation (EGU 2017 and/or the GGOS CB meeting in April 2017)
  - Status report (IAG Assembly or other venue in July 2017)
  - Prototype of Phase 1 implementation (GGOS Days in October 2017)
  - Implementation of the operational data product metadata scheme (December 31, 2017)

- Adopt and implement a full metadata system including site information and relevant tools and capability (e.g., the Australian GL scheme)
  - Definition of the requirements; definition of Phase 1 (March 1, 2018)
  - Resolve issues and applicability of the Australian GL scheme and recommend schema (EGU 2018)
  - Metadata implementation plan including definition of tasks, roles, and distribution of tasks, and plans for integration of components (June 2018)
  - Demonstration of Phase 1 prototype (GGOS Days, 2018)
  - Demonstration of Phase 1 first operational system (June 2019)
GGOS Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO)
(Joint WG with IAG Commission 1)

Chair: Daniela Thaller (Germany)
Vice-Chair: Benjamin Männel (Germany)

Contributing Institutions (in alphabetical order):
- AIUB, Switzerland
- BKG, Germany
- CNES/IGN, France
- DGFI-TU Munich, Germany
- ETH Zürich, Switzerland
- GFZ/TU Berlin, Germany
- IfE University Hannover, Germany
- JPL, USA
- NASA GSFC/JCET, USA
- NMA, Norway
- TU Vienna, Austria

Purpose and Scope

- Develop optimal methods of deploying next generation stations, and estimate the dependence of reference frame products on ground station architectures
- Estimate improvement in the reference frame products as co-located and core stations are added to the network
- Estimate the dependence of the reference frame products on the quality and number of the site ties and the space ties
- Estimate the improvement in the reference frame products as other satellites are added, e.g., cannonball satellites, LEO, GNSS constellations
- Estimate the improvement in the reference frame products as co-locations in space are added, e.g., use co-locations on GNSS and LEO satellites, add special co-location satellites (GRASP, E-GRASP/Eratosthenes, NanoX, etc.)

Achievements over the past two years:

- Several projects related to simulation studies became funded (DGFI-TUM, AIUB, TU Vienna, GFZ)
- Simulations for the planned E-GRASP/Eratosthenes mission were carried out by several institutions; E-GRASP/Eratosthenes is a proposal for an ESA Earth-Explorer-9 Mission, with the science team led by Richard Biancale (CNES)
- Several geodetic software packages have been augmented by the capability to carry out realistic simulation scenarios (VieVS, DOGS, Bernese, Geodyn)
- Simulations for improved global SLR station network were carried out
- Simulations for an SLR station in Antarctica (Syowa, co-located with VLBI) were carried out, showing the benefit for geocenter
- The impact of the local ties (LT) on the reference frame products were studied regarding different stochastic models of the LT, selection of the LT, and the impact of systematically wrong LT. It was shown that the LT standard deviations of 1 mm or better lead to the best
datum realization of an SLR+VLBI-TRF. Simulating wrong LT indicate Wettzell, Badary and AGGO as important LT sites in the SLR and VLBI combination.

- Starting simulations for improved SLR tracking of GNSS satellites
- Simulations (and analysis of data as far as available) for new VGOS telescopes by using next generation broadband VLBI technology, showed that the GGOS requirements of 1 mm accuracy and 0.1 mm/year stability will likely be fulfilled for the reference frame.
- Simulations and analysis of VLBI tracking data of GNSS satellites and the Chinese APOD cube-satellite (i.e., using co-locations in space) were carried out using the Australian VLBI antennas for several sessions during 2016.
- Simulations related to more LLR data assuming millimeter ranging accuracies (up to three future single-prism reflectors on the moon and two additional LLR sites on the southern hemisphere) were carried out. The effect on the lunar reflector coordinates, the mass of the Earth-Moon system and two relativistic parameters (temporal variation of the gravitational constant and equivalence principle) was studied. Especially, the measurements to the new type of reflectors would lead to an improved accuracy of the estimated parameters up to a factor of 6 over a decade of new measurements.

Objectives and Planned Efforts for 2017-2019 and Beyond

- Examine trade-off options for station deployment and closure, technology upgrades, impact of site ties, etc. (December 31, 2017)
- Simulation studies “ground” to assess impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties (December 31, 2017)
- Simulation studies “space” to assess impact on reference frame products of: co-location in space, space ties, available satellites (October 31, 2018)
- Project future network capability over the next 5 and 10 year periods using projected network configuration in new system implementation; (February 28, 2018)
- Develop improved analysis methods for reference frame products by including all existing data and available co-locations (October 31, 2018)
- Analysis campaign with exchanged simulated observations (December 31, 2018)
- Status reports will be given at IAG Scientific Assembly (July 2017), GGOS days (October 2017) and REFAG Meeting (autumn 2018)
- Annual meetings are foreseen in conjunction with EGU General Assembly

Publications:

IERS Working Group on Site Survey and Co-location

*Chair:* Sten Bergstrand (Sweden)
*Co-Chair:* John Dawson (Australia)

**Members:**

**Purpose and Scope**

The working group was established in 2004 as part of the IERS to homogenize local surveying activities at different space geodetic sites. In 2014, it was agreed that the working group would also act for GGOS under the IERS name. The overall goal is to provide a base necessary for rigorous terrestrial reference frame realizations, and to highlight the presence of technique- and/or site-specific biases. The main effort aspires to provide the means of an uncertainty assessment that can be included in the next ITRF.

**Activities and Actions**

- Recent work has first been to establish a general and common terminology to all techniques, which is also valid outside the space geodetic community, and to fulfill the local tie requirements set out in the GGOS book. The DORIS community has adapted the common terminology, and improved its surveying procedure as well as communication of results.
- IGS terminology has been adapted without alterations; the concepts are there, but the technique specific terminologies vary. The main focus of the IGS component has been a reassessment of existing sites rather than surveying as such.
- The ILRS maintains a list of current and historical sites. A combined effort from several institutes involved a common application to the European EMPIR program. The application fulfilled the acceptance criteria, but was not granted funding due to limited resources.
- The VLBI terminology concerning site surveys has been consolidated, and an automated terrestrial monitoring system for telescopes called Heimdall has been developed, as well as a complete model for telescope deformation.
- A campaign to examine the short-term combination of VLBI, GNSS and automated terrestrial monitoring at two baseline ends has been performed, with some processing left to be finished.

**Objectives and Planned Efforts for 2017-2019 and Beyond**

- Assess the ground truth uncertainty of different techniques to include in the next ITRF;
- Evaluate the VLBI-GNSS-terrestrial campaign of the Onsala-Metsähovi baseline; additionally, more sites should be surveyed. However, this is an activity that the respective station managers need to allocate funding for. The working group does not have the means to do this, and would appreciate any help to create a pull in this direction.

**Website**
GGOS Bureau of Products and Standards

Director: Detlef Angermann (Germany)
Vice Director: Thomas Gruber (Germany)

Members
- Michael Gerstl (Germany)
- Robert Heinkelmann (Germany)
- Urs Hugentobler (Germany)
- Laura Sánchez (Germany)
- Peter Steigenberger (Germany)

GGOS entities associated to the BPS:
- Committee Contributions to Earth System Modelling, Chair: Maik Thomas (Germany)
- WG1 ITRS Standards for ISO TC211, Chair: Claude Boucher (France)
- WG2 Establishment of the Global Geodetic Reference Frame (GGRF), Chair: Urs Marti (Switzerland)

Associated members of the BPS:
The IAG Services and other relevant entities involved in the definition and maintenance of standards and conventions designated their representatives as associated member of the BPS to support the BPS business and to ensure the interaction between the different components.

<table>
<thead>
<tr>
<th>Position (IAG Service, ...)</th>
<th>Representatives</th>
<th>Entity Contributing</th>
</tr>
</thead>
<tbody>
<tr>
<td>IERS Conventions Center</td>
<td>Gérard Petit (2010-2016)</td>
<td>BIPM (France)</td>
</tr>
<tr>
<td></td>
<td>Nick Stamatakis (since 2017)</td>
<td>USNO (USA)</td>
</tr>
<tr>
<td>IERS Analysis Coordinator</td>
<td>Thomas Herring</td>
<td>MIT (USA)</td>
</tr>
<tr>
<td>IGS Representative</td>
<td>Urs Hugentobler (BPS staff)</td>
<td>TUM (Germany)</td>
</tr>
<tr>
<td>ILRS Analysis Coordinator</td>
<td>Erricos Pavlis</td>
<td>UMBC/NASA (USA)</td>
</tr>
<tr>
<td>IVS Analysis Coordinator</td>
<td>John Gipson</td>
<td>GSFC/NASA (USA)</td>
</tr>
<tr>
<td>IDS Representatives</td>
<td>Frank Lemoine, John Ries, Jean-M. Lemoine, Hugues Capdeville</td>
<td>GSFC/CSR (USA)</td>
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<tr>
<td>IGFS Chair</td>
<td>Riccardo Barzaghi</td>
<td>CNES/GRGS (France)</td>
</tr>
<tr>
<td>BGI Chair</td>
<td>Sylvain Bonvalot</td>
<td>Politec. Milano (Italy)</td>
</tr>
<tr>
<td>ISG President</td>
<td>Mirko Reguzzoni</td>
<td>IRD (France)</td>
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<tr>
<td>ICGEM Chair</td>
<td>Franz Barthelmes</td>
<td>Politec. Milano (Italy)</td>
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<tr>
<td>IDEMS Director</td>
<td>Kevin M. Kelly</td>
<td>GFZ (Germany)</td>
</tr>
<tr>
<td>IGETS Chair</td>
<td>Hartmut Wziontek</td>
<td>ESRI (USA)</td>
</tr>
<tr>
<td>Gravity Comm. (Corresp. Member)</td>
<td>Jürgen Kusche</td>
<td>Uni. Bonn (Germany)</td>
</tr>
<tr>
<td>IAG Representative to ISO</td>
<td>Johannes Ihde (2010-2016)</td>
<td>BKG (Germany)</td>
</tr>
<tr>
<td>IAG Comm. and Outreach</td>
<td>Josef Ádám</td>
<td>Uni. Budapest (Hungary)</td>
</tr>
<tr>
<td>IAU Representative</td>
<td>Robert Heinkelmann (BPS staff)</td>
<td>GFZ (Germany)</td>
</tr>
<tr>
<td>Control Body for ISO Geodetic Registry</td>
<td>Mike Craymer (Chair)</td>
<td>NRCan (Canada)</td>
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<tr>
<td></td>
<td>Larry Hothem (Vice Chair)</td>
<td>USA</td>
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</tbody>
</table>
Overview

The Bureau of Products and Standards (BPS) is a key component of IAG’s Global Geodetic Observing System (GGOS). It supports IAG in its goal to obtain consistent products describing the geometry, rotation and gravity field of the Earth, along with its temporal variations. The BPS is built upon existing observing and processing systems of IAG.

Mission and overall objectives of the BPS:

- to serve as contact and coordinating point for the homogenization of IAG/GGOS standards and products;
- to keep track of the adopted geodetic standards and conventions across all IAG components, and initiate steps to close gaps and deficiencies;
- to focus on the integration of geometric and gravimetric parameters and to develop new products needed for Earth sciences and society.

Figure 3. The integration of the three pillars of geodesy: geometry, Earth rotation and gravity field requires consistent standards to obtain consistent geodetic products as the basis for Earth system research and for precisely quantifying global change phenomena.

Activities during the period 2015-2017

During the period 2015-2017 the BPS performed the following activities:
- Internal BPS meetings of the staff members were held every two months to coordinate and manage the Bureau business.
- Evaluation of constants, standards and conventions used across the IAG components.
- Focus on relevant IAG products: CRS/CRF, TRS/TRF, EOP, GNSS orbits, gravity field and geoid, vertical reference system.
- Assessment of the present status, identification of deficiencies, recommendations to resolve inconsistencies and to close gaps (interaction with IAG Services).
- Contributions to the Global Geodetic Reference Frame (GGRF) activities:
  a) BPS was involved in the writing of the IAG position paper “Description of the Global Geodetic Reference Frame (GGRF)”, adopted by the IAG Executive Committee in 2016;
  b) IAG representation to the UN-GGIM GGRF Working Group for the Key Area “Data Sharing and Development of Geodetic Standards” (since 2017).
• Contribution to the definition and adoption of a new IAG conventional \( W_0 \) value (IAG resolution No. 1, 2015).
• The BPS acted as a proposer for the “New Work Item Proposal” ISO/TC 211: Revision of ISO 19111 “Geospatial Information – Spatial references by coordinates”;
• Contribution to the development of new integrated products (e.g., GGRF, International Height Reference Frame (IHRF), atmosphere products, …)
• Presentation of BPS activities and achievements at scientific conferences (e.g., IAG, AGU, EGU, see selected publications and references below)
• Compilation of the BPS Implementation Plan 2017-2018. The planned schedule for the BPS communications and operational business is shown below.

<table>
<thead>
<tr>
<th>GGOS communications with BPS participation</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>Coordinating Board meetings</td>
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<tr>
<td>Consortium meetings</td>
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<td>EC telecons (monthly)</td>
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<tr>
<td>CO/BNO/BPS/SP (quarterly)</td>
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<tr>
<td>Reporting (1-page reports)</td>
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<table>
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<tr>
<th>Operational BPS bureau business</th>
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</thead>
<tbody>
<tr>
<td>Internal BPS meetings</td>
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<td></td>
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<tr>
<td>BPS Board meetings</td>
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<tr>
<td>Reporting of BPS entities</td>
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<tr>
<td>Monitoring progress</td>
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</tbody>
</table>

As an example taken from the BPS inventory, the present situation concerning numerical standards is summarized below:

• Different sets of numerical standards are in use within IAG (see below).
• Different time and tide systems are used in geodetic products.
• The IAG Resolution No. 16 (1983) recommends the zero tide system for gravity field parameters and zero (=mean) tide system for geometry (this is not fulfilled yet).
• The present situation concerning numerical standards and the different use of time and tide systems has to be correctly considered by the users of geodetic products; transformations are necessary if different parameters or standards were used.
• Thus the consistent use of geodetic products is very difficult (in particular for users who are not specialized in geodetic theory).
• A new Geodetic Reference System GRS20XX with new best estimates for the defining parameters should be developed.
Table 1: Numerical standards of conventional parameters presently in use within IAG. The defining parameters of the GRS80 are $a$, $GM$, $J_2$ and $\omega$. The IAG Resolution No. 1 (2015) recommends a new conventional $W_0$ value of 62 636 853 m$^2$s$^{-2}$. This $W_0$ value could be used as a defining parameter for a new GRS20XX, the semi-major axis $a$ would then become a derived. Note the consequential decoupling of $W_0$ and $L_G$. The advantage of $W_0$ is that it does not depend on the tide system, which is not the case of the semi major axis $a$.

<table>
<thead>
<tr>
<th></th>
<th>$a$ [m]</th>
<th>$GM$ [10$^{12}$ m$^3$s$^{-2}$]</th>
<th>$J_2$ [10$^{-8}$]</th>
<th>$\omega$ [10$^{-8}$ rad s$^{-1}$]</th>
<th>$U_0$ or $W_0$ [m$^2$s$^{-2}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRS80 (1979)</td>
<td>6 378.137</td>
<td>398 600.5</td>
<td>1 082.63</td>
<td>7.292 115</td>
<td>62 636 860.850</td>
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<tr>
<td>EGM2008</td>
<td>6 378 136.3</td>
<td>398 600 441.5</td>
<td>1 082 636 1</td>
<td>7.292 115</td>
<td>62 636 853.4 (2015)</td>
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<td>GRS20XX ?</td>
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</table>

BPS board meetings during the period 2015-2017:

- IUGG General Assembly 2015, Prague, Czech Republic, June 27, 2015.
- GGOS Days, Frankfurt am Main, Germany, October 22, 2015.
- EGU 2016, Vienna, Austria, April 19, 2016.
- GGOS Days, Cambridge, USA, October 26, 2016.

Selected Publications and Presentations:


Committee on Earth System Modeling

Chair: Maik Thomas (Germany)

During the period 2015-2017 the activities concentrated on model intercomparisons, parameterization of model interactions, and data assimilation techniques. In particular, the following progress could be achieved:

- A module for a realistic representation of the elastic response of the lithosphere to short-term variations of surface mass loading has been developed and implemented into various model approaches.
- Several time series are operationally provided to the community via the GGFC/IERS Combination Center, e.g., time series of site displacements due to hydrological loading derived from model simulations applying the new loading module or effective angular momentum functions based on atmosphere-hydrosphere models.
- Kalman-based algorithms for the assimilation of (integral) geodetic observations have been implemented into stand-alone model components in order to improve numerical predictions of variations of surface deformation and Earth rotation parameters. Possible alternative techniques for the introduction of observational data into dynamically coupled models are under discussion.
- A strategy for the development of a tool for cross-validation and consistency tests of various geodetic monitoring products is being developed.
- Feasibility studies for the provision of error estimates based on single- and multi-model ensembles have been performed.

Figure 4. Concept of a modular Earth system model for geodetic applications.

Selected Publications:


BPS WG1: ITRS Standards for ISO TC 211

Chair: Claude Boucher (France)

Members
- Detlef Angermann (Germany)
- Sten Bergstrand (Sweden) chair IERS WG Site surveys and collocations
- Claude Boucher (France) chair WG, ISO project leader
- Xavier Collilieux (France) IAG SC1.2 chair
- Thierry Gattacceca (France) ISO project editor
- Larry Hothen (USA)
- Ruth Neilhan (USA)
- Guy Woppelmann (France)

Purpose and Scope

The mission of the WG is to coordinate the IAG community in the support of the development of the ISO standard on ITRS.

In order to ensure this support, some specific objectives have been identified (this list may be updated if needed):
1. To establish the list of IAG contributors to the work of the WG.
2. To collect comments and proposals on any draft documents provided by the ISO TC211/19161-1.
3. To establish a glossary of geodetic terms in relation with the scope of the WG.

Activities and Actions

1 IAG contributors

The present status of WG members is given at the beginning of this report. Any update is welcome. In addition, some IAG related persons are members of the ISO committee, in addition to Thierry Gattacceca and myself: Zuheir Altamimi, Michael Craymer, Larry Hothen.

2 ISO TC211/19161-1

The group is presently working on a draft standard (presently version 1-5). As soon as this document will be approved as initial draft, it will be circulated in the WG for comments.

3 Glossary of terms

For information, here is the list of terms planned to be included in the terminology part of 19161-1:
- Alignment to a TRF
- Coordinate system
- Geocentric Terrestrial Reference System (GTRS)
- Positioning process
- Satellite ephemeris
- Terrestrial Reference Frame (TRF)
- Terrestrial Reference System (TRS)
BPS WG2: Establishment of the Global Geodetic Reference Frame (GGRF)

Chair: Urs Marti (Switzerland)

Members
- Jonas Ågren (Sweden), Commission 2
- Detlef Angermann (Germany), Director of GGOS Bureau of Products and Standards
- Riccardo Barzaghi (Italy), IGFS
- Johannes Ihde (Germany), Working Group on Height Systems
- Hansjörg Kutterer (Germany), GGOS Chair
- Jaakko Mäkinen (Finland), Tidal Systems
- Pavel Novak (Czech Republic), ICCT
- Roland Pail (Germany), Commission 2
- Nikolaos Pavlis (USA), Global Gravity Field Models
- Laura Sanchez (Germany), Working Group on Height Systems
- Harald Schuh (Germany), IAG President
- Hartmut Wziontek (Germany), Global Gravity Reference Network

Corresponding Members
- Gary Johnston (Australia), Commission 1, UN GGIM WG
- Johannes Böhm (Austria), Commission 1

Activities and Actions

This WG is a joint activity of IAG Commissions 1 and 2, the ICCT, the IERS and the IGFS. It works under the umbrella of the GGOS Bureau of Products and Standards (BPS).

The start-up meeting of this WG took place during the EGU Assembly 2016 in Vienna. In this meeting, the tasks of the WG discussed and defined. A clear separation between this WG and the UN GGIM WG on the GGRF was reached. Thus, the IAG WG will concentrate on the practical issues of the realisation of the GGRF and the setup of a consistent use of geometry and gravity field related quantities in the global reference frames. Key roles in this discussion play the realisation of the International Height Reference System (IHRS) and the definition and realisation of a global Absolute Gravity Reference System (see corresponding reports of these WGs).

At the GGHS2016 conference in Thessaloniki, a further meeting of the WG was held. Some concrete tasks were defined, such as:
- Work towards a conventional global reference gravity field model.
- Develop or define a global, conventional combined gravity field model and a conventional satellite-only model.
- Study the influence of permanent tide models on all kind of data (position, potential, gravity, gravity anomalies, heights, ...) and develop transformation methods.
- Study the redefinition of a global GRS based on actual values of $W_0 / GM / \omega$ and derived quantities.
- Study the necessity to replace GRS80.
- Study relativistic effects and their influence on the GRS.
- Get an overview of parameters and models (e.g. tides, loading effects, atmosphere) used in products and conventions of IAG and other communities. (see BPS Inventory).
- Intensify the contacts to IAU and IERS.
Main discussion in Thessaloniki was the assignment of a conventional global gravity field model, where not all WG members agree that it is necessary. A second point of disagreement was, if it is really a good idea to replace GRS80 by a new model. A good summary of the main aspects can be found in “Considerations on a Concept for future handling Geodetic Parameters/Numerical Standards in Conventions” by J. Ihde.

The IAU assigned two contact persons to this WG: Catherine Hohenkerk (President of Division A Commission ‘Fundamental Standards’ and Robert Heinkelmann. A contact person to the IERS is not assigned yet.

The concepts and activities of the WG were presented as well at TGSMM conference in St.Petersburg in April 2016 and during the GGOS days in Cambridge in October 2016.

Presentations and Publications

GGOS Focus Area “Unified Height Systems” and JWG 0.1.2 “Strategy for the Realization of the International Height Reference System (IHRS)”

Chair: Laura Sánchez (Germany)

Members
J. Ågren (Sweden),
M. Amos (New Zealand),
R. Barzaghi (Italy),
S. De Freitas (Brazil),
W. Featherstone (Australia),
T. Gruber (Germany),
J. Huang (Canada),
J. Ihde (Germany),
G. Liebsch (Germany),
J. Mäkinnen (Finland),
U. Marti (Switzerland),
P. Novák (Czech Republic),
M. Poutanen (Finland),
D. Roman (USA),
D. Smith (USA),
M. Véronneau (Canada),
Y. Wang (USA),
M. Blossfeld (Germany),
J. Böhm (Austria),
X. Collilieux (France),
M. Filmer (Australia),
B. Heck (Germany),
R. Pail (Germany),
M. Sideris (Canada),
G. Vergos (Greece),
C. Tocho (Argentina),
H. Denker (Germany),
D. Avalos (Mexico),
H. Wziontek (Germany),
M. Varga (Croatia),
I. Oshchepkov (Russia),
D. Blitzkow (Brazil),
A.C.O.C. Matos (Brazil),
J. Bouman (Germany).

Activities

The objectives and planned activities of the GGOS-FA “Unified Height System” are described in the Geodesist’s Handbook 2016 (Drewes, H., et al., 2016, J Geod 90(10): 1091, DOI: 10.1007/s00190-016-0948-z). The main goal at present is the implementation of the International Height Reference System (IHRS) defined by the IAG 2015 Resolution No. 1 (ibid. page 981). The progress is summarized as follows:

- In December 2015, the joint working group (JWG) Strategy for the Realization of the IHRS was installed with the objective of developing an appropriate scheme for the realization of the IHRS; i.e., the establishment of the International Height Reference Frame (IHRF). This
Global Geodetic Observing System (GGOS)

JWG is supported by the International Gravity Field Service (IGFS), the IAG Commissions 1 and 2 (Reference Frames and Gravity field), the Inter-commission Committee on Theory (ICCT), the regional sub-commissions for reference frames and geoid modelling, and both GGOS Bureaus (Networks and Observations and Products and Standards).

- A brainstorming and definition of action items took place at a JWG meeting carried out during the International Symposium on Gravity, Geoid and Height Systems 2016 (GGHS2016) in Thessaloniki (Greece) in September 2016. This JWG meeting was attended by 70 colleagues and allowed us to identify the activities to be faced immediately. A main output of this meeting are the criteria for the selection of IHRF reference stations:
  - collocation with fundamental geodetic observatories to ensure a consistent connection between geometric coordinates, potential and gravity values, and reference clocks (to support the implementation of the GGRF);
  - continuously operating reference stations to detect deformations of the reference frame;
  - preference of stations belonging to the ITRF and the regional reference frames (like SIRGAS, EPN, APREF, etc.);
  - collocation of GNSS stations with reference tide gauges and connection to the national levelling networks to facilitate the vertical datum unification;
  - availability of terrestrial gravity data around the IHRS reference stations as main requirement for high-resolution gravity field modelling (i.e., precise estimation of potential values).

- During the GGOS Days 2016 (Boston (MA), USA, October 2016), a preliminary station selection for the IHRF was performed. This selection is based on a global network with worldwide distribution, including a core network (to ensure sustainability and long-term stability of the reference frame) and regional/national densifications (to provide local accessibility to the global frame).

- Based on the conclusions of the meetings in Thessaloniki and Boston, regional and national experts were asked
  - to evaluate whether the preliminary selected sites are suitable to be included in the IHRF (availability of gravity data or possibilities to survey them), and
  - to propose additional geodetic sites to improve the density and distribution of the IHRF stations in their regions/countries.

- After the feedback from the regional/national experts, the first approximation to the IHRF is based on about 170 reference stations (Fig. X).

- With this preliminary selection, next efforts concentrate on the computation of the station potential values and the assessment of their accuracy. Different approaches are being evaluated:
  - As national/regional experts provided the JWG with terrestrial gravity data around some IHRF sites, a direct computation of potential values (and their accuracy) is being performed. In this case, following experiments are being conducted:
    - simulations about the distribution and quantity of gravity points needed around the IHRF stations,
    - simulations about the variation of potential values with time,
    - comparison of different mathematical formulations (least-squares collocation, FFT, radial basis functions, etc.).
  - Computation of potential values (and their accuracy) by national/regional experts responsible for the geoid modelling using their own data and.
  - Computation of potential values (and their accuracy) based on global gravity models of high-degree (like XGM2016, EIGEN-6C, EGM2008, etc.).
  - Recovering potential values from existing local quasi-geoid models.
The comparison of the results obtained from these different approaches will provide a basis to outline further steps; especially, the identification of detailed standards and conventions for the IHRS realization and the implementation of a roadmap based on the available geodetic data.

A web site summarizing the main characteristics of the GGOS-FA “Unified Height System” has been prepared and is now available at http://ihrs.dgfi.tum.de/. This information is also mirrored at http://www.ggosdays.com/en/focus-areas/unified-height-system/.

Figure 5. Proposed IHRF stations as of April 2017.

The activities reported in this document were (and are) possible thanks to the support of many colleagues. Their contribution is deeply acknowledged: M. Véronneau, J. Huang, D. Roman, M. Amos, I. Oshchepkov, S.R.C. Freitas, R.T. Luz, M. Pearlman, C. Estrella, C. Brunini, U. Marti, D. Piñon, D. Avalos, S.M.A. Costa, H. Denker, D. Blitzkow, J. Ågren, A.C.O.C. Matos, R. Pail, J. Ihde, R. Barzaghi, M. Sideris, J. Chire, A. Álvarez, C. Iturriaga, I. Liepiņš, N. Suárez, J. Krynski, R. Forsberg, G. Vergos, R. Ruddick, ...

Publications


Presentations


Gruber Th.: Geodetic space sensors for height system unification and absolute sea level determination. Fourth Swarm Science Meeting & Geodetic Missions Workshop, Banff, Canada, 2017-03-22.

Willberg M., Gruber Th., Pail R.: Geoid Requirements for Height Systems and their Unification; Fourth Swarm Science Meeting & Geodetic Missions Workshop, Banff, Canada, 2017-03-22.


GGOS Focus Area “Geohazards”

Chair: John LaBrecque (USA)

Activities, Actions, and Publications during 2015-2017:

The Geohazards Focus Area (GFA) determined that its first initiative should be focused upon the application of GNSS upon improvement in tsunami warning. The publication of significant advances in real-time technology and analysis laid a compelling case for the implementation of this geodetic capability. The GFA began its first initiative with a program to inform influential organizations of the important contributions that real-time GNSS analysis towards and effective and efficient tsunami warning systems. These efforts included presentations (listed below and included in the GATEW Dropbox) at significant scientific and governmental meetings. This extensive speaking initiative resulted in the publication of supporting resolutions and recommendations as summarized in the GGOS GATEW Call for Participation. On April 1, 2016, the GGOS released the GATEW Call for Participation (CfP) in support of the IUGG-2015 (https://www.dropbox.com/sh/fg20mtydg136vx6/AABNr2kSnMo429nCxEHhBDfoa?dl=0).

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<tr>
<td>Colombia</td>
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<td>France</td>
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<td>Germany</td>
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<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>
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“Real-Time GNSS Augmentation of the Tsunami Early Warning System”

The International Union of Geodesy and Geophysics

**Considering**
- That large populations may be impacted by tsunamis generated by megathrust earthquakes,
- That among existing global real-time observational infrastructure, the Global Navigation Satellite Systems (GNSS) can enhance the existing tsunami early warning systems,

**Acknowledging**
- The need to coordinate with the UNESCO Intergovernmental Oceanographic Commission (IOC) and the established intergovernmental coordination framework to define GNSS network requirements, data sharing agreements and a roadmap for the development and integration of the GNSS tsunami early warning augmentation.

**Urges**
- Operational agencies to exploit fully the real time GNSS capability to augment and improve the accuracy and timeliness of their early warning systems,
- That the GNSS real-time infrastructure be strengthened,
- That appropriate agreements be established for the sharing of real-time GNSS data within the tsunami early warning systems,
- Continued support for analysis and production of operational warning products,

**Resolves**
- To engage with IUGG member states to promote a GNSS augmentation to the existing tsunami early warning systems.
- Initially to focus upon the Pacific region because the high frequency of tsunami events constitutes a large risk to the region’s large populations and economies, by developing a prototype system, together with stakeholders, including scientific, operational, and emergency responders.

The GATEW CfP called upon the community of agencies and institutions to join the GATEW working group to support and promote GNSS Augmentation to Tsunami Early Warning system as recommended by IUGG 2015 Resolution 4.

During the first year of its release the working group for GNSS Augmentation to the Tsunami Early Warning (GATEW) grew to 16 agencies and institutions from 11 nations as listed above in the GFA membership above. The GATEW is functioning well and is likely to grow in importance in the months and years ahead as it moves from member recruiting and organization to program implementation.

**First Meeting of the GATEW:** The GATEW Working Group will hold its first meeting in Sendai Japan as part of the GTEWS 2017 workshop July 25-27, 2017. ([https://geodynamics.org/cig/events/calendar/gnss-workshop/age/](https://geodynamics.org/cig/events/calendar/gnss-workshop/age/)). The GGOS Geohazards Focus Area collaborated with the Association of Pacific Rim Universities (APRU), NASA, Rice University, Tohoku University to support this meeting of interested organizations in the advancement of the IUGG2015 Resolution #4. Over 90% of the GATEW organizations have registered for GTEWS2017 and GATEW fills a majority of the speaking positions. The GTEWS 2017 will provide an opportunity for GATEW membership to meet with representatives of non-GATEW agencies and institutions. GATEW will offer its organizational structure for the continuing promotion of international cooperation, infrastructure development and data sharing collaborations and agreements. The local organizing committee has expressed interest in publishing the findings of the GTEWS 2017 workshop.
The rapid growth of the GATEW working group in the past year will challenge the IAG definition of a working group. In the coming year the GGOS Coordinating Board should consider the transformation of the GATEW Working Group of the Geohazards Focus Area to a GGOS GATEW Program or similar structure in partnership with the IGS.

**GATEW on line library:** The GATEW maintains a library containing relevant documents, presentations, newsletters, videos and other files of interest to the GATEW community at the link https://www.dropbox.com/sh/fg20mtydg136vx6/AABNr2kSnMo429nCxEHhBDfoa?dl=0. The GFA will shift these files to the GGOS.org website when the GGOS Geohazards Focus Area web page is activated.

**Presentations on GATEW were made at the following meetings with representative presentation files in the GATEW Online Library:**


2015, June 22-July 2, IUGG-2015 Prague, Czech Republic

2015, August 10-15, 9th ACES International Workshop, Chengdu, China


2015, November 1-6, International Committee on GNSS-10, Boulder, US

2015, December 1-4, Asia-Pacific Regional Space Agency Forum (APRSAF 22) Bali, Indonesia


2016, November 6-11, International Committee on GNSS-11, Sochi, Russia

2016, April 17-22, European Geosciences Union General Assembly-2016, Vienna, Austria

2016, May 3-5, COCONet Workshop, Punta Cana, Dominican Republic

2016, September 29-October 1, Subduction Zone Observatory Workshop, Boise, US

2016, November 14-16 8th Multi-GNSS Asia (MGA) Conference, Manila, Phillipines

2017, April 23-28, European Geosciences Union General Assembly-2017, Vienna, Austria


GGOS Focus Area “Sea-Level Change, Variability and Forecasting”

Chair: Tilo Schöne (Germany)
Co-Chairs: CK Shum (USA), Mark Tamisiea (UK), Phil Woodworth (UK)

Purpose and Scope

Sea level rise and its impact on human habitats and economic well being have received considerable attention in recent years by the general public, engineers, and policy makers. A GGOS retreat in 2010 has identified sea level change as one of the cross-disciplinary themes for geodesy. Sea Level is also a major aspect in other observing systems, like e.g. GEO or GCOS. The primary focus of GGOS Focus Area 3 is to demonstrate and apply geodetic techniques, under the umbrella of GGOS, to the possible mitigation or adaption of sea level rise hazards including studies of the impacts of its change over the world’s coastal and deltaic regions and islands, and to support practical applications such as sustainability. One major topic is the identification of gaps in geodetic observing techniques and to advocate enhancements to the GGOS monitoring network and Services where necessary.

Activities and Actions

Focus Area 3 has identified actions to be undertaken to advance geodetic techniques and technologies applied to sea level research. These are

- Identification or (re)-definition of the requirements for a proper understanding of global and regional/local sea-level rise and its variability especially in so far as they relate 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 organizations or individuals who can take forward each requirement, or act as points of contact for each requirement, where they are primarily the responsibility of bodies not related to GGOS.
- Identification of a preliminary set of practical or application (as opposed to scientific) pilot projects, which will demonstrate the viability, and the importance of geodetic measurements to mitigation of sea-level rise at a local or regional level. This identification will be followed by construction of proposals for pilot projects and their undertaking.

In the long-term, the aim is to support forecasting of global and regional sea level for the 21st century with an expected forecast period of 20 to 30 years or longer.

An open Call for Participation was issued in 2012. Special emphasis is given to local and regional projects which are relevant to coastal communities, and which depend on the global perspective of GGOS. Three projects have been accepted. Thus, GGOS Focus Area 3 now has approved “Landmark” projects

The Use of Continuous GPS and Absolute Gravimetry for Sea Level Science in the UK
(NERC British Isles continuous GNSS Facility (BIGF), University of Nottingham, UK)
(NERC National Oceanography Centre (NOC), Liverpool, UK)

Revisiting the Threat of Southeast Asian Relative Sea Level Rise by Multi-Disciplinary Research (Delft University of Technology (DUT), Delft, Netherlands; University of Leeds, Leeds, United Kingdom; Ecole Normale Supérieure, Paris, France; Chulalongkorn University, Bangkok, Thailand; Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands)

Bangladesh Delta Relative Sea-Level Rise Hazard Assessment (Division of Geodetic Science, School of Earth Sciences, The Ohio State University, Columbus, Ohio, USA; University of Bonn, Bonn, Germany; GeoForschungsZentrum Potsdam (GFZ), Germany)
Subsidence Monitoring in Urban Areas of the Republic of Indonesia with GNSS-controlled tide gauges and supporting methods (National Geospatial Agency (BIG) of Indonesia; Helmholtz Centre Potsdam GFZ, Germany; Institut Teknologi Bandung, Indonesia) together with the University of Cologne working on social aspects. which is in preparation for submission.

All projects have their major focus on the combination of sea level and geodetic monitoring in an integrative approach. Also in the reporting period, Focus Area 3 continued communications with organizations, dealing with other than geodetic aspects of sea level monitoring. These are, e.g., the UNESCO International Oceanographic Commission Group of Experts (UNESCO/IOC GE) and the World Glacier Monitoring Service (WGMS). In Germany in 2016 a special research program (SPP 1889 - Regional Sea Level Change and Society, www.spp-sealevel.de) started and is dealing with many aspects relevant to GGOS Focus Area 3. Also cooperation with the IGS Tide Gauge Benchmark Monitoring Working is continued. A major step for GGOS Focus Area 3 was the alignment of its activities with the GGOS Bureau of Networks and Observations (B&O). The improvement of the observation network for sea level research is a major open topic. In 2015, the GLOSS Group of Experts (GLOSS-GE), the IGS TIGA-WG and the GGOS Focus Area 3 had submitted the Report "Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges" for consideration by GGOS. This report is now accepted by the GGOS CB and the GGOS B&O.

The GNSS-controlled tide gauges are an important monitoring component in climate and geodetic science. Over the years, the network of collocated stations has been growing, not at least through the constant effort of IOC/GLASS Group of Experts, the IGS TIGA-WG, and GGOS. Focus Area 3 plays a significant role in improving the network coverage and the establishment of local ties between GNSS and tide gauges.

Objectives and Planned Efforts for 2017-2019 and Beyond

- Review and Refine current and future aspects of geodetic contributions for sea level research with groups identified in AS-SL-01/AS-SO-02
- Work on to identify and contact emerging Focus Area 3 pilot projects
- Support Focus Area 3 projects
- Establish/improve the outreach activities with the help of the GGOS-CO
- Work with IGS/TIGA on results of the TIGA reprocessing
- Work with GGOS CB and GGOS B&O on the findings of the report "Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges"
- Identify geodetic monitoring aspects relevant to Focus Area 3
- Maintain the GGOS web space for the Focus Area 3.

Website

Publications and Presentations


