# Global Geodetic Observing System (GGOS)

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President: Laura Sánchez (Germany)
Vice President: Anna Riddell (Australia)
Coordinating Office Director: Martin Sehnal (Austria)

GGOS website - https://geodesy.science/ggos


## 1 GGOS General

### Overview

In recognition of the synergistic opportunities afforded by the advantages of satellite-based measurements for global observation of the planet, the availability of modern technologies for geodetic data acquisition, transmission and analysis, and the improvement of the accuracy of geodetic measurements and products by more than three orders of magnitude compared to classical (i.e. pre-satellite) geodetic methods, the IAG recognized the capability of modern geodesy to monitor the Earth system and measure global change, envisioning using geodetic data and products to serve science and society far beyond the traditional task of measuring and mapping the Earth's surface. To realize this vision, the IAG initiated in the late 1990s and early 2000s the implementation of the Global Geodetic Observing System (GGOS) as an integrating framework for all IAG Components (Services, Commissions, Inter-Commission Committees and

Projects) to move from the provision of the basic geodetic products (station coordinates, geoid, Earth orientation parameters) to a level of consistent modelling and interpretation of Earth system processes and interactions, and to ensure an integrated observing system rather than a flood of individual technique-dependent products. This report summarizes the main achievements of GGOS from 2023 to 2025.

## GGOS Structure

When introducing the Observing System, the IAG established an operational component to deal with the day-to-day business of implementing, maintaining and ensuring the long-term availability of the GGOS. This operational component, also called GGOS, serves as a clearinghouse for geodetic information expertise and acts as a central interface between science and society. As any IAG component, GGOS follows specific Terms of Reference which are regularly updated according to changes in the Statutes and Bylaws of its parent organization, new strategic challenges for GGOS, achieved objectives, and organizational changes to meet new user needs or to be in line with global initiatives in geodesy matters. Figure 1 shows the current organizational structure of GGOS. Recent changes to this structure include, among others, the merging of the former GGOS Consortium and GGOS Coordinating Board into the new GGOS Governing Board and the increasing of the number of voting members. This helps to streamline decision making within GGOS and enhances the involvement of all IAG components in the governance of GGOS.

The GGOS Governing Board is the central oversight and decision-making body of GGOS and the collective voice for all GGOS matters, as it is composed of one representative from each of the IAG Components and the Chairs of the organizational elements of GGOS (see Table 1). This Board is responsible for the governance, strategic policy and direction of GGOS. For the period 2023-2027, the GGOS-GB is composed of 45 voting members and 10 non-voting members. They are from 20 countries: Argentina, Australia, Austria, Czech Republic, People's Republic of China, Finland, France, Germany, Greece, India, Iran, Japan, Netherlands, Poland, South Africa, Spain, Sweden, Switzerland, United Kingdom and United States of America. 18 members are women and 27 are early career scientists. This renewal ensures the flow of fresh ideas and new impetus to take GGOS forward.

The GGOS Executive Committee (Table 2) is responsible for the day-to-day activities necessary to carry out the mandate given by the decision-making body. The two GGOS Bureaus (Products and Standards and Networks and Observations) coordinate the implementation of the GGOS core strategic activities. The Science Panel provides advice on scientific aspects relevant to GGOS. The Focus Areas are cross-disciplinary and are intended to address gaps and needed future products, and the GGOS Affiliates are national or regional organizations that coordinate geodetic activities in that country or region. Permanent Committees and limited-term Working/Study Groups are the thematic working bodies of GGOS and are distributed over the two Bureaus, the Science Panel, and the Focus Areas. The GGOS Coordinating Office serves as the Secretariat of GGOS and carries out the administrative work as directed by the Governing Board and the Executive Committee. The work of the Coordinating Office includes communications, outreach, external relations and the maintenance and en-

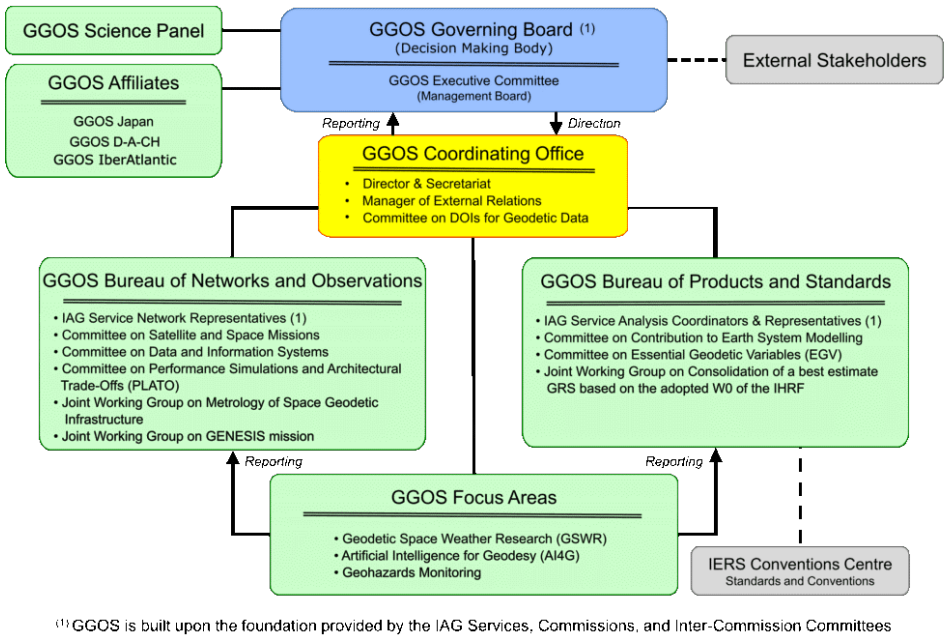


**Fig. 1.** Organization chart of GGOS.

hancement of the GGOS website and social media presence. As of June 2025, more than 220 colleagues are contributing to GGOS activities through this organizational structure. They present their recent achievements and upcoming challenges in the following sections. Without their support, the GGOS enterprise would not be successful. Their support is therefore highly appreciated.

In addition to the achievements summarized in the following sessions of this report, we would like to highlight the following (more detail in Sánchez et al. 2024c):

### GGOS Strategic Plan 2024 – 2034: Geodesy for Science and Society

GGOS regularly reviews and updates its strategic priorities to meet emerging needs in geodesy, always with a focus on strengthening GGOS' role as a collaborative hub in support of sustainable geodesy through the promotion and integration of diverse geodetic technologies and applications. Based on an extensive community survey consisting of six closed questions (multiple choice with predetermined answers) and seven SWOT (Strengths, Weaknesses, Opportunities, Threats) questions, between July 11 and September 30, 2022, 70 colleagues from 32 countries participated in the GGOS Strategic Survey. The GGOS Strategic Planning Committee then convened a two-day

community workshop based on this brainstorming to discuss and identify updated long-term goals, as well as cross-cutting community needs that each strategic goal will address. The result of this collaborative effort is the GGOS Strategic Plan 2024–2034, whose motto is "Geodesy for Science and Society" (Sánchez et al. 2024a). The long-term goals focus on (Fig. 2): visibility and engagement, science-policy networking, capacity enhancement and sustainability, and comprehensive and cross-cutting analysis. Guided by these goals, the community needs are presented as elements of a holistic effort to support the geodetic community and advance the recognition and use of geodesy for public benefit through innovation, advocacy, communication, and integration. The new GGOS Strategic Plan was unanimously approved by the GGOS Governing Board 25 January 2024.

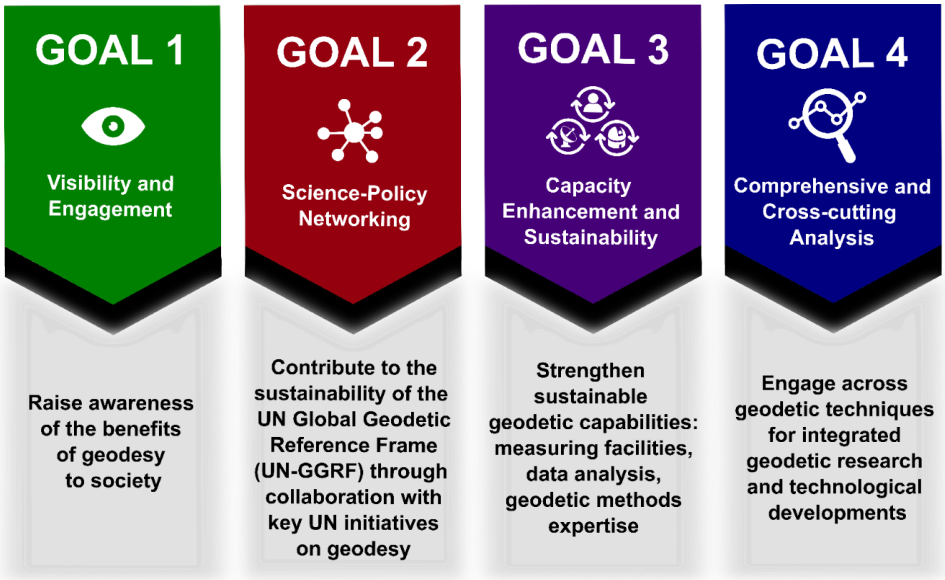


**Fig. 2.** Strategic goals of GGOS for the period from 2024 to 2034.

### GGOS Implementation Plan 2024 – 2027

The implementation of the GGOS Strategic Plan 2024 - 2034 is planned in four-year phases 2024 - 2027, 2028 - 2031 and 2032 - 2035. The last phase extends beyond the period covered by the Strategic Plan so that the renewal/updating of the GGOS Strategic Goals can be addressed as a key action in the last phase of the current Implementation Plan. This will ensure consistency and continuity in the GGOS strategy. For the implementation phase 2024 – 2027, an implementation action has been defined for each of the 16 objectives outlined in the Strategic Plan. Each implementation action is in turn made up of several activities (from one to six). These activities ultimately

represent the work to be done and follow the SMART criteria: Specific, Measurable, Achievable, Relevant, Time-bound. Over-ambitious actions are avoided as they are doomed to failure.

A total of 64 implementation activities have been identified (Sánchez et al. 2024b). Each activity is assigned to a GGOS component, which coordinates the interaction/-support of other GGOS components (and external stakeholders as appropriate) and monitors progress and completion. The implementation activities can be broadly categorized as follows: - Geodetic information and expertise: Development and maintenance of organizational intangibles, including geodetic information, expertise, and capacity building. - Global Geodetic Infrastructure: Identification of gaps in the geodetic infrastructure and advocacy for the modernization, extension, and maintenance of the existing global geodetic infrastructure. - Standardization, Integration and Optimization: Interaction with all IAG components to provide unique standards and mutually consistent, highly reliable and easily accessible geodetic products. - Communication, Education and Outreach: Public relations, marketing, outreach, and engagement to ensure a long-term sustainable geodetic enterprise.

The Implementation Plan for the period 2024-2027 was unanimously approved by the GGOS Governing Board 18 September 2024.

**Definition of Essential Geodetic Variables (EGVs)**

The Chair of the GGOS Committee on EGVs, the Director of the BPS, and the GGOS President have prepared a White Paper outlining an approach to defining EGVs (Gruber et al., 2025). The paper aims to describe how geodesy contributes to Earth observation using the same terminology as other global observing systems, such as the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). This will increase the visibility of geodesy and make its products more useful to other sciences and society. The current concept considers 18 EGVs based on 54 geodetic products. The EGVs are divided into three domains: Global (covering the entire Earth), Land, and Ocean. A subdomain indicates whether an EGV relates to the geometry or gravity field of the Earth (Fig. 3). The GGOS Science Panel and the GGOS Governing Board have reviewed and endorsed this concept. The IAG Executive Committee and the members of the UN Global Geodetic Centre of Excellence (UN-GGCE) have reviewed it. After incorporating their feedback into the White Paper, we will begin outlining the requirements for reliably making the EGVs available. This should be implemented with the support of IAG Services. After that, we will launch a dissemination and consultation exercise with the global geodetic community to reach a consensus.

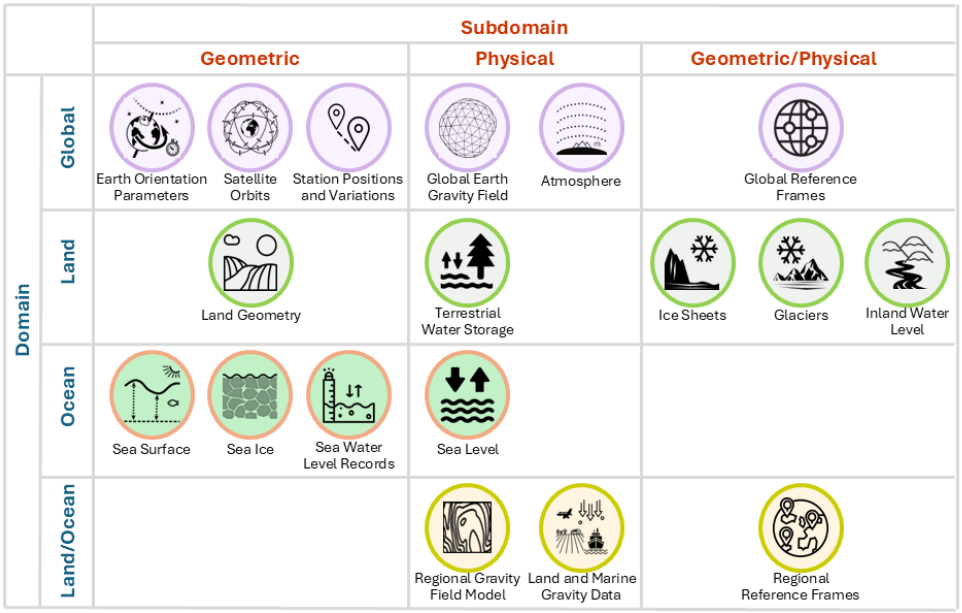


**Fig. 3.** Classification of Essential Geodetic Variables (EGVs) as of June 2025.

### Establishment of a new GGOS Affiliate: GGOS IberAtlantic

GGOS Affiliates are national or regional geodesy-related organizations that facilitate greater collaboration across regions, communities and new technologies. Fostering regional alliances is a powerful tool to identify, enable and develop sustained geodetic observations, products and services following regional and national priorities, aligned with the global goals of GGOS. During the GGOS Days 2022 (14-15 November 2022 in Munich, Germany) our colleagues Esther Azcue Infanzón and José Antonio López Fernández from the Yebes Observatory, Instituto Geográfico Nacional of Spain approached GGOS to evaluate the possibility of establishing a GGOS Affiliate. In 2023, they hosted the GGOS Days 2023 (20-22 September 2023 in Alcalá de Henares and Yebes Observatory, Spain) and gave dedicated presentations on the status of geodesy in Spain and Portugal, which provided a framework to concretize the proposal for GGOS IberAtlantic. Based on the outcomes of the GGOS Days 2023, the national geodetic authorities of both countries, the Instituto Geográfico Nacional and the National Section of Geodesy in Spain and the Direção Geral do Território in Portugal, signed letters of intent and defined terms of reference to initiate the operation of GGOS IberAtlantic. In March 2024, GGOS received a formal request to create the GGOS subsidiary GGOS IberAtlantic and on 12 April 2024, the GGOS Governing

Board unanimously approved GGOS IberAtlantic. GGOS welcomes the Spanish and Portuguese colleagues: Esther Azcue Infanzón, Helena Cristina Ribeiro, Luisa Magalhaes, José Antonio López Fernández, Marcelino Valdés Pérez De Vargas, and Manuel Ángel Sánchez Piedra, and highly appreciate their contribution. GGOS IberAtlantic now joins the two existing GGOS Affiliates: GGOS Japan and GGOS D-A-CH.

**Fostering multidisciplinary research in Space Weather**

GGOS is leading a joint initiative between IAG and the International Association of Geomagnetism and Aeronomy (IAGA) to establish a multidisciplinary network of scientists to integrate geodetic and geophysical technologies for comprehensive monitoring of the Magnetosphere, Ionosphere, Plasmasphere and Thermosphere as a coupled system. To this end, we prepared the project "Characterization of the ionized atmosphere in terms of essential variables", which has been approved in the frame of the IUGG Grants Program 2024 – 2025. Framed in this project, we organized the GGOS Topical Meeting on the Atmosphere, held in Potsdam, Germany, 7-9 October 2024. The meeting was attended by 76 participants from 21 countries. 36 participants are early career scientists. Thanks to the generous support of the IUGG, the IAG and the IAG, travel grants were provided to six colleagues to enable them to attend the meeting. More details in the report of the GGOS Focus Area Geodetic Space Weather Research.

**GGOS interaction with the UN Global Geodetic Centre of Excellence (UN-GGCE)**

The GGOS Coordinating Office and the UN-GGCE have regular monthly meetings to report and agree on outreach activities. Recently, a joint short video on reference frames, based on previous GGOS videos, was jointly released. The GGOS BPS and BNO support UN-GGCE activities related to the survey of needs and challenges of IAG services as input for the Global Geodesy Needs Assessment. The GGOS Executive Committee completed a survey on the GGOS contribution (according to the GGOS Implementation Plan) to the First Joint Global Geodesy Development Plan. GGOS input was included in the IAG contribution to this plan.

**Joint Commission 2, IGFS and GGOS Symposium GGHS2024 (Gravity, Geoid and Height Systems 2024), 4-6 September 2024**

For the first time, GGOS was a direct co-organizer of a Gravity Symposium. In addition to participating in the definition of the scientific program of the meeting, GGOS had the opportunity to present several GGOS topics in detail, which undoubtedly contributed to promote the GGOS activities within the gravity field community.

**Geodesy in Africa at the UN Science Summit and towards GGOS Africa**

Thanks to the initiative of our colleague Aletha de Witt, Director of Radio Astronomy Projects, Department of Science and Innovation (DSI), South Africa, and member of the GGOS-GB, GGOS had the opportunity, together with the DSI and the UN-GGCE,

to organize the event "Africa Rising: Shaping Our Common Future Through Geodesy" held on 27 September 2024 within the framework of the UN Science Summit 2024 in New York. The main objective of this event was to identify challenges and opportunities for the implementation of the UN Resolution on the "Global Geodetic Reference Frame for Sustainable Development" in Africa. Opening keynotes highlighted the contribution of geodesy to sustainable development and how geodesy provides the essential reference layer for public infrastructure, as well as the hidden risks that threaten critical infrastructure and sustainable development, with a focus on Africa. Two panel discussions then extended and complemented the views presented in the keynote speeches. The first panel focused on achievements and ongoing challenges since the adoption of the UN Resolution on the GGRF. The second panel discussion focused on African perspectives on the 1st Joint Development Plan for Global Geodesy to sustain the global geodesy supply chain. In the afternoon, the workshop Sustaining the Global Geodesy Supply Chain in Africa provided further insights into the challenges and opportunities of a robust geodetic infrastructure in Africa. According to the session outcomes, the main opportunities may be summarized as follows:

- Revitalization of the African Geodetic Reference Frame (AFREF): Significant efforts are underway to develop a continent-wide geodetic reference network that promotes data consistency and facilitates geospatial applications.
- Regional cooperation: Initiatives such as the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi, the Geospatial Information Section of the UN Economic Commission for Africa (UNECA) in Ethiopia, or the Africa Chapter of the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM Africa) foster geodetic training and capacity building and provide a framework for cooperation at the continental level.
- Increased participation in global geodetic organizations: The interaction of African scientists and institutions in global communities such as the IUGG, IAG and the International Federation of Surveyors (FIG) facilitates participation in global initiatives that highlight the essential role of African geodesy in the global framework and promote collaborative projects of mutual benefit.
- GGOS Africa: The establishment of the GGOS Affiliate GGOS Africa will bring together regional scientists and technicians involved in the collection, analysis, management and use of geodetic data to facilitate greater collaboration across regions, communities and new technologies, and promote geodetic capacity building. This regional alliance will be a powerful tool to identify, enable and develop sustainable geodetic observations, products and services according to regional and national priorities, in line with global goals.

### Merging GGOS and IAG Internet and Social Media channels

GGOS and IAG have merged their internet and social media channels to create a unified and streamlined online presence. This major milestone fulfills a key objective outlined in the GGOS Implementation Plan, which called for the development of an integrated and harmonized digital presence for the IAG and GGOS. The result is the official launch of the new joint website https://geodesy.science in June 2025 (Fig. 4). This coordinated effort was led by the GGOS Coordinating Office

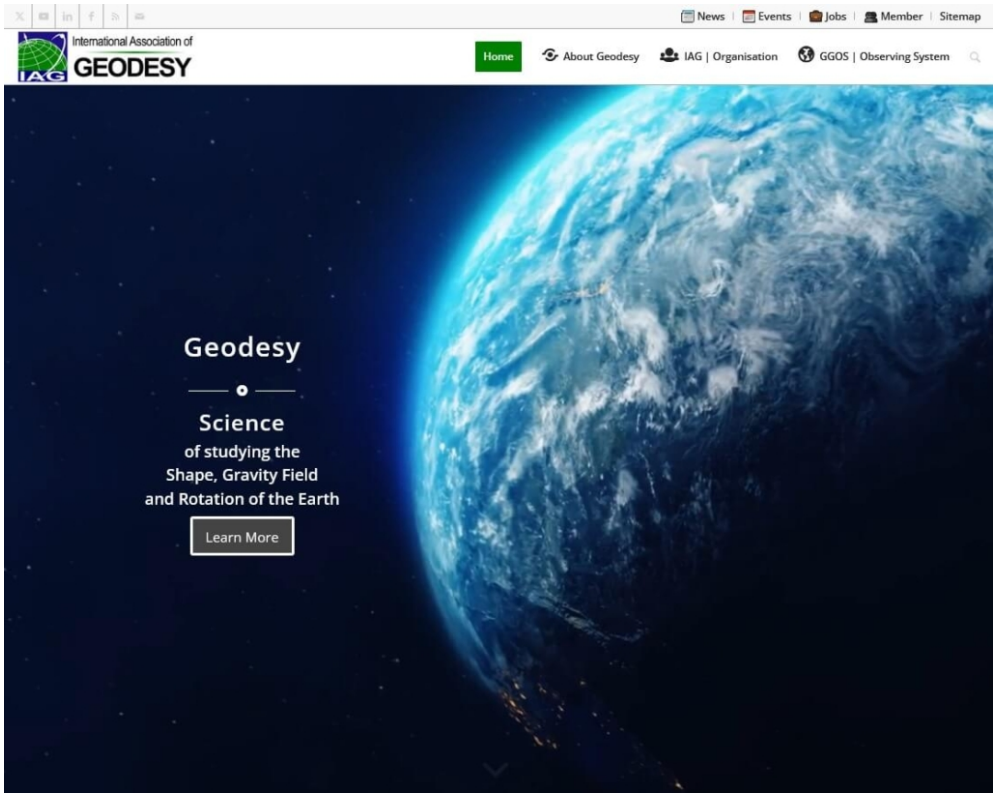


**Fig. 4.** The new IAG/GGOS website https://geodesy.science

and the IAG Secretariat at BEV (Federal Office of Metrology and Surveying, Austria), in close collaboration with the IAG Office, IAG COB (Communication and Outreach Branch), and GGOS colleagues between 2024 and 2025. The new website features a modern, user-friendly design with a visually engaging homepage and a dedicated About Geodesy (https://geodesy.science/about-geodesy/) section aimed at making geodesy more accessible to a wide audience. It also introduces a centralized job platform and a new cloud infrastructure (https://cloud.geodesy.science). Social media posts, news updates, and event announcements are now being shared through joint IAG-GGOS channels, enabling more efficient outreach and fostering a stronger, more recognizable voice for the global geodetic community. This integration supports our ongoing commitment to increase the visibility, accessibility, and coherence of geodetic communication and to engage audiences at all levels.

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## GGOS Members

Table 1: Members of the GGOS Governing Board

| **Name** | **Position and Affiliation** |
|---|---|
| **GGOS Officers** | |
| Laura Sánchez | GGOS President, Deutsches Geodätisches Forschungsinstitut der Technischen Universität München, Germany |
| Anna Riddell | GGOS Vice President, Geoscience Australia, Australia |
| Basara Miyahara | Immediate Past President of GGOS, Geospatial Information Authority of Japan, Japan |
| Martin Sehnal | Director of GGOS Coordinating Office, Federal Office of Metrology and Surveying, Austria |
| José Rodríguez | Director of Bureau of Networks and Observations, Instituto Geográfico Nacional, Spain |
| Detlef Angermann | Director of Bureau of Products and Standards, DGFI-TUM, Germany |
| José Manuel Ferrándiz | Chair of GGOS Science Panel, University of Alicante, Spain |
| Allison Craddock | Manager of External Relations, NASA Jet Propulsion Laboratory, USA |
| Richard Gross | IAG President, NASA Jet Propulsion Laboratory, USA |
| Michael Schmidt | Chair FA Geodetic Space Weather Research, DGFI-TUM, Germany |
| Benedikt Soja | Chair FA on Artificial Intelligence for Geodesy, ETH Zurich, Switzerland |
| Timothy Melbourne | Chair FA on Geohazards Monitoring, Central Washington University, USA |
| Alexander Kehm | Chair Committee on PLATO, Federal Agency for Cartography and Geodesy, Germany |
| Roger Fraser | Chair Committee on DIS, Department of Transport and Planning, Australia |
| Roland Pail | Chair Committee on SCM, TU München, Germany |

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| Name | Position and Affiliation |
|---|---|
| Maik Thomas | Chair Committee on EM, GFZ Potsdam, Germany |
| Thomas Gruber | Chair Committee on EGV, TU München, Germany |
| Kirsten Elger | Chair Committee on DOI, GFZ Potsdam, Germany |
| **Representatives of IAG Services, Commissions, ICCs and Projects** | |
| Daniela Thaller | IERS representative, Federal Agency for Cartography and Geodesy, Germany |
| Ryan Ruddick | IGS representative, Geoscience Australia, Australia |
| Toshimichi Otsubo | ILRS representative, Hitotsubashi University, Japan |
| Lucia McCallum | IVS representative, University of Tasmania, Australia |
| Karine Le Bail | IDS representative, Chalmers / Onsala Observatory, Sweden |
| Elizabeth Bradshaw | PSMSL representative, British Oceanographic Data Centre, UK |
| Georgios S. Vergos | IGFS representative, Aristotle University of Thessaloniki, Greece |
| E. Sinem Ince | ICGEM representative, GFZ Potsdam, Germany |
| Kevin M. Kelly | IDEMS representative, ESRI, USA |
| Christoph Förste | IGETS representative, GFZ Potsdam, Germany |
| Urs Marti | ISG representative, Swisstopo, Switzerland |
| Sylvain Bonvalot | BGI representative, IRD France |
| Christopher Kotsakis | IAG Commission 1, Aristotle University of Thessaloniki, Greece |
| Derek van Westrum | IAG Commission 2, NOAA National Geodetic Survey, USA |
| Rebekka Steffen | IAG Commission 3, Lantmäteriet, Sweden |
| Krzysztof Sosnica | IAG Commission 4, University of Wroclaw, Poland |
| Pavel Novák | ICCT representative, University of West Bohemia, Czech Republic |
| Annette Eicker | ICCC representative, HafenCity University Hamburg, Germany |
| Pierre Sakic | ICCM representative, Institut de Physique du Globe de Paris, France |
| Jürgen Müller | QuGe Project representative, Leibniz Universität Hannover, Germany |
| **Members-at-Large** | |
| Aletha de Witt | HartRAO, South Africa |
| Claudia N. Tocho | FCAG, National University of La Plata, Argentina |
| Ropesh Goyal | IIT (BHU), India |
| **Appointed Members** | |
| Julia Azumi Koch | Early Career Scientist Representative, ETH Zurich, Switzerland |
| Yamin Dang | CASM, China |
| **Representatives of the GGOS Affiliates** | |
| Yusuke Yokota | GGOS Japan, University of Tokyo, Japan |
| Hansjörg Kutterer | GGOS D-A-CH, Karlsruhe Institute of Technology, Germany |
| Esther Azcue Infanzón | GGOS IberAtlantic, Instituto Geográfico Nacional, Spain |
| **Non-Voting Members** | |
| Helmut Klima | GGOS Web and Social Media Manager, BEV, Austria |
| Urs Marti | BPS JWG on GRS, Swisstopo, Switzerland |
| Cornelia Eschelbacher | BNO JWG 1.2.2, University Frankfurt, Germany |

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| Name | Position and Affiliation |
|---|---|
| Johannes Böhm | BNO JWG 1.1.1 Genesis, TU Wien, Austria |
| Fabricio S. Prol | FA GSWR – JSG 1, NLS Finland |
| Günther March | FA GSWR – JSG 2, ESA, Netherlands |
| Haixia Lyu | FA GSWR – JSG 3, Wuhan University, China |
| Andrés Calabia Aibar | FA GSWR – JSG 4, Universidad de Alcalá, Spain |
| Milad Asgarimehr | FA AI4G – JSG1, GFZ Potsdam, Germany |
| Saniya Behzadpour | FA AI4G – JSG2, Swisscom, Switzerland |
| Mohammad Ali Sharifi | FA AI4G – JSG4, University of Tehran, Iran |

Table 2: Members of the GGOS Executive Committee

| Name | Position and Affiliation |
|---|---|
| **Laura Sánchez** | GGOS President, Deutsches Geodätisches Forschungsinstitut der Technische Universität München, Germany |
| **Anna Riddell** | GGOS Vice President, Geoscience Australia, Australia |
| **Allison Craddock** | Manager of External Relations, NASA Jet Propulsion Laboratory, USA |
| **Martin Sehnal** | Director of GGOS Coordinating Office, Federal Office of Metrology and Surveying, Austria |
| **José Rodríguez** | Director of Bureau of Networks and Observations, Red de Infraestructuras Geodésicas, Instituto Geográfico Nacional, Spain |
| **Detlef Angermann** | Director of Bureau of Products and Standards, Deutsches Geodätisches Forschungsinstitut der Technische Universität München, Germany |
| **Georgios S. Vergos** | GGOS-GB representative, GravLab, School of Rural and Surveying Engineering at the Aristotle University of Thessaloniki, Greece |
| **Claudia N. Tocho** | GGOS-GB representative, Facultad de Ciencias Astronómicas y Geofísicas (FCAG), National University of La Plata (UNLP), Argentina |
| **José Manuel Ferrándiz** | Chair of GGOS Science Panel, University of Alicante, Spain (permanent guest) |
| **Basara Miyahara** | Immediate Past President of GGOS, Geospatial Information Authority of Japan, Japan (permanent guest) |
| **Richard Gross** | IAG President, NASA Jet Propulsion Laboratory, USA (permanent guest) |

## 2 GGOS Coordinating Office

**Website:** https://geodesy.science/ggos/structure/co/

**Director:** Martin Sehnal (BEV, Austria)
**Web and Social Media Manager:** Helmut Klima (BEV, Austria)
**Assistant:** Lucas Triebenbacher (BEV, Austria)

The GGOS Coordinating Office (CO) serves as the Secretariat of GGOS and is hosted by the Federal Office of Metrology and Surveying (BEV – Bundesamt für Eich- und Vermessungswesen) in Vienna, Austria. In general, the CO coordinates the administrative work in support of the various GGOS structural elements, and is responsible for outreach and communications. It ensures information flow, maintains documentation of the GGOS activities, and manages specific assistance functions that enhance the administrative coordination across all areas of GGOS, including inter-services coordination and support for meeting and 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 and social media presence. This report summarizes the present status and progress of the CO, including the following GGOS associated components:

- Office of External Relations (Manager of External Relations: Allison Craddock)
- Committee "DOI's for Geodetic Data Sets" (Chair: Kirsten Elger)

**Present Status and Progress (2023-2025)**


**Fig. 5.** A new 2.5 minutes video explaining the importance of terrestrial reference frames to a general audience (https://youtu.be/zfqq-0d2txk)

The major activities and progress of the CO are summarized below:

- **GGOS Video Production:** The CO produced a 10 minutes video about "Terrestrial Reference Frames" in 12 languages (https://youtu.be/vvNXv05646M) which was published in September 2023 and was viewed more than 46,000 times (all versions together). In addition, the CO collaborated with the UN-GGCE and produced a short version (2.5

minutes) of it targeting a more general audience and politicians (https://youtu.be/zfqq-0d2txk) - Fig. 5.

- **UN-GGCE Collaboration:** The CO has been meeting with the UN-GGCE on a monthly basis since November 2023 to share information about planned outreach activities, avoid duplication of work and work on joint projects.
- **Social Media Campaigns** were successfully carried out for the AGU Fall Meeting 2023 and 2024 as well as for the EGU General Assembly 2024 and 2025.
- **Organization of GGOS Meetings:** GGOS GB meeting (22 April 2023, 14 April 2024, 26 April 2025 Vienna, Austria), GGOS Days 2023 (20-22 Sep., Alcala de Hénares, Spain) and 2024 (10-11 Oct., Potsdam, Germany) and GGOS Topical Meeting on the Atmosphere (7-9 Oct. 2024, Potsdam, Germany).
- **GGOS Portal - Feasibility Study:** Together with the Vienna University of Technology (TU Wien), the CO has carried out a feasibility study to examine the realization of such a portal. (Bachelor thesis by Lena Steiner: DOI 10.5281/zenodo.10255995).
- **IAG Secretariat at BEV:** Building on recent successes of the GGOS CO at BEV, the IAG suggested creating a new IAG Secretariat at BEV. In April 2024, the IAG and BEV signed a memorandum of understanding to initiate this. All outreach activities of the IAG Communication and Outreach Branch (COB) and the long-term activities of the IAG Office will be handled together with the GGOS CO at BEV in future. This will make it easier to work together with GGOS CO and avoid duplication of tasks. The Director of GGOS CO will then also act as the Executive Secretary of the IAG.
- **New Integrated IAG and GGOS Website and Social Media Channels:** A major objective outlined in the GGOS Implementation Plan [GGOS IP 4.4.a] was the development of an integrated and harmonized online presence for the IAG and GGOS. This goal has now been realized with the launch of a joint website under the new domain https://geodesy.science (Fig. 4), along with the unification of IAG and GGOS social media channels. This effort was led primarily by the GGOS Coordinating Office and the IAG Secretariat at BEV, in close collaboration with the IAG Office, IAG Bureau, and GGOS colleagues between 2024 and 2025. The new website was officially launched in the first week of June 2025. Key features of the new platform include a fresh, user-friendly design, a visually engaging homepage, and a comprehensive "About Geodesy" https://geodesy.science/about-geodesy/ section aimed at promoting the importance and impact of geodesy. Additionally, it introduces a centralized platform for job opportunities and a new cloud infrastructure https://cloud.geodesy.science) that replaces the former GGOS Cloud. The new site now fully incorporates the web presence of both GGOS and the ICCT, representing a major step forward in unifying and modernizing the digital presence of IAG and its components.
- **Geodesy Cartoons – Engaging the Public through Visual Storytelling:** To raise public awareness of geodesy the CO has started a key initiative is the creation of geodesy-themed cartoons (https://geodesy.science/cartoon) that explain geodetic concepts, observation methods, and geodetic products through engaging visuals. The initiative refine and expand outreach activities, with the goal of making geodesy more accessible and relevant to broader audiences. During the EGU General Assembly in April 2025 the first cartoon illustrated by Riccardo Barzaghi was published (Fig. 6).

**Planned Actions and Milestones**

Beside of the day-to day activities of serving as a Secretariat of GGOS and the support of other GGOS components, the leaded planned actions by the GGOS Coordinating Office are defined in the GGOS Implementation Plan (GGOS IP) as follows:

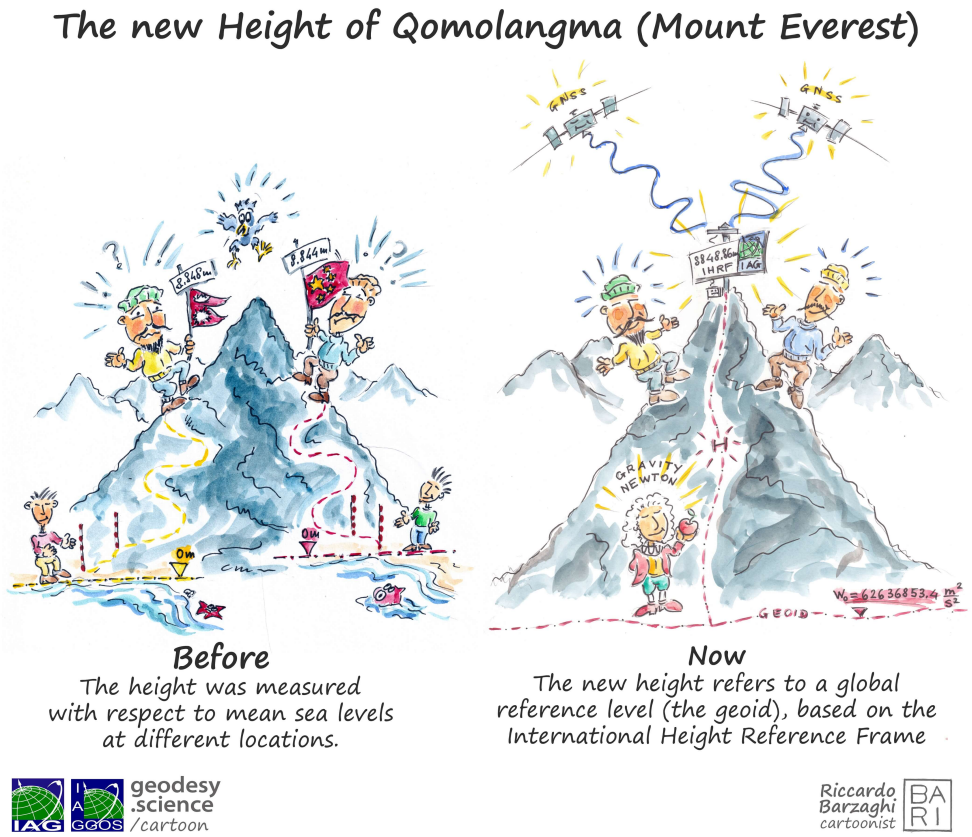


**Fig. 6.** The first Geodesy Cartoon https://geodesy.science/cartoon explaining height systems.

*GGOS Portal and Internet Presence:*

- **GGOS Portal:** Definition and implementation of the basic functionalities of the GGOS Portal (2025/2026) [GGOS IP 4.4.d]. This includes an operational web platform for the GGOS portal, the inclusion of all available geodetic product metadata integrated in the GGOS portal and promotional campaigns to encourage data providers to generate metadata for their products.
- **Expansion of descriptions on the GGOS website:** Inclusion on the GGOS website of descriptions of geodetic products and observations not covered by the IAG Services [GGOS IP 4.4.c]
- **GGOS Website Updates:** Revision and update of the GGOS webpage contents regularly (continuous) [GGOS IP 4.4.b].

*Outreach and Communication Materials:*

- **Popularize the importance of geodesy** (observations, products, community) and the IAG Services through the GGOS webpage, videos, and social media campaigns (continuous) [GGOS IP 2.1.a]
  - **One new GGOS video a year**
  - **Continuous social media posts** on GGOS and IAG related activities
  - Four dedicated **social media campaigns** a year on geodetic products (every three months a different geodetic product will be promoted through social media posts)
  - **Statistics** on the website or in social media
- **Creation of Factsheets:** Compile the observation and product descriptions in https://geodesy.science/ggos into summary factsheets that can be made available online to everyone through GGOS and can also be translated into national languages by appropriate national agencies. (continuous) [GGOS IP 2.1.c]. The plan is to create four Factsheets a year.

## GGOS External Relations Office

**Manager of External Relations:** Allison Craddock (NASA JPL, California Institute of Technology, USA)

With support from the GGOS Coordinating Office, GGOS Executive Committee, and GGOS Focus Area leadership. The position of Manager of External Relations resides within the GGOS Coordinating Office. The Manager of External Relations coordinates, in consultation with the GGOS President, GGOS engagement with external organizations.

The vision of the International Association of Geodesy's Global Geodetic Observing System (GGOS) is "Advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time." This mission, as well as work toward the goals and objectives of the GGOS Strategic Plan, is partly supported by targeted engagement with external stakeholders, managed as a component of the GGOS Coordinating Office. GGOS External Relations includes a work portfolio that focuses on advocacy, visibility, and collaboration to ensure geodesy is a visible, valued, and sustainable worldwide asset. Working toward proactive engagement with the broader Earth observations community, GGOS external outreach and engagement centers on advocacy for interoperable, discoverable, and openly available geospatial data; promoting infrastructure development; identifying geodetic contributions to United Nations frameworks, as well as working with external partners to leverage the use of geodesy in broader Earth Observations campaigns

### Present Status and Progress

GGOS participation in diverse stakeholder organizations works to identify synergies, making connections across organizations in the name of geodesy and mutual benefit. GGOS participation and leadership – often on behalf of the IAG – works to ensure Earth observation organizations are aware of their dependency on geodetic infrastructure for applications such as climate change and disaster risk reduction will be discussed. Significant progress toward the GGOS Implementation Plan's Action 2.1: Raise awareness of IAG Services for Earth Observation and societal needs; and Action 2.3: Scientific Roadmaps to support Policy Makers in Geodetic Issues is described below.

*Collaborations with the United Nations Global Geodetic Center of Excellence (UN-GGCE):*

GGOS External Relations has collaborated with the GGOS Coordinating Office Communications Team, as well as GGOS Executive Committee, to support collaborations with the

United Nations Global Geodetic Center of Excellence in Bonn, Germany. Since collaborations commenced in mid-2023, the following outputs have been achieved:

- The GGOS informative video on "Terrestrial Reference Frames" was condensed, re-scoped, and re-written in collaboration with the GGCE in order to best communicate the essential role of terrestrial reference frames to policy makers, diplomats, and the general public. Craddock served as English language editor and narrator;
- Feedback to the GGCE was provided for the following documents:
  - Global Geodesy Needs Assessment
  - Hidden Risk Report
  - First Joint Development Plan for Global Geodesy

*Collaborations with the Group on Earth Observations (GEO):*

GGOS External Relations maintains contacts in numerous Earth observations stakeholder groups, and plays an active role in the Group on Earth Observations (GEO) by serving on behalf of the International Association of Geodesy on the GEO Programme Board (the international steering committee responsible for shaping GEO's work portfolio). Through this and the GEO Disaster Risk Reduction Working Group, GGOS has been able to ensure that geodesy and terrestrial reference frames were mentioned in a major policy brief co-authored by GEO and the UN Framework Convention on Climate Change. This policy brief, titled "Realizing Early Warnings for All: Innovation and Technology in support of Risk-Informed Climate Resilience Policy and Action " was launched at the 29th annual meeting of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) – aka COP 29 – which took place in Baku, Azerbaijan, from November 11 to 22, 2024. This comprehensive resource emphasizes the importance of technology, particularly Earth observations, in strengthening multi-hazard early warning systems (MHEWS). The brief highlights how climate technology policies and scalable solutions, including those based on Earth observations, can improve climate information and disaster risk knowledge. GGOS External Relations provided content ensuring awareness and visibility of geodesy's role in early warning systems. This will be the first of four such policy briefs centering on the four pillars of the UN's Early Warnings for All initiative, with future opportunities for highlighting the essential role of geodesy and reference frames in these forthcoming documents already established.

*Collaborations with the International Committee on GNSS (ICG):*

The International Committee on GNSS (ICG) Working Group on Reference Frames, Timing, and Applications (WG-D) is co-chaired by ICG Associate Member organizations: International GNSS Service (IGS), International Association of Geodesy (IAG), and International Federation of Surveyors (FIG). Through the participation of IAG and IGS, and following discussions around the hidden risks to the Global Geodesy Supply Chain, GGOS is supporting co-chairs of the ICG WG-D in organizing a high-level statement to communicate the key role that other geodetic infrastructure (SLR, VLBI, gravity, etc.) and capacity building plays in supporting GNSS providers and GNSS-enabled technologies.

*Collaborations with the International Federation of Surveyors (FIG):*

The GGOS External Relations Manager was invited to give a keynote presentation explaining the role of the global geodesy supply chain for surveying and land management at

the FIG Working Week in Brisbane, Australia, April 2025.

**Planned Actions and Milestones**

Looking forward, GGOS External Relations plans to continue active collaborations with the UN GGCE and GEO, with periodic interactions with FIG, CEOS, and other stakeholder groups as needed. Specific interactions with GEO will include future contributions to international policy briefs, and as well as overall advocacy for the visibility of geodesy as GEO initiates an Implementation Plan working toward integrated, innovative, and co-designed open Earth observations products and services.

GGOS anticipates continued participation with the UN GGCE to support advocacy and visibility of the global geodetic supply chain, with a planned policy brief to be developed in collaboration with the United Nations International Committee on GNSS.

## GGOS Committee on "DOI's for Geodetic Data Sets"

**Chair:** Kirsten Elger (GFZ German Research Centre for Geosciences, Germany)

**Present Status and Progress**

With the 28th IUGG General Assembly in Berlin (11-20 July 2023) the status of the "Working Group on digital object identifier (DOI) for geodetic data (GGOS DOI WG) was changed to the permanent "Committee on Digital Object Identifiers (DOIs) for Geodetic Data Sets" (GGOS DOI Committee). This includes the participation of the chair of the committee as full member of the GGOS Coordination Board (CB).

The main goal for the GGOS Committee on DOIs for geodetic data was the preparation of the Metadata Recommendations for Geodetic Datasets – part 1: GNSS Data. The draft document was introduced during the CB meeting 2023, and shared with the working group members and the co-chairs of the IGS Infrastructure Committee. A revised version was presented during the AGU2023 meeting with a call for public comments. On 29th January 2025, the GGOS DOI recommendations were approved by the IGS Governing Board. To support their implementation, a dedicated ad-hoc IGS DOI task force was installed with the aim to finalise dedicated recommendations for specific IGS data sets and products and to address the question if it would be possible to recommend one or two licenses for GNSS data that could be adopted globally. The document is now in the final revision phase and a first version is planned to be published by summer 2025.

The work of the GGOS DOI Committee was and will be presented during the following meetings: EGU General Assembly (2023, 2024, 2025), 28th IUGG General Assembly (invited talk and a dedicated side meeting to reach out to the community), IGS Governing Board Meetings (GB64 10-11 July 2023, Potsdam; GB66 30 June 2024, Bern), AGU2023, 13th IVS General Meeting and 25th Anniversary (invited talk, 4-9 March 2024, Tsukuba), and the GGHS (4-8 Sep 2024, Thessaloniki). Timely correlated with the 13th IVS General Meeting, the chair of the GGOS DOI Committee participated and presented the Committee in the annual GGOS Japan meeting and a dedicated DOI workshop for geodetic data for Japanese institutions (11-12 March 2024, Tachikawa).

**Planned Actions and Milestones**

Planned actions and milestones for 2025 are to further develop the DOI Metadata Recommendations for other geodetic techniques and services and to initiate discussions on ethical

aspects of DOI assignment. These mainly include the results of common practices that geodetic data products are often distributed via more than one data center or repository and that there are different approaches about the DOI assignment. The ethical question here is: Should a new DOI be assigned for all representations of the same data product or can the original DOI and publisher be conserved. Recent activities reveal the timely need for discussions and the development of guidance that can be agreed upon widely.

# 3 GGOS Bureaus

## 3.1 GGOS Bureau of Networks and Observations (BNO)

**Website:** https://geodesy.science/ggos/structure/bureau/bno/

**Director:** José C. Rodríguez (IGN, Spain)
**Deputy Director:** Martin Lidberg (Lantmäteriet, Sweden)

The new Chairs of the Bureau were elected in February 2024, after a fruitful period of service by Mike Pearlman (CfA). This coincided with several changes in the Committees associated with the BNO:

- New leadership in PLATO and C-DIS.
- Updated Joint Working Group: Metrology of Space Geodetic Infrastructure (replaces JWG on Site Survey and Co-locations).
- New Joint Working Group: IAG WG 1.1.1 on Genesis.

The Bureau and its Committees have contributed to the revision of the new GGOS Implementation Plan, the basis for its future activities for the forthcoming 10-year period. Some of the activities assigned to the BNO are of relevance to the activities and goals of the recently created UN-GGCE, informing from the point of view of the geodetic science community the goals of the Centre. In particular, activities within the "Science-Policy Networking" and "Capacity Enhancement and Sustainability" goals of the GGOS Implementation Plan, some of which have been started within the relevant Committees. A current stream of work within the BNO is related to the definition of GGOS Core Sites. The BNO membership and the broader community has been consulted to seek feedback. Clearer, updated definitions will be the basis for the updated documentation detailing the requirements for Core Sites, to be done with the participation of the Services. This in turn will inform other reports expected to be produced by the Bureau, related to the challenges and practices required to host geodetic stations, and the priorities for its deployment. The Bureau has continued to have presence at various scientific venues, with presentations given highlighting the collaboration and significant synergies with the UN-GGCE.

### Standing Committee on Performance Simulations and Architectural Trade-Offs (PLATO)

**Chair:** Alexander Kehm (DGFI, Germany)
**Vice-Chair:** Benjamin Maennel (GFZ, Germany)

Current Status and Progress:

- Splinter meeting at EGU 2025 and several studies related to PLATO presented at EGU.
- Co-operation with the IAG JWG 1.1.1 on Genesis.
- New contributing institutions in Australia and India.
- Updated inventory of PLATO-related studies and publications as basis for future plans.

Examples of recently finished and ongoing studies:

- Simulation studies on VLBI scenarios for Genesis (TU Wien).
- Simulation study on the integration of Genesis into VGOS (University of Tasmania).
- SLR simulation studies on Genesis and geodetic satellites (WUELS Wrocław).

- Studies towards a novel approach to treat co-location sites with common clock and common target (DFG RU Clock Metrology; Uni Bonn, DGFI-TUM).
- Simulation studies on NextGNSS4GGOS (GFZ, Uni Bonn).
- Troposphere simulations for VLBI (ETH Zurich).
- Simulation studies to determine best location for a new VGOS telescope in India (IIT Kanpur).
- Studies towards an optimal exploitation of VLBI Intensive sessions for EOP determination (BKG).

Plans:

- Publication of a White Paper on robustness of the space-geodetic ground networks.
- Continue to encourage additional groups to contribute to PLATO.

### Standing Committee on Data and Information Systems DIS

**Chair:** Roger Fraser (Victoria Department of Transport and Planning, Australia)
**Vice-Chair:** Taylor Yates (NASA GSFC, USA)

Having established revised Terms of Reference and tasks for 2024-2028, the Committee has commenced work on activities to revise the conceptual model, harmonise / aggregate work undertaken by Royal Observatory of Belgium and Geoscience Australia to improve FAIRness of data, investigate how to incorporate metadata from other measurement techniques (e.g. DORIS, SLR, VLBI), and to output the data in more widely adopted and accessible formats. Accordingly, representation on the committee has broadened to include experts from different geodesy and data modelling domains.

The work to revise the conceptual model is twofold. Firstly, work will be undertaken to incorporate the latest developments in ISOs and best practices for metadata modelling (either outdated or unavailable at the time of the original schema development). Secondly, the conceptual model will be transitioned from what is largely a terrestrial geodetic data and GNSS CORS site log schema, to a more holistic geodetic observing system sschema, with profiles to support specialisation of the respective geodetic measurement techniques and equipment. This will enable information to be represented and exchanged by a single metadata schema and displayed consistently on Web mapping servers regardless of the GGOS site or equipment type.

### Standing Committee on Satellite Missions

**Chair:** Roland Pail (TUM)
**Vice-Chair:** C.K. Shum (OSU)

Current Status and Progress:

- Evaluating contribution of current and near-term satellite missions to the GGOS 2020 goals.
- Advocate the realization of future gravity field missions.
- Support of MAGIC double-pair constellation, being composed of: 1) GRACE-C: polar pair, funded by NASA and DLR; 2) NGGM: inclined pair, funded by ESA.

Plans:

- Set-up a new concept of the Committee to increase participation by potential members.

- Advocate and support national and international space agencies in their processes towards future gravity missions, by providing/exchange available technical information, and propose to support/participate in missions studies towards their realization.
- Communicate with Chinese IAG colleagues to seek advice and collaborations to advocate for possible availability of Chinese gravity mission data to the scientific community.
- Continue exchange with PLATO on joint interests and possible collaborations.
- Evaluate the impact of SWOT to IAG/GGOS products.
- Advocate and support Genesis.

### IAG Joint Working Group 1.2.2: Metrology of Space Geodetic Infrastructure

**Chair:** Ryan Hippenstiel (NOAA, USA)
**Vice-Chair:** Cornelia Eschelbach (University Frankfurt University of Applied Sciences, Germany)

The name of the committee was updated after desire from IAG to refresh it. New Co-Chair joining this year, with Sten Bergstrand stepping down. The update is a good opportunity to expand on new protocols, technology and sensors, all at the service of improving local tie determination and other challenges (e.g. deformation, monitoring).

Activities:

- Measurement and modelling gravitational deformations of the receiving unit of Hobart26, Hobart, Australia, in 2024 (University of Tasmania, Frankfurt UAS) - https://doi.org/10.1186/s40623-024-02110-8
- Measurement of antenna surface of HARTRAO and HART15M, South Africa, in 2024 (SARAO, TUM and TU Wien) - https://zenodo.org/records/15268723
- Gravitational deformation measurement of 20 m radio telescope on Svalbard, Norway (RISE, Kartverket) - https://zenodo.org/records/15210004
- Tie surveys for connecting DORIS stations (IGN): Everest (Nepal), Metsahovi (Finland), Owenga (New Zealand- Chatham Island), Ulaanbataar (Mongolia), Le Lamentin (France – La Martinique).
- Survey including the use of photogrammetry to determine the SLR instrument reference point Grasse (France) (IGN).
- Investigations on the stability of reference points of VGOS antennas at OSO (Chalmers Univ.Tech., Frankfurt UAS).
- Local tie survey at Goddard, including all four space geodetic techniques (NOAA).
- Local tie survey at Shimosato (Shimosato Hydrographic Observatory, Japan Coast Guard, GSI).
- Local tie vector measurement at Syowa (GSI).
- Technical developments for Deflection of the Vertical measurements (NOAA).

### IAG Joint Working Group 1.1.1: Genesis

**Chair:** Johannes Böhm (TU Wien, Austria)

Genesis is a mission of the European Space Agency (ESA), approved for launch in 2028. A satellite in a near-polar circular orbit at about 6000 km altitude will be equipped with a VLBI transmitter, an SLR retroreflector and well as GNSS and DORIS receivers. While ESA will realize the mission and has set up a Science Team, there is close co-operation with the scientific community at large. Consequently, this joint working group on Genesis by IAG,

IERS, and GGOS serves as an open forum for the international scientific community to exchange ideas and information, and to work for the best possible implementation of Genesis and the exploitation of its opportunities.

Current status and progress:

- Terms of Reference as well as goals and objectives have been defined
- List of members and webpage have been set up: https://colab.tuwien.ac.at/display/GW/
- Three hybrid WG meetings were held at TU Wien (April 2024, October 2024, May 2025)
- Fourth WG meeting will be held in November 2025
- Inventory of peer-reviewed publications with relation to Genesis and of possible contributions by the various groups to the analysis of Genesis observations has been generated
- Feedback has been given to ESA on orbit inclination and metadata of the satellite

Plans and ongoing work:

- Identification of possible scenarios for the utilization of Genesis for the improvement of the terrestrial reference frame
- Combined orbit determination of the Genesis satellite; among the strategies possible, the combination at the normal equation level will be investigated
- Set up and implement a work plan with timeline to make the most promising scenarios possible once data is available
- Review and investigate existing co-locations in space between GNSS, DORIS, and SLR, as well as VLBI observations to satellites
- Identify and investigate new scientific opportunities, which will become possible with Genesis

## 3.2 GGOS Bureau of Products and Standards (BPS)

**Website:** https://geodesy.science/ggos/structure/bureau/bps/

**Director:** D. Angermann (1)
**Deputy Director:** T. Gruber (2)
**Members:** M. Gerstl (1), R. Heinkelmann (3), U. Hugentobler (2), L. Sánchez (1), P. Steigenberger (4)

(1) Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Germany (2) Institut für Astronomische und Physikalische Geodäsie (IAPG), Technische Universität München, Germany (3) GFZ Helmholtz Centre for Geosciences, Potsdam, Germany (4) Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany

**Present Status and Progress**

This report summarizes the present status and progress of the GGOS Bureau of Products and Standards (BPS), including the three GGOS components associated to the BPS:

- Committee "Contributions to Earth System Modeling" (Chair: Maik Thomas)
- Committee "Definition of Essential Geodetic Variables (EGVs)" (Chair: Thomas Gruber)
- Working Group "Consolidation of best estimate GRS based on the adopted W0 of the IHRF" (Chair: Urs Marti)

The BPS is chaired by DGFI-TUM and operated jointly with TUM's Chair of Astronomical and Physical Geodesy. Further involved partners are GFZ (Helmholtz Centre for Geosciences, Potsdam) and DLR (German Aerospace Centre, Oberpfaffenhofen). The Bureau comprises the staff members, the chairs of the associated GGOS components, as well as representatives of the IAG Services and other entities involved (see GGOS website at https://geodesy.science/ggos/structure/bureau/bps/ for more information).

The BPS supports GGOS in its key goal to obtain consistent geodetic products describing the geometry, rotation and gravity field of the Earth as global functions of space and time. The primary objectives of the BPS are to:

- Serve as contact and coordinating point for the homogenization of geodetic standards and products
- Keep track of the adopted standards and conventions across all IAG components
- Motivate the development of integrated geodetic products needed for Earth sciences and society
- Promote geodetic products to improve the visibility and awareness of geodesy

Major activities and the progress of the BPS are summarized below:

- A long-term activity of the BPS is to keep track and foster the homogenization of the standards, constants and conventions adopted by the IAG. The BPS has compiled an inventory of standards and conventions used for the generation of IAG products (published in the Geodesists Handbook 2016 and 2020), which is being updated on a regular basis to incorporate the latest developments regarding standards and geodetic products. In the framework of the revision of the IERS Conventions, the BPS contributes to the revision of Chapter 1 "General definitions and numerical standards" in its function as Chapter Expert.

- In collaboration with the IAG and other GGOS components, the BPS has created used-friendly descriptions of geodetic products, which have been implemented at the GGOS website (https://geodesy.science/ggos). The BPS also supports the GGOS Coordination Office in the development of the GGOS Portal that serves as a unique search and access point (one-stop-shop) for geodetic data and products.
- With the involvement of the BPS, the United Nations Global Geodetic Centre of Excellence (UN-GGCE) team organized a series of virtual meetings with representatives from the IAG Services (including the IERS, IGS, ILRS, IVS, IDS, and IGFS) to collect information on the status, needs, products, users, and costs associated with the running of the global geodesy supply chain. For this purpose, a set of questions was prepared, addressing the focus areas of evidence, resources, governance, capacity and awareness. These meetings aimed to gain a deeper understanding of the specific needs of each IAG Service and to provide information for UN-GGCE's Global Geodesy Needs Assessment [1] and a First Joint Development Plan for Global Geodesy [2] to strengthen the global geodesy supply chain.
- The BPS contributes to promote geodetic results to other disciplines and to make geodesy more visible in the geoscientific community and beyond (Angermann et al. 2023). In collabo-ration with the GGOS Coordinating Office and the UN-GGCE, the BPS contributes to outreach activities in social media, e.g., through the creation of videos and cartoons about geodesy and the publication of geodetic results in non-specialist language.
- Furthermore, the director of the BPS contributes to the UN GGIM "GGRF" Subcommittee on Geodesy (SCoG), mainly to the Working Group "Data sharing and development of geodetic standards" and serves as IAG representative to ISO/TC 211. The BPS also contributes to the activities of the Committees "Definition of Essential Geodetic Variables (EGVs)" and "DOIs for geodetic data", and to the GGOS Working Group "Consolidation of best estimate GRS based on the adopted W0 of the IHRF".

**Ongoing Activities and Planned Actions**

The ongoing activities and planned actions of the Bureau can be divided into four main categories:

- Coordination activities: This category comprises GGOS Governing Board meetings (twice per year) and monthly telecons of the GGOS Executive Committee to ensure a regular exchange of information among the GGOS components and to manage the strategic planning and day-to-day activities. Furthermore, external and internal BPS meetings are regularly scheduled to coordinate and perform the operational Bureau work.
- Unification of standards: A continuous task of the BPS is to keep track of adopted geodetic standards and conventions across all GGOS components as a fundamental basis for the generation of consistent geodetic products. This task requires the interaction with the IAG Services, the IERS Conventions Center, the IAU Commission A3 "Fundamental Standards", and ISO/TC 211. An important long-term activity is a regular updating of the BPS inventory of standards and conventions to incorporate the latest developments in these fields.

[1] Global Geodesy Needs Assessment, United Nations Global Geodetic Centre of Excellence, Version 1.0, 9 May 2024, https://ggim.un.org/UNGGCE/documents/20240509-Global_Geodesy_Needs_Assessment.pdf, 2024

[2] 1st Joint Development Plan for Global Geodesy, United Nations Global Geodetic Centre of Excellence, Bonn, Germany, https://ggim.un.org/UNGGCE/documents/Version_1.0_1st_Joint_Development_Plan_for_Global_Geodesy_EN.pdf, 2025

- Geodetic products: Ongoing BPS activities and planned actions are to generate further product descriptions (e.g., terrestrial water storage, time series of inland water, ...), to foster the development of new geodetic products needed for Earth sciences and society, to perform an accuracy assessment, gap analysis, and to define requirements for geodetic products. The latter tasks are related to the work of the Committee "Definition of Essential Geodetic Variables". In collaboration with the UN-GGCE and the IAG Services, the BPS contributes to the mapping of the global geodesy supply chain regarding infrastructure, governance and product generation.
- Outreach: The BPS supports the GGOS Coordinating Office concerning the updating of the GGOS website, particularly regarding the description and representation of geodetic products. The BPS also contributes to the generation of GGOS films dedicated to specific geodetic products (e.g., terrestrial reference frames) to make other disciplines and society aware of geodesy and its beneficial products. Furthermore, the BPS contributes to other GGOS outreach activities such as popular science articles, brochures, fact sheets, and the creation of cartoons about geodesy, etc.

**Reference:**

Angermann D., Pail R., Seitz F., Hugentobler U.: The importance of geodetic reference frames – A uniform basis to tackle current and future challenges. GIM International, 37(7), 2023.

## GGOS Committee on Earth System Modeling

**Chair:** Maik Thomas (GFZ Helmholtz Centre for Geosciences, Potsdam, Germany)

**Role:** The main intention of this committee is 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 processes responsible for the observed variations;
- The establishment of a link between the GGOS products 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.

**Present Status and Progress**

Recent activities of the committee related to the combination of data assimilation techniques and AI algorithms as well as on model error estimates have been continued. Foci were in particular placed on:

- Application of neural networks in system model approaches for mid-term predictions of Earth orientation parameters;
- Sensitivity experiments for the estimation of the importance of anelasticity in forward, i.e., unconstrained surface deformation models;
- Evaluation of simulated third-degree ocean tides by means of in situ measurements with superconducting gravimeters and estimation of their relevance in background models for the processing of satellite gravity missions;
- Assessment of recent approaches for the estimation of inherent model errors and uncertainties.

Furthermore, the discussion on purposes (and disadvantages) of the implementation of algorithms based on artificial intelligence into numerical model components is ongoing. Due to its complexity as well as strategic relevance this will be an important topic also in the following years.

**Planned Actions and Milestones**

Planned activities in the next year will mainly focus on:

- Continuation of feasibility studies regarding the coupling of neural networks with data assimilation techniques and application of the combined approach in stand-alone models;
- Evaluation of various approaches for the representation of nonlinear friction and their impact on shallow water tide dynamics;
- Discussion of implications of upcoming new hardware architectures for computationally intensive system model simulations;
- Discussion of consequences of open sciences principles for the geodetic model community, e.g., in view of open access to model source codes, analysis tools, etc.

**References**

1. Dill, R., Stumpe, L., Saynisch-Wagner, J., Thomas, M., Dobslaw, H. (2025): Benefits of refined 10-day effective angular momentum forecasts for earth rotation parameter prediction. Journal of Geodesy, 99, 15. https://doi.org/10.1007/s00190-025-01941-x
2. Jung, H., Saynisch-Wagner, J., Schulz, S. (2024): Can eXplainable AI Offer a New Perspective for Groundwater Recharge Estimation?—Global-Scale Modeling Using Neural Network. Water Resources Research, 60, 4, e2023WR036360. https://doi.org/10.1029/2023WR036360
3. Shihora, L., Liu, Z., Balidakis, K., Wilms, J., Dahle, C., Flechtner, F., Dobslaw, H. (2024): Accounting for residual errors in atmosphere–ocean background models applied in satellite gravimetry. Journal of Geodesy, 98, 27. https://doi.org/10.1007/s00190-024-01832-7

## GGOS Committee on the Definition of Essential Geodetic Variables EGV

**Chair:** Thomas Gruber (Technical University of Munich, Germany)

**Present Status and Progress**

The GGOS Committee "Definition of Essential Geodetic Variables" was established in 2018 in order to define a list of Essential Geodetic Variables and to assign requirements to them. Geodesy observes the Earth as a whole, from the interior to the surface, including the atmosphere, with regional and local refinements, and provides a large number of products for this purpose. Moreover, geodetic products are needed for all positioning and satellite navigation tasks, and thus play an elementary role in modern society. So far, however, these products suffer from a lack of visibility for the global society (non-geodetic communities, administration, decision makers, science and others) and in some cases they are also not easy to understand for non-experts. Therefore, these products are regarded as contribution of geodesy to Earth observation providing substantial information to a set of Essential Geodetic Variables (EGVs), which are crucial (essential) to characterizing the geodetic properties of the Earth and that are needed to understand the dynamics of the Earth system in all its

components and their interplay. An EGV is a geometrical or a physical variable or a group of linked variables that critically contributes to the characterization of the geometrical and physical shape of the Earth and to its orientation in space. All essential variables shall be continuously monitored and shall meet specific requirements in terms of spatial and temporal resolution and in terms of latency and consistency. They are essential to continuously monitor the Earth system, to assess possible risks, to develop mitigation strategies and to underpin the availability of sustainable geodetic services.

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. Between 2019 and 2023 an initial gap analysis was performed and first ideas about the definition of EGVs and requirements to them were developed within the committee and presented at various occasions (IUGG 2019 and 2023, GGOS days 2019 to 2023). After IUGG 2023 a white paper was written as discussion basis, where a first set of high level EGVs is described in more detail and where the links between EGVs and geodetic products are identified. The white paper has been reviewed in autumn 2024 by the GGOS Science Panel, in winter 2025 by the GGOS Governing Board and in spring 2025 by the IAG Executive Committee and the United Nations Global Geodetic Centre of Excellence (UN-GGCE). From each review valuable comments have been received and were and are considered in the current or will be considered in next version of the document. In January 2025 the current version of the document was published as a citable GGOS document in order to inform the broader scientific community about the initiative and the status (Gruber et al., 2025).

**Planned Actions and Milestones**

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

- Assign requirements for high level EGVs and analyze if existing geodetic products meet these requirements or identify needs. This will be done in close contact to the IAG services who provide the products contributing to the EGVs.
- Publish high level EGVs and their requirements to the scientific Earth observation community with an update of the GGOS document.
- Discuss the purpose of and needs for lower level EGVs, e.g., as a tool to assess deployed and needed geodetic infrastructure and update the list of EGVs accordingly.

**Reference:**

Gruber, T.; Angermann, D.; Sánchez L. (2025), Definition of Essential Geodetic Variables (EGV): Contribution of Geodesy to Earth Observation, White Paper, Global Geodetic Observing System (GGOS) https://doi.org/10.5281/zenodo.14619439.

## GGOS WG "Consolidation of a best estimate GRS based on the adopted W0 of the IHRF"

**Chair:** Urs Marti (Federal Office of Topography swisstopo, Wabern, Switzerland)

**Present Status and Progress**

The main task of this WG is to define a consistent set of parameters and formulas for the definition of a new conventional Global Reference System (GRS). This includes the geometry (size and shape of a reference ellipsoid), the gravity field (normal gravity field of this ellipsoid), physical heights, terrestrial time and Earth rotation.

The new set of parameters is based on the four fundamental parameters: W0 (Potential at Reference Level), J2 (dynamic form factor, "flattening"), GM (geocentric gravitational constant) and $\omega$ (angular velocity of the Earth). All these quantities are well observed and monitored by various geodetic space techniques. Besides of the fact that the chosen parameters are physically meaningful, a further argument in favor to use these parameters was presented by Panou et al. at the EGU2024: They are less correlated among each other than to the semi-major and semi-minor axis a and b. Therefore, the derived parameters can be calculated with smaller formal errors.

Most of the defining parameters change with time. This includes seasonal variations and long-term trends. These changes are important and must be considered for the consistency of the ITRF (e.g. ellipsoidal heights). Nevertheless, in order to keep things simple for the user, this time variability will not be treated in the published definition of a new GRS. All quantities will be fixed to a certain epoch. All calculations are done in the zero-tide system. Only at the very end, conversion formulas to mean-tide and tide-free will be given for all quantities. In order to keep things simple, some very minor terms in these conversions will be neglected.

It is not the goal of the WG to determine new "best estimate" parameters. We will rely on already published and well documented values. The main goal is to reach consistency in the use of the GRS in geodesy and in all related sciences.

This gives us the following preliminary set of defining parameters:

- $W_0 = U_0 = 62\,636\,853.4 \pm 0.02\ \mathrm{m^2\,s^{-2}}$
  (Zero Tide, from Sánchez et al. 2016, IAG resolution 2015)
- $GM = (398\,600\,441.5 \pm 0.4) \times 10^6\ \mathrm{m^3\,s^{-2}}$
  (from Ries 2007, IERS Conventions 2010, converted to Terrestrial Time)
- $J_2 = (1.082\,635\,9 \pm 0.000\,000\,045) \times 10^{-3}$
  (from Cheng et al. 2013, from SLR time series)
- $\omega = (7\,292\,115 \pm 10) \times 10^{-11}\ \mathrm{rad\,s^{-1}}$
  (conventional value from IERS Conventions 2010)

An agreement on which basic formulas have to be used for the calculation of derived quantities could be reached in the WG. The correct calculation of all the derived quantities could be verified with three different independent software packages. Further work on the influence of the tidal system and the treatment of changes in the time system have been performed. A study on the influence on the normal gravity field is under way.

**Planned Actions and Milestones**

A draft version of a paper with the calculation of the parameters is available. It has to be finished and discussed in the WG. It follows more or less the structure of the papers by Moritz (1980) and Groten (2004). The progress of the work has been presented at the IUGG 2023 in Berlin and at the GGOS days 2024. Several presentations at conferences (EGU 2024, GGHS2024, EGU2025) have been given by WG members.

The definitive choice of the numerical values of the defining parameters will be one of the next steps. For this, a large agreement in the geodetic community is needed.

The calculation of a new set of parameters is one thing. The main problem will be to convince the users to adopt such a system as a new global reference. Many users don't see

the necessity to replace GRS80, as they just see it as a conventional model for the conversion of geocentric coordinates or for the calculation of gravity anomalies. Main concerns are the danger of confusion and the necessity to update many software packages. This discussion has still to be lead. A list of arguments in favor and against changing the GRS is in preparation.

Another question to be answered is the necessity to define a conventional global gravity field model. For many applications (e.g., global height system, reference for local geoid determination), the assignment of such a standard model would have some advantages. For different application we would need a low-resolution satellite-only model and a high-resolution combined model.

**Reference:**

Panou, G. and Marti, U.: Current adjustment of the mean Earth ellipsoid parameters, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-4313, https://doi.org/10.5194/egusphere-egu24-4313, 2024.

# 4 GGOS Science Panel

**Website:** https://geodesy.science/ggos/structure/science-panel/

**Chair:** José M. Ferrándiz (University of Alicante, Spain)

The handover of the chairmanship of the GGOS Scientific Panel (SP) took place by November 2023. During the GGOS Days 2023 the previous chair, Kosuke Heki, had presented the SP activity report and, after the end of his term of office continued overseeing the organization of the AGU 2023 and EGU 2024 GGOS sessions whose preparation he had already started. These sessions were, respectively:

- Global Geodetic Observing System: The Reference for Earth System Monitoring and featuring VLBI component
- Serving Global Geodesy: Innovations Enabled by the IGS and IAG-GGOS

The organization of the GGOS sessions at the following AGU and EGU meetings was already under the responsibility of the current chair. That of the AGU Fall Meeting in 2024 was entitled "Geodetic Standards for Improved Accurate and Consistent Earth Observation Products from the Global Geodetic Observing System Techniques" and, and, as it received enough abstracts to be assigned an oral session, it featured two invited presentations: one by Benedikt Soja, with the topic of "Harnessing the power of AI for Geodesy: recent developments within the GGOS Focus Area AI4G", and the other by Alberto Escapa, who spoke on "On Earth Rotation Standards and their Potential Update". The oral presentations and posters illustrated a variety of topics within the broad field of interest of GGOS, with contributions from several IAG Services, such as IVS, ILRS and DORIS, whose techniques do not have their own sessions unlike the IGS, as well as the new Iberatlantic Affiliate. It should be noted that the media promotion work, already carried out with great success in previous meetings, continued, with the invaluable help of Allison Cradock and Martin Sehnal, among others.

The GGOS session at the 2024 EGU General Assembly was "GGOS: Fostering collaboration in geodesy to address challenges for science and society" and managed to take place as the previous one without the need to merge with another proposal. This session included the special guest participation of Nicholas Brown, Head of the UN GGCE, who presented an interesting talk on the current state of geodesy entitled "Hidden Risks: The weakness in the global geodesy supply chain that threaten modern society". Also worth mentioning is the invited presentation by Laura Sanchez, Thomas Gruber and Detlef Angermann on "The Strategic Role of Essential Variables in Geodesy", after which the advances of the last few years can be considered to have moved to the stage of wider dissemination and discussion in the scientific community.

To conclude this information on the organization of scientific sessions on GGOS at major conferences, we would like to mention that the proposal for a session entitled “A Scientific and Observational Network for a Connected Planet: The Contribution of Geodesy to Earth System Monitoring” is currently pending acceptance at the AGU 2025 Fall Meeting.

On the other hand, the SP members have participated as usual in the tasks required by the EC, in particular the review of drafts related to the strategic plan and its implementation and to the essential geodetic variables.

# 5 GGOS Focus Areas

## 5.1 Focus Area: Geodetic Space Weather Research (GSWR)

**Website:** https://geodesy.science/ggos/structure/fa/geodetic-space-weather-research/

**Chair:** Michael Schmidt (DGFI-TUM, Germany)
**Vice-Chair:** Ehsan Forootan (Denmark)

### Introduction

Space weather is a very up-to-date and interdisciplinary field of research. It describes physical processes in the near-Earth space mainly caused by the Sun's radiation of energy. The manifestations of space weather are multiple, e.g. variations of the Earth's magnetic field, variations of the upper atmosphere consisting of the compartments magnetosphere, ionosphere, and thermosphere, also known as the MIT system (due to coupling processes), including the plas-masphere, as well as the solar wind, i.e. the permanent emission of electrons and photons in-cluding the interplanetary magnetic field (IMF), i.e. the component of the solar magnetic field that is dragged out from the solar corona by the solar wind flow. The magnetosphere is the part of the near-Earth space, in which the total magnetic field is dominated by the Earth's magnetic field and not by the IMF. It is well-known that the pressure of the solar wind com-presses the magnetic field on the day side of the Earth and stretches it into a long tail on the night side.

### Objectives and structure

The GGOS Focus Area on Geodetic Space Weather Research (FA-GSWR) was initiated in 2017. Current main objectives concentrate on the

- development of improved ionosphere and plasmasphere models,
- development of improved thermosphere models,
- study of the coupled processes within the MIT system,
- improved understanding of space weather events and their monitoring by geodetic and non-geodetic space missions and techniques.

The first objective aims at the high-precision and the high-resolution (spatial and temporal) modelling of the electron density. This finally allows to compute a signal propagation delay, which will be used in many geodetic applications, such as positioning, navigation and timing (PNT) based on the use of the space geodetic observation techniques. Moreover, it is also im-portant for other techniques using electromagnetic waves, such as satellite- or radio communi-cations. The second objective is beneficial for satellite geodesy, especially precise orbit deter-mination (POD), but there are further technical matters like collision analysis or re-entry calcu-lation, which will become more reliable when using high quality thermosphere models. The third objective links the first two by introducing physical laws and principles such as continui-ty, energy and momentum equations and solving partial differential equations to describe the thermosphere-ionosphere coupling processes. The fourth objective finally connects the im-proved understanding to the monitoring techniques and vice versa. Figure 7 visualizes the structure of the FA-GSWR including the magnetosphere which is the region of the space around the Earth where the dominant magnetic field is the Earth's magnetic field, rather than the IMF. The bottom boxes in Fig. 7 show the results, which should finally be provided as IAG (geodetic) products to the users for direct applications. Furthermore, Fig.

7 shows the places of the 4 newly installed Joint Study Groups (JSGs) of the FA-GSWR for 2023-2027, in the structure.

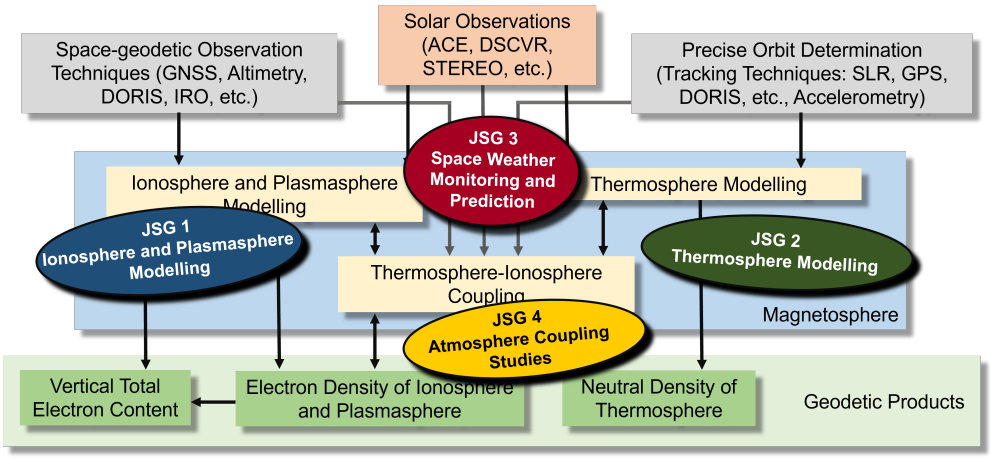


**Fig. 7.** Structure of the IAG GGOS Focus Area on Geodetic Space Weather Research (FA-GSWR) for the period 2023-207, including the components Magnetosphere, Plasmasphere, Ionosphere and Thermosphere as well as the 4 Joint Study Groups (JSG) of the FA-GSWR.

To reach the objectives of FA-GSWR, 4 Joint Study Groups (JSG) have been defined and implemented into the IAG GGOS program, namely:

- **GGOS.GSWR.JSG 1**: Understanding Ionospheric and Plasmaspheric Processes (led by GGOS; joint with IAG Commission 4, Sub-Commissions 4.1 and 4.3), Chair: Fabricio dos Santos Prol (Finland), Vice-Chair: David R. Themens (United Kingdom)
- **GGOS.GSWR.JSG 2**: Thermosphere Modelling and Applications (led by GGOS; joint with IAG Commission 4, Sub-Commission 4.3), Chair: Guenther March (Netherlands), Vice-Chair: Armin Corbin (Germany)
- **GGOS.GSWR.JSG 3**: Space Weather Monitoring and Prediction (led by GGOS; joint with IAG Commission 4, Sub-Commission 4.3), Chair: Haixia Lyu (China), Vice-Chair: Benedikt Soja (Switzerland)
- **GGOS.GSWR.JSG 4**: Atmospheric Coupling Studies (led by ICCT; joint with GGOS FA-GSWR and IAG Commission 4, Sub-Commission 4.3), Chair: Andres Calabia Ai-bar (Spain), Vice-Chair: Binod Adhikari (Nepal)

Other established IAG Study and Working Groups have been providing valuable input for the FA-GSWR, in particular from the Commission 4, Sub-commission 4.3. The work within the FA-GSWR is being carried out in close relation to the International Association of Geomag-netism and Aeronomy (IAGA), since this organization is also concerned with the understand-ing of properties related, e.g. to the ionosphere and magnetosphere as well as the Sun and the solar wind. In this context, we want to mention the Interdivisional Commission on Space Weather (ICSW). Partly, the work in the FA-GSWR is related to the International Association of Meteorology and Atmospheric Sciences (IAMAS).

In what follows, an overview of the scientific work of the four JSGs of the FA-GSWR within the last two years, i.e. the reporting period 2023 to 2025, is provided.

## Activities

In the previous 4-year IAG period from 2019 to 2023 the 4 groups (1 Joint Study Group and 3 Joint Working Groups) of the FA-GSWR worked very successful on many scientific pieces to reach the objectives of the individual groups. Thus, during this time the 4 groups worked mostly independent. In the current 4-year IAG period from 2023 to 2027, the work, in partic-ular the results of the 4 groups from the previous 4-year period 2019 to 2023, is being linked in such a way that we get closer to, for example, the study of coupling processes and the com-bination of solar and space geodetic observation techniques; this includes also the comparison with physical models such as Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM). Finally, we want to better understand the whole chain of physical pro-cesses between the Sun and the Earth' surface.

From each of the 4 JSGs we will need so-called 'Foreseen GGOS Products'. These products, such as global and regional VTEC or electron density maps should be finally provided to us-ers. They should also be interchanged between to JSGs for joint activities, e.g. comparison studies. In this term, the FA-GSWR continues working on the following aspects:

- Extensive simulation studies to assess the impact of space weather events on technical systems to define necessary actions in case of severe space weather events,
- Development of ionosphere/plasmasphere models as well as thermosphere models (maps) as stated above as IAG (geodetic) products for direct applications,
- Definition/refinement and selection of the Essential Geodetic Variables (EGV) in the framework of the scientific work within FA-GSWR,
- Establishment of recommendations for the applications of relevant models, e.g., in precise satellite orbit determination, for collision avoidance, in space debris analysis, and for re-entry computations.

Additionally, following new aspects are being faced:

- Extend the investigation area within the FA-GSWR from the upper atmosphere to the lower atmosphere. This leads to an integrated analysis of the MIT coupling processes and the vertical coupling processes (co-operations with the new proposed Focus Area on Combined Tropospheric Products),
- In connection to the vertical coupling processes, we are investigating the projection of climate change effects from the lower to the upper atmosphere (co-operations with the Inter Commission Committee on Climate Research, ICCC).

Other planned activities are:

- Special Issue to disseminate the results of the FA-GSWR,
- Producing a GGOS film on the contribution of Geodesy to Space Weather Monitoring and Forecasting.

## GGOS Topical Meeting on the Atmosphere, held in Potsdam, Germany, 7-9 October 2024

The FA-GSWR convened geodetic and geophysical communities to participate in the GGOS Topical Meeting on the Atmosphere, held in Potsdam, Germany, 7-9 October 2024. The

main objectives were a general brainstorming and in-depth discussions on the challenges and oppor-tunities of integrating geodetic and geophysical technologies for a comprehensive monitoring of the lower atmosphere (i.e. troposphere and stratosphere), the mid atmosphere (mesosphere) and the upper atmosphere (incl. thermosphere, ionosphere and plasmasphere). This Topical Meeting was organised as a main activity of the project Characterisation of the Ionised Atmos-phere in terms of Essential Variables granted by the IUGG for 2024/2025 with the support of IAGA and IAG. The meeting was attended by 76 participants from 21 countries. 36 partici-pants are early career scientists. Thanks to the generous support of the IUGG, the IAG and the IAG, travel grants were provided to six colleagues to enable them to attend the meeting.

**Fig. 8.** Participants of the GGOS Topical Meeting on the Atmosphere, Potsdam, Germany, 7-9 October 2024 (Photo R. Heinkelmann)

56 contributions, 36 oral and 20 posters, were distributed in the following sessions:

- Session 1: Magnetosphere, Ionosphere, Plasmasphere and Thermosphere, as a coupled system
- Session 2: Ionosphere modelling and applications
- Session 3: Climate application of geodetic atmospheric parameters
- Session 4: Geohazards monitoring
- Session 5: Geodetic Methods for Water Vapor Monitoring
- Session 6: Severe Weather
- Session 7: Atmospheric modelling based on artificial intelligence

More information at

- Presentations: https://zenodo.org/communities/ggos-topical-meeting-atmosphere/
- Event website, meeting summary and photos: https://geodesy.science/event/ggos-topical-meeting-atmosphere/

## EGU 2025 session on Geodetic Observation Methods for Space Weather, held in Vienna 27 April–2 May 2025

**Convener:** Fabricio Prol
**Co-conveners:** Ehsan Forootan, Benedikt Soja, Günther March, Ana Lucia Christovam de Souza

The FA-GSWR convened a special session in EGU 2025, held in Vienna 27 April–2 May 2025. This session aimed to bring together scientists and researchers to discuss modelling methodologies and accuracy of space-based observations for advancing the accuracy and resilience of space weather modelling, monitoring, and forecast. Emphasis was placed on the use of geodetic observations (e.g., GNSS, GNSS-RO, VLBI, DORIS, InSAR) to provide insights into the ionosphere, plasmasphere, and thermosphere. The session explored recent advance-ments in total electron content (TEC) estimation and prediction, in three-dimensional iono-spheric modelling techniques such as tomography, in using data assimilation and machine learning techniques, in electron density retrieval from recent GNSS radio-occultation missions, and ionospheric scintillation impacts on GNSS data. We also encouraged studies assessing the impacts of atmospheric drag on low Earth orbit (LEO) satellites, aiming to improve neutral density estimation within the thermosphere through precise orbit determination (POD) and high-resolution accelerometer observations. Additionally, we welcomed contributions on monitoring space weather events through geodetic observations, including but not limited to geomagnetic storms, ionospheric plasma bubbles, and traveling ionospheric disturbances. Discussions on the implications of these space weather phenomena for positioning and navigation systems were also encouraged.

22 contributions, 10 oral and 11 posters, were presented. More information at https://meetingorganizer.copernicus.org/EGU25/session/51892.

## GGOS.GSWR.JSG 1: Understanding Ionospheric and Plasmaspheric Processes (Led by GGOS; joint with IAG Commission 4, Sub-Commissions 4.1 and 4.3)

**Chair:** Fabricio S. Prol (Finland)
**Vice-Chair:** David R. Themens (United Kingdom)
**Members:** Marcio Muella (Brazil), Artem Smirnov (Germany), Alessio Pignalberi (Italy), Zhe Yang (China), Yan Xiang (China), Tatjana Gerzen (Germany), Ehsan Forootan (Denmark), Min-Yang Chou (United States), Chris Watson (Canada), Sean Elvidge (United Kingdom), Paulo Sérgio de Oliveira Jr (Brazil), Timothy Kodikara (Germany), Ana Lucia Christovam (Brazil)

The need for improved global-scale electron density models has been widely acknowledged in the past years, particularly with the rise in space activity. Over decades, numerous studies have been conducted with particular interest on ionospheric and plasmaspheric models for geodetic positioning, space weather monitoring, aeronomy, and telecommunications. The JSG1 group aims to advance three-dimensional (3D) ionospheric and plasmaspheric models that are specifically developed for geodetic applications. The reason for this initiative arises from the demand for highly precise electron density models of the ionosphere and plasmasphere, essential for satellite-based navigation and precise orbit determination of artificial satel-lites. We are targeting both empirical- and physics-based models; however, accomplishing this task presents inherent challenges, including the need for comprehensive data coverage,

accu-rate measurement inversions, reliable measurements on a global scale, and an accurate initial guess of the modelling system. Therefore, our main objectives are:

- To promote solutions to overcome the challenges facing highly accurate ionospheric and plasmaspheric modelling.
- Promote the development of instruments to observe the ionosphere and plasmasphere.
- Evaluation and development of 3D imaging techniques of the ionosphere and plas-masphere. The parameters of interest include vertical electron density profiles, electron density peak and peak height, scale height, and vertical total electron content (VTEC), i.e. the column-integrated electron density.
- Improve our capacity to model the coupling and interaction between the ionosphere and plasmasphere.
- Enhance the feasibility of using 3D ionospheric maps for Precise Point Positioning (PPP).
- Propose perspectives and recommendations for future developments in 3D electron density estimation, with particular interest in geodetic positioning.

**Activities**

Activities achieved:

- Promote the development of new instruments for measuring the ionosphere.
- Development of an initial database of measurements for validation and testing.
- Development of several models of the ionosphere and plasmasphere.
- Development of tools for using 3D models in PPP.
- Coordinated the special issue "Ionospheric Imaging: Recent Advances and Future Directions" in Advances in Space Research, outlining emerging challenges in the field.
- Application for an in-person meeting together with the International Space Science Institute (ISSI) in Bern.

Current activities:

- Improving 3D ionospheric models.
- Enhancing the integration of ionospheric models with the plasmasphere.

Planned for the near future:

- Development of new model for the topside ionosphere.
- Review on the topside ionosphere.

**Recent publications**

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2. Christovam A. L., Prol F. S., Hernández-Pajares M., Camargo P. O. (2023) Plasma bubble imaging by single-frequency GNSS measurements. GPS Solut., 27, 124. https://doi.org/10.1007/s10291-023-01463-z
3. Forootan, E., Kosary, M., Farzaneh, S., Schumacher, M. (2023), Empirical Data Assimilation for Merging Total Electron Content Data with Empirical and Physical Models. Surv Ge-ophys 44, 2011–2041 (2023). https://doi.org/10.1007/s10712-023-09788-7

4. Hernández-Pajares M., Olivares-Pulido G., Hoque M. M., Prol F. S., Yuan L., Notarpietro R., Graffigna, V. (2023) Topside Ionospheric Tomography Exclusively Based on LEO POD GPS Carrier Phases: Application to Autonomous LEO DCB Estimation. Remote Sensing, 15, 390. https://doi.org/10.3390/rs15020390
5. Hoque M. M., Prol F. S., Hernandez-Pajares M., Notarpietro R., Yuan L., Olivares-Pulido G., Graffigna V., Von Engeln A., Marquardt C. (2023) Assessment of GRAS Ionospheric Measurements for Ionospheric Model Assimilation. Remote Sensing, 15, 3129. https://doi.org/10.3390/rs15123129
6. Hoque M. M., Yuan L., Prol F. S., Hernández-Pajares M., Notarpietro R., Jakowski N., Oliva-res Pulido G., Von Engeln A., Marquardt C. (2023) A New Method of Electron Density Retrieval from MetOp-A's Truncated Radio Occultation Measurements. Remote Sensing, 15, 1424. https://doi.org/10.3390/rs15051424
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8. Lyu, H., Hernández-Pajares, M., Li, M. et al. (2024) Global 3D ionospheric shape function modeling with kriging. J Geod 98, 10. https://doi.org/10.1007/s00190-024-01908-4
9. Olivares-Pulido G., Hernández-Pajares M., Monte-Moreno E., Lyu H., Graffigna V., Cardellach E, Hoque M., Prol F. S., Notarpietro R., Garcia-Fernandez M. (2023) Real-Time Tomographic Inversion of Truncated Ionospheric GNSS Radio Occultations. Remote Sens-ing, 15, 3176. https://doi.org/10.3390/rs15123176
10. Pezzopane M., et al. (2024) An Update of the NeQuick-Corr Topside Ionosphere Modeling Based on New Datasets. Atmosphere, 15, 498. https://doi.org/10.3390/atmos15040498
11. Pignalberi A., Bilitza D., Coïsson P., Haralambous H., Nava B., Pezzopane M., Prol F., Smirnov A., Themens D. R., Xiong C. (2024) Validation of the IRI-2020 topside ionosphere options through in-situ electron density observations by low-Earth-orbit satellites. Advances in Space Research, In Press. https://doi.org/10.1016/j.asr.2024.05.056
12. Prol F. S., Hoque M. M., Hernández-Pajares M., Yuan L., Olivares-Pulido G., von Engeln A., Marquardt C., Notarpietro R. (2023) Study of Ionospheric Bending Angle and Scintillation Profiles Derived by GNSS Radio-Occultation with MetOp-A Satellite. Remote Sensing, 15, 1663. https://doi.org/10.3390/rs15061663
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16. Smirnov, A., Shprits, Y., Lühr, H. et al. (2025) Extreme two-phase change of ionospheric elec-tron temperature overshoot during geomagnetic storms. Sci Rep 15, 5043 (2025). https://doi.org/10.1038/s41598-025-89602-z

## GGOS.GSWR.JSG 2: Thermosphere Modelling and Applications (led by GGOS; joint with IAG Commission 4, Sub-Commission 4.3)

**Chair:** Guenther March (Netherlands)
**Vice-Chair:** Armin Corbin (Germany)

**Members:** Michael Schmidt (Germany), Günther March (Netherlands), Armin Corbin (Germany), Ehsan Forootan (Denmark), Christian Siemes (Netherlands), Kristin Vielberg (Germany), Jose van den IJssel (Netherlands), Mona Kosary (Iran), Sandro Kraus (Austria), Andreas Strasser (Austria), Saniya Behzadpour (Switzerland), Timothy Kodikara (Germany), Peter Nagel (USA), Andres Calabia (Spain), Federico Gasperini (USA), Florian Woeske (Germany, Chuntao Chang (China), Sabin Anton (Netherlands), Jack Wang (USA)

Neutral mass density, temperature, composition and winds are important state parameters of the thermosphere that affect aerodynamic forces on satellites, especially drag force. Since these significantly influence the orbits of space objects flying at altitudes below 700 km, accu-rate 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. However, recent models and accelerometer derived observations of the neutral mass density have significant discrepancies. Therefore, the objectives of the JSG2 are related to the improve thermosphere models. We aim for a better consistency between da-tasets and investigate new applications from a modelling perspective including novel data ex-ploitations. Namely, our objectives are:

- Update review on space geodetic observations and state-of-the-art processing meth-ods including an overview of novel thermosphere datasets and model applications.
- Advance thermosphere modelling to increase consistency between observational da-tasets and enable new applications.
- Assess accuracy level of available space geodetic observations.
- Investigate the impact of improved observational data sets and advanced processing methods, including data assimilation, on orbit determination and prediction.
- Use of improved thermosphere models and observational data sets to advance the study of thermospheric variations in the context of climate change and space weath-er monitoring.

**Activities:**

- Virtually meetings on a regular basis and during conferences to monitor and share advances in thermosphere modelling
- Update the list of state-of-the-art processing methods and currently available thermosphere data sets
- Step-by-step comparison of the processing and estimations of neutral mass density from different measurements and models to advance thermosphere modelling capabili-ties
- Initiate cooperations and synergies with other study groups

**Planned for the near future:**

- Exchange scientific results and gain knowledge from invited talks within the field of thermosphere modelling and applications.
- Implement over multiple processing chains the latest modelling advances in thermosphere modelling with a special focus on gas-surface interactions and radiation modelling.
- Compare and discuss results of such modelling advancements.
- Compare and discuss uncertainty quantifications for thermosphere products.
- Propose novel thermosphere products applications for currently operative missions (e.g., Swarm) and future missions.

- Non-gravitational accelerations from GNSS-derived precise orbit data of the CAScade SmallSat and IOnospheric Polar Explorer (CASSIOPE) satellite
- Investigate vertical non-gravitational accelerations (up-track component) of CASSIO-PE during major geomagnetic storms

**Recent publications:**


1. Bruinsma, S., Boniface, C., Sutton, E. K., Fedrizzi, M. (2021). Thermosphere modeling capa-bilities assessment: geomagnetic storms. In Journal of Space Weather and Space Climate (Vol. 11, p. 12). EDP Sciences. https://doi.org/10.1051/swsc/2021002
2. Corbin A., Kusche J. (2022). Improving the estimation of thermospheric neutral density via two-step assimilation of in situ neutral density into a numerical model," Earth, Planets and Space, vol. 74, no. 1, p. 183, Dec. 2022, doi: 10.1186/s40623-022-01733-z.
3. Kosary, M., Farzaneh, S., Schumacher, M., Forootan, E. (2024). Assimilating space-based thermospheric neutral density (TND) data into the TIE-GCM coupled model during peri-ods with low and high solar activity. Space Weather, 22, e2023SW003811. https://doi.org/10.1029/2023SW003811
4. Forootan, E. (2023), ESA's multi-level global thermosphere data products consistent with Swarm and GRACE(-FO), ESA Technical Report, https://earth.esa.int/eogateway/documents/20142/4335041/Swarm-DISC-Pre-Study-5-2_2023.pdf
5. Forootan, E., Farzaneh, S., Kosary, M., Borries, C., Kodikara, T., and Schumacher, M. (2023). Predicting global thermospheric neutral density during periods with high geomagnetic activity. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-47440-x.
6. Forootan, E., Kosary, M., Farzaneh, S., Kodikara, T., Vielberg, K., Fernandez-Gomez, I., Borries, C., and Schumacher, M. (2022). Forecasting global and multi-level thermospheric neutral density and ionospheric electron content by tuning models against satellite-based accelerometer measurements. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-022-05952-y
7. Hładczuk, N. A., van den IJssel, J., Kodikara, T., Siemes, C., and Visser, P. (2024). GRACE-FO radiation pressure modelling for accurate density and crosswind retrieval. Advances in Space Research: The Official Journal of the Committee on Space Research (COSPAR), 73(5), 2355–2373. https://doi.org/10.1016/j.asr.2023.12.059
8. March, G. (2020). Consistent thermosphere density and wind data from satellite observations: A study of satellite aerodynamics and thermospheric products, https://doi.org/10.4233/uuid:862e11b6-4018-4f63-8332-8f88066b0c5c
9. Siemes, C., Borries, C., Bruinsma, S., Fernandez-Gomez, I., Hładczuk, N., den IJssel, J., Ko-dikara, T., Vielberg, K., and Visser, P. (2023). New thermosphere neutral mass density and crosswind datasets from CHAMP, GRACE, and GRACE-FO. Journal of Space Weather and Space Climate, 13, 16. https://doi.org/10.1051/swsc/2023014
10. Vielberg, "Thermosphere and radiation effects in forward and inverse non-gravitational force modelling," phdthesis, Rheinische Friedrich-Wilhelms-Universität, Bonn, 2024. doi: 10.48565/bonndoc-213.


## GGOS.GSWR.JSG 3: Space Weather Monitoring and Prediction (led by GGOS; joint with IAG Commission 4, Sub-Commission 4.3)

**Chair:** Haixia Lyu (China)
**Vice-Chair:** Benedikt Soja (Switzerland)
**Members:** Anna Belehaki (Greece), Jens Berdermann (Germany), Yao Chen (China), Yanhong Chen (China), Jinsil Lee (Republic of Korea), Anthony J. Mannucci (USA), Enric Monte-Monero (Spain), Xiaoqing Pi (USA), Rami Qahwaji (UK), Jean-Pierre Raulin (Brazil),

Pietro Zucca (Netherlands), Louise Harra (Switzerland)

Space weather refers to the dynamic conditions in the Earth's outer space environment as influenced by the sun and the solar wind. It can affect different systems with increasing human activity reliance, such as satellite navigation systems, communication systems, power grids, etc. In the 25th solar cycle, characterized by heightened solar activity, the occurrence of intense coronal mass ejections (CMEs) and solar flares in 2023 underscores the critical importance of space weather monitoring and prediction. It is still challenging to monitor space weather in real time due to the inherent complexity and unpredictability of solar-terrestrial interactions, limitations in observational capabilities, and the computational demands of processing vast amounts of data in a timely manner. The JSG3 focuses on combining spaceborne observation systems and ground-based observations to better understand the process of space weather events and their effect on the near-Earth environment, developing space weather forecasting methods or models, trying to give more accurate prediction for ionospheric variations. The synergy with JSG1, JSG4 and JSG AI for GNSS Remote Sensing of the new Focus Area – AI for Geodesy is promoted by identifying connected key questions to achieve a com-prehensive understanding of the impact of space weather events. Our main objectives are:

- Comparison and inter-validation among different space-based and ground-based ob-servations of space weather events
- Investigate in detail the impact of different space weather information on TEC predictions
- Study the impact of selected geomagnetic storms on ionospheric modeling and GNSS positioning performance
- Development of AI and Data Fusion techniques for improving real-time space weather prediction capabilities

**Activities**

- Selection of space weather events with available dedicated space-based and ground-based observations; create data archives for comparison
- Selection of representative geomagnetic storms
- Analyse TEC prediction results with different space weather information as input
- Synergy with JSG1 in the impact study of geomagnetic storms on ionospheric model-ling and GNSS positioning
- Synergy with the Focus Area AI for Geodesy in real-time space weather prediction studies.

**Recent publications**

1. Lyu, H., Hernández-Pajares, M., Li, M. et al. (2024) Global 3D ionospheric shape function modeling with kriging. J Geod 98, 10. https://doi.org/10.1007/s00190-024-01908-4
2. Balan, N., Zhang, Q. H., Ram, S. T., Shiokawa, K., Manu, V., and Xing, Z. Y. (2024). How to identify and forecast severe space weather events. Journal of Atmospheric and Solar-Terrestrial Physics, 256, 106183.
3. Vourlidas, A., Turner, D., Biesecker, D., Coster, A., Engell, A., Ho, G., et al. (2023). The NASA space weather science and observation gap analysis. Advances in Space Research.
4. Laker, R., T. S. Horbury, H. O'Brien, E. J. Fauchon-Jones, V. Angelini, N. Fargette, T. Amer-storfer et al. "Using Solar Orbiter as an upstream solar wind monitor for real time space weather predictions." Space Weather 22, no. 2 (2024): e2023SW003628.

5. Georgoulis, Manolis K., Stephanie L. Yardley, Jordan A. Guerra, Sophie A. Murray, Azim Ahmadzadeh, Anastasios Anastasiadis, Rafal Angryk et al. "Prediction of solar energetic events impacting space weather conditions." Advances in Space Research (2024).
6. Wang, Chi, Jiyao Xu, Libo Liu, Xianghui Xue, Qinghe Zhang, Yongqiang Hao, Gang Chen et al. "Contribution of the Chinese Meridian Project to space environment research: Highlights and perspectives." Science China Earth Sciences 66, no. 7 (2023): 1423-1438.

## GGOS.GSWR.JSG 4: Atmospheric Coupling Studies (led by ICCT; joint with GGOS FA-GSWR and IAG Commission 4, Sub-Commission 4.3)

**Chair:** Andres Calabia Aibar (Spain)
**Vice-Chair:** Binod Adhikari (Nepal)

Since this study group is part of the Inter-Commission Committee on Theory (ICCT), the mid-term report of JSG 1 (JSG T.XX) can be found in the ICCT Section of this report and is not repeated here.

## 5.2 Focus Area: Geohazards Monitoring

**Website:** https://geodesy.science/ggos/structure/fa/geohazards/

**Chair:** Timothy I. Melbourne (Pacific Northwest Geodetic Array, Central Washington University, USA)

### Present Status and Progress

- The Geohazards Focus Area (GFA) is focused upon the implementation of the IUGG 2015 General Assembly Resolution #4 to expand the use of geodetic techniques and infrastructure in mitigation of natural hazards.
- Since the establishment of GATEW working group in 2019 that was global in scope comprising 18 members from 12 nations, we refocused the effort into Oceania and rechristened it the GeTEWS working group, the GNSS-enhanced Tsunami Early Warning System. The working group now comprises 15 members from 10 nations (chart below) and is focused on GNSS deployments in Oceania.
- The GAR 2019 white paper articulates the role of GTEWS technology and the GTEWS 2017 recommendations in the implementation of the Sendai Framework. GeTEWS WG has focused on developing a proposal for a three-year plan to create an Oceania-wide, intergovernmental, multi-use, open-data and continuously operating GNSS geospatial observations network.
- Organized a joint workshop between the Pacific Geospatial Surveying Council (PGSC), IUGG GeoRisk Commission, Joint Tsunami Commission, the IAG/GGOS Group on Earth Observations Geodesy for Sendai Pilot Initiative, and the UN International Committee on GNSS. This workshop will be held Nov 4-8, 2025 online and will be hosted by the Tonga Ministry of Lands and Natural Resources.
- CWU, a member of the GeTEWS working group, initiated a demonstration Tonga pilot project to install five continuously operating GNSS stations at each of the five major island groups that comprise the Kingdom of Tonga. As of this writing four stations have been installed and are operating in Nuku'alofa on the main island of Tongatapu, on the northern archipelagos of Vava'u and Ha'apai, and the easternmost island of 'Eua. Two more stations are being installed during summer, 2025 on Niaus Island at the north end of the archipelago and at Nomuku north of Tongatapu. The purpose of pilot is to demonstrate the feasibility of deploying a GNSS intergovernmental geospatial network broadly across Oceania. All four receivers have operated and log data continuously since deployment but as expected, and we are in the process of upgrading the telemetry to dedicated Starlink systems.

### Planned Actions and Milestones

- Continue the buildout of the Tonga pilot project by installing the final two of five CORS on the northernmost island of Niuas and the island of Nomoku. This effort will continue on through 2026. By so doing we fulfill the request of the UNOOSA ICG's Task Force on GNSS Applications for Disaster Risk Reduction by deploying GNSS to reduce, in this case, tsunami hazard.
- Continue the series of the GeTEWS-Oceania joint workshop, this time in November 3-7 2025. The purpose of these events is to review and recommend a proposal from the GeTEWS Working Group to create the Oceania Geospatial Network. The primary elements of the proposal are:

- o A "Suva Declaration" from conference attendees endorsing a three-year plan to create a coordinated Oceania-wide, intergovernmental, multi-use, open-data, continuously operating GNSS Geospatial network for GNSS-enhanced Tsunami Early Warning (GeTEWS), environmental monitoring, regional capacity building, and real-time surveying.
- o Establish the GeTEWS-Oceania network deployment as a project of the Pacific Geospatial and Surveying Council. Create a GeTEWS-Oceania advisory group to guide development, operation and maintenance of the project, with membership inclusive of the nations and territories of Oceania. Specify Terms of Reference for this GeTEWS-Oceania advisory group, ratified and adopted by representatives from the nations and territories of Oceania.
- o Draft 3-year plan for implementing Suva Declaration.
- o Write a meeting report for publication as an addendum to the Suva Declaration.
- o Write Policy Brief which embodies the concept of collaboration and joint analysis inclusive of all GNSS networks within the Oceania Region. Tonga Use Case as an example.

### The GeTEWS Oceania Working Group

| **Name** | **Affiliation** |
|---|---|
| Tim Melbourne (Chair) | Central Washington University, USA |
| Allison Craddock | NASA Jet Propulsion Laboratory, California Institute of Technology, USA |
| Elisabetta D'Anastasio | GNS Science, New Zealand |
| Viliami Folau | Ministry of Land and Natural Resources, Tonga |
| Bill Fry | GNS Science, New Zealand |
| John LaBrecque | Center for Space Research, University of Texas, USA & IUGG GeoRisk Commission |
| Andrick Lal | Geoscience Energy & Maritime, Pacific Community (SPC), Suva, Fiji |
| Léo Martire | IGS Central Bureau, Jet Propulsion Laboratory |
| Basara Miyahara | Geospatial Information Authority (GSI), Japan |
| Adrienne Moseley | Geoscience Australia, Australia |
| Felix Perosanz | Centre National D'Etudes Spatiales (CNES), France |
| Michela Ravanelli | Institut de Physique du Globe de Paris, France & University of Rome, Italy |
| Lucie Rolland | Université Côte d'Azur, France |
| Ryan Ruddick | Geoscience Australia, Australia |
| Yuhe Tony Song | NASA Jet Propulsion Laboratory, California Institute of Technology, USA |

## 5.3 Focus Area: Artificial Intelligence for Geodesy (AI4G)

**Website:** https://geodesy.science/ggos/structure/fa/ai-for-geodesy/

**Chair:** Benedikt Soja (ETH Zurich, Switzerland)
**Vice-Chair:** Maria Kaselimi (National Technical University of Athens, Greece)

With contributions from:

- Milad Asgarimehr (GFZ Potsdam, Germany)
- Santiago Belda (University of Alicante, Spain)
- Fupeng Li (University of Bonn, Germany)
- Lei Liu (University of Colorado Boulder, USA)
- Sadegh Modiri (BKG, Germany)
- Mohammad Omidalizarandi (Leibniz University Hannover, Germany)
- Mohammad Ali Sharifi (University of Tehran, Iran)
- Justyna Śliwińska-Bronowicz (Polish Academy of Sciences, Poland)

GGOS Focus Area on Artificial Intelligence for Geodesy (AI4G) was officially approved in May 2023 by the GGOS Coordinating Board. In the following months, the structure of the Focus Area with initially three Joint Study Groups was established. In autumn 2023, an additional Joint Study Group (JSG) was formed with the title AI for Geodetic Deformation Monitoring. This report covers the activities within the Focus Area after this initial establishment of its structure. The report focuses on tangible outcomes and joint initiatives. In addition, significant research efforts are under way related to the overall goals of the Focus Area, i.e. the improvement of geodetic products using AI and their evaluation. Several journal and conference papers have been published in this regard, which are too numerous to list in this report. Currently, AI4G has over 100 members, demonstrating the great interest of the geodetic community in this growing field of research.

**Activities of the Focus Area FA-AI4G:**


**Fig. 9.** Advertisements for the EGU 2025 (left) and AGU 2024 (right) session organized by AI4G chairs

- EGU 2024 session G1.3 “Data science and machine learning in geodesy” organized by five AI4G chairs. 22 abstracts were received, and an oral session was secured, which had very strong attendance.

- AGU 2024 session G004 “Applications of AI/ML in Geodesy” co-convened by the AI4G chair (Fig. 9). This session was proposed for the first time, and it already attracted 15 abstracts, which will be presented in the frame of an eLightning session.
- GGOS Topical Meeting on the Atmosphere 2024: AI4G chair involved in Science Team and chairing the session on “Atmospheric modelling based on artificial intelligence”
- EGU 2025 session G1.2 “Machine learning for geodesy” organized by five AI4G chairs (Fig. 9). 25 abstracts were received, which is a record for this session, and for the first time, an oral session in one of the large conference rooms was possible.
- IAG Scientific Assembly 2025: Symposium "Data Science and Machine Learning in Geodesy" is currently under preparation by the AI4G chairs in collaboration with the ICCT JSG T.48 on “Theoretical foundations of ML in Geodesy”. The symposium consists of three sessions, covering a wide range of topics. Following the call for abstracts, 38 submissions have been received.
- COSPAR Scientific Assembly 2026: the session “The Risks and Rewards of Machine Learning in Earth Science”, proposed by the AI4G chair, has been approved.
- Special issue in the journal Remote Sensing: “Signal Processing and Machine Learning for Space Geodesy Applications” edited by two AI4G chairs
- COST Action proposal “Artificial Intelligence for Geodesy” (AI4GEOD) was submitted in October 2023. A large European consortium of 27 proposers was established by the chairs of AI4G. 61% of the proposers came from COST Inclusiveness Target Countries, 56% were female, and 74% were Young Researchers and Innovators. The composition of the network was very positively evaluated, although the proposal was ultimately not selected for funding.
- The COST Action proposal AI4GEOD was revised and re-submitted in November 2024. Again, 27 proposers supported the proposal, with 50% from COST Inclusiveness Target Countries.
- Talks at international conferences about the activities of the Focus Area by the AI4G chairs
  - Soja, B., Kaselimi, M., Asgarimehr, M., Modiri, S., Sun, A., Sharifi, M. A., Behzadpour, S., Belda, S., Liu, L., Śliwińska, J., & Omidalizarandi, M. (2023). Advancing Geodesy with Artificial Intelligence: Opportunities, Challenges, and Perspectives within GGOS. AGU Fall Meeting 2023.
  - Soja, B., Kaselimi, M., Asgarimehr, M., Modiri, S., Sharifi, M. A., Belda, S., Liu, L., Omidalizarandi, M., & Śliwińska-Bronowicz, J. (2024). Harnessing the Power of AI for Geodesy: Recent Developments within the GGOS Focus Area AI4G. AGU Fall Meeting 2024.
- Invited talks about applications of AI in geodesy given by the AI4G chair Benedikt Soja:
  - AI Perspectives for Geodetic Hazard Monitoring. March 13, 2024. ITU/WMO/UNEP Workshop on "Resilience to Natural Hazards through AI Solutions"
  - Artificial Intelligence for Geodesy – AI4G. July 19/20, 2024, Qingdao EOP Prediction Seminar
  - Machine Learning for Predicting Earth’s Rotation: Insights into a Dynamic System. June 6, 2024, University of Bonn, Geodetic Colloquium.
  - Geodetic Earth Observation Empowered by Machine Learning. February 27, 2024, ESA $\Phi$-lab
  - Demystifying AI for Applications in Geodesy. March 12, 2024, NKG Science Week

**Activities of JSG AI for GNSS Remote Sensing:**

- A kickoff meeting was successfully held with overview talks and topical discussions

- The JSG chair organized a workshop on GNSS-R, with a strong focus on AI, held in November 2024 at GFZ in Potsdam.

**Activities of JSG AI for Gravity Field and Mass Change:**

- A Google Group was established to foster active discussions among the JSG members.
- Change in leadership: Alexander Sun and later Saniya Behzadpour stepped down as chairs of this JSG. Fupeng Li has taken over as chair of this JSG.
- Members of this JSG participated in the ISSI Workshop on "Remote Sensing in Climatology – Essential Climate Variables (ECVs) and their uncertainties".
- As an outcome of this workshop, a review paper on "Uncertainties of Satellite-based Essential Climate Variables from Deep Learning" has been written, with a focus on ECVs monitored by GRACE and GRACE-FO. The pre-print is available under https://arxiv.org/abs/2412.17506. Advancing uncertainty quantification in machine learning applications is a major goal of the Focus Area AI4G.

**Activities of JSG AI for Earth Orientation Parameter Prediction:**

- A kickoff meeting and several further meetings were organized with overview talks and topical discussions. An important matter of discussion was the performance of machine learning algorithms during the 2nd EOP Prediction Comparison Campaign.
- Collaboration with the IERS/IAG/IAU Working Group on the Prediction of Earth Orientation Parameters (PEOP) in analyzing data from the 2nd EOP PCC sub-campaign that are based on machine learning approaches
- The JSG supported the launch of the new EOP Prediction Comparison Campaign dedicated to evaluating machine learning-based approaches for EOP prediction (EOP PML). EOP PML has standardized rules for input data and thus a stronger focus on methodology, revealing the impact of the different ML approaches.
- Invited talks about applications of AI for EOP Prediction:
  - AI for Earth Orientation Parameter Prediction a Joint Study group at GGOS, July 19/20, 2024, Qingdao EOP Prediction Seminar
  - Insights from the AI4EOP joint study group at GGOS, Sep 30, 2024, Alicante, International Workshop on Space Dynamics, Satellite Geodesy, and Numerical Methods.
- Four webinars on Earth Orientation Parameters Innovation and Insight (EOP I&I) were organized (see Fig. 10):
  - Junyang Gou: Recurrent neural networks and their applications for EOP prediction. Recording: https://www.youtube.com/watch?v=pcbTavxUHbg
  - Mostafa Kiani: Explaining the Causes of Polar Motion by Physics-Informed Neural Networks. Recording: https://www.youtube.com/watch?v=MsEuDnabS1k
  - Justyna Śliwińska-Bronowicz: Insights from the New EOP Prediction Comparison Campaign Dedicated to ML-Based Approaches (EOP PML). Recording: https://www.youtube.com/watch?v=i6ivEZniBvw
  - Yuanwei Wu: Report on Our Activities of the 1st Chinese EOP Prediction Comparison Campaign. Recording: https://www.youtube.com/watch?v=36HCnm7ZZyE

**Activities of JSG AI for Geodetic Deformation Monitoring:**

- A kickoff meeting was successfully held. This JSG was established about half a year after the other three JSGs.


**Fig. 10.** Announcements of the four EOP I&I webinars

# 6 GGOS Affiliates

## 6.1 GGOS Japan

**Website:** https://geodesy.science/ggos/structure/affiliates/ggos-japan/

**Chair:** Basara Miyahara (GIA, Japan)
**Secretary:** Yusuke Yokota (GIA, Japan)

This multi-institution entity was initially established as the *GGOS Working Group of Japan* in 2013, later approved as a *GGOS Affiliate* in 2017 and renamed *GGOS Japan* in 2019. The purpose was to strengthen collaboration among Japan's geodetic stations and colleagues and to foster Japanese space geodetic activities internationally.

In recognition of its contributions to geodesy both globally and domestically over the past decade, GGOS Japan received the *Geodetic Society of Japan (GSJ) Tsuboi Award for Group* in 2024. GGOS Japan co-hosted domestic and international geodesy meetings, including the *13th IVS General Meeting* in March 2024. It organized English-spoken sessions in geodesy-related domestic meetings and invited speakers from the IAG community. The chairs of the *GGOS Committee on DOIs for Geodetic Data Sets* and the *International DORIS Service* were invited to the GGOS Japan annual meeting in 2024. The *IAG President* and *ILRS Central Bureau Secretary* were invited to the *Japan Geoscience Union (JpGU)* annual meeting in 2024.

Through a joint initiative with the GSJ, the *Data DOI WG* of GGOS Japan pioneeringly established a new platform to assign DOIs for geodetic data sets as a Japanese academic society related to geosciences. In 2024, the *Marine Geodesy WG* was established within GGOS Japan to contribute to the *IAG Inter-Commission Committee on Marine Geodesy (ICCM)* and is playing a leading role in this field.

The SLR representative of GGOS Japan has been working to strengthen collaboration among GGOS Japan member institutions and arranged local-tie surveys at the *Shimosato station* of the Japan Coast Guard and at the newly established *JAXA's Tsukuba SLR Station*, with strong technical support by the *Geospatial Information Authority of Japan (GSI)*. The *Omni-SLR project experiment* started at the *Ishioka VLBI station* in 2024 with support from GGOS Japan.

GGOS Japan is a loose organization of public sector and university members. It does not have formal membership qualifications, but its core members are selected. As of May 2025, they are:

- **Chair:** Basara Miyahara (Geospatial Information Authority of Japan)
- **Secretary:** Yusuke Yokota (University of Tokyo)
- **Outreach:** Masafumi Ishigaki (Geospatial Information Authority of Japan)
- **Chair of Data DOI WG:** Yusuke Yokota (University of Tokyo)
- **Chair of Marine Geodesy WG:** Shun-ichi Watanabe (Japan Coast Guard)
- **Technique Representatives:**
  - VLBI: Masafumi Ishigaki (Geospatial Information Authority of Japan)
  - SLR: Takehiro Matsumoto (Japan Aerospace Exploration Agency)
  - GNSS: Keitaro Ohno (Geospatial Information Authority of Japan)
  - DORIS: Yuichi Aoyama (National Institute of Polar Research)
  - Gravity: Koji Matsuo (Geospatial Information Authority of Japan)

These members have actively participated in session planning for the annual JpGU and GSJ meetings, where "GGOS" is always used as (a part of) a session name. Likewise, every effort is made to utilize "GGOS" as a keyword for budget acquisition, aiming at future *GGOS Core Sites* in Japan or Antarctica.

Inter-regional geodetic collaboration is another focus, and GGOS Japan seeks more opportunities for discussion with other GGOS Affiliates. Encouraging geodetic technology development is also within scope—in addition to achieving high precision and operability, there is recognition of the need to significantly reduce costs per geodetic facility, envisioning a denser global geodetic network in the future.

## 6.2 GGOS D-A-CH

**Website:** https://geodesy.science/ggos/structure/affiliates/ggos-dach/

**Chair:** Hansjörg Kutterer (Karlsruhe Institute of Technology, Germany)

GGOS D-A-CH is the GGOS affiliate of the so-called D-A-CH region representing those countries in Central Europe with significant German-speaking populations: Germany (D), Austria (A), Switzerland (CH). GGOS D-A-CH is based on a joint initiative of the national geodetic commissions DGK, ÖGK and SGK in 2020. It was approved by GGOS CB on May 19, 2021, as the second regional GGOS affiliate after GGOS Japan.

GGOS D-A-CH was initiated by the members and guests of the Geodesy department of DGK and the respective members of ÖGK and SGK. There is a long-term and outstanding tradition of cooperation within these commissions both contributing to and benefitting from activities in mathematical, physical and space geodesy. GGOS D-A-CH was established as basis and forum for GGOS-related activities in the D-A-CH region and in particular as a stimulator and incubator for GGOS-related coordinated research. The publication "Geodesy 2030" by J. Müller and R. Pail[3], with contributions from a multitude of scientists in the D-A-CH region, serves as scientific guideline.

GGOS D-A-CH comprises university members and members from the public sector. Qualification for membership is based on an expression of interest. As of May 2025, there are the following participations in terms of member institutions:

- **Universities:** Technical University Berlin, University Bern, University Bonn, Technical University Dresden, Leibniz University Hannover, Karlsruhe Institute of Technology, Technical University Munich, University Stuttgart, Technical University Vienna, ETH Zurich
- **Research institutions and national agencies:** Federal Office of Metrology and Surveying (BEV, Austria), Federal Agency for Cartography and Geodesy (BKG, Germany), GFZ German Research Centre for Geosciences (GFZ, Germany)

The ongoing activities towards formulating and launching a cooperative research format (such as Research Units funded by the German Research Foundation – DFG) are addressing the relation between integrated geodetic parameters and products on the one hand and respective Earth system models on the other hand, with the main focus towards so far untreated model interfaces and respectively unexploited constraints.

[3] https://geodaesie.info/zfv/zfv-archiv/zfv-147-jahrgang/zfv-2022-4/geodesy-2030

In 2024, a topical issue of the German scientific journal *avn* was published, initiated by GGOS D-A-CH, with state-of-the-art contributions in English from various GGOS members, addressing geodetic Earth observation, ITRF, IHRF, GGOS and regional monitoring applications, aiming at educational and outreach purposes:

1. Angermann, D., Seitz, M., Bloßfeld, M., and Seitz, F. (2024): *Terrestrial Reference Frames: The fundament for geodetic Earth observation and all positioning applications.* In: allgemeine vermessungs-nachrichten (avn). 131(2024)5–6. https://doi.org/10.14627/avn.2024.5-6.2
2. Kutterer, H. (2024): *Earth observation and the role of geodesy.* In: allgemeine vermessungs-nachrichten (avn). 131(2024)5–6. https://doi.org/10.14627/avn.2024.5-6.1
3. Sánchez, L., Vergos, G. S., and Barzaghi, R. (2024a): *Establishment of a geopotential-based world height system – The International Height Reference System (IHRS) and its realisation, the International Height Reference Frame (IHRF).* In: allgemeine vermessungs-nachrichten (avn). 131(2024)5–6. https://doi.org/10.14627/avn.2024.5-6.3
4. Sánchez, L., Riddell, A., Angermann, D., Rodríguez, J., Sehnal, M., Gruber, T., Gross, R., Lidberg, M., Craddock, A., and Ferrándíz, J. M. (2024b): *The Global Geodetic Observing System (GGOS) – Harnessing geodesy for the benefit of science and society.* In: allgemeine vermessungs-nachrichten (avn). 131(2024)5–6. https://doi.org/10.14627/avn.2024.5-6.4
5. Seidel, A., Even, M., Kutterer, H., and Westerhaus, M. (2024): *Monitoring Eight Years of Surface Displacements at the Storage Cavern Field Epe with Multitemporal InSAR.* In: allgemeine vermessungs-nachrichten (avn). 131(2024)5–6. https://doi.org/10.14627/avn.2024.5-6.5

## 6.3 GGOS IberAtlantic

**Website:** https://geodesy.science/ggos/structure/affiliates/ggos-iberatlantic/

**Chair:** Esther Azcue Infanzón (IGN, Spain)
**Secretary:** Luísa Magalhães (RAEGE, Spain)

GGOS IberAtlantic was established in 2024 as a regional affiliate spanning Spain and Portugal. Formally approved in April 2024 with the support of geodetic experts and national geodetic agencies from both countries, GGOS IberAtlantic established its Governing Board in September of the same year. This board, which remains in place to date, is composed of:

- **Esther Azcue Infanzón** – Chair. Head of GNSS and VLBI analysis centres, National Geographic Institute of Spain (IGN).
- **Luísa Magalhães** – Secretary. Member of the Azores Mission Structure for Space and Chairman of the Board of Directors, RAEGE Azores Association.
- **Paula Sanches** – Hydrographic Institute of Portugal. Newly appointed member in March 2025, replacing João Agria.
- **José Manuel Ferrandiz Leal** – Emeritus Professor at the University of Alicante. President of IAU Commission A3 Fundamental Standards, Vice President of IAG Commission 3 Earth Rotation and Geodynamics, and Chair of the GGOS Science Panel.
- **Paulo Manuel Patrício** – Director of Geodesy, Mapping and Geographic Information Services, Directorate-General for the Territory (DGT), Portugal.
- **Antonio Pazos García** – Captain, Director, Royal Observatory of the Spanish Navy (ROA).
- **Helena Ribeiro** – GNSS representative. Directorate-General for the Territory (DGT), Portugal.

- **Javier González García** – VLBI representative. Yebes Observatory, National Geographic Institute of Spain (IGN).
- **Clara Lázaro** – Gravimetry representative. Faculty of Sciences, University of Porto.
- **Manuel Ángel Sánchez Piedra** – SLR representative. Head of San Fernando laser station, Royal Observatory of the Spanish Navy (ROA).
- **Isabel Vigo** – Combination/multitechnique representative. University of Alicante.
- **Mariana Moreira** – Outreach representative. R&D member of Santa Maria RAEGE Station, RAEGE Azores Association.

GGOS IberAtlantic builds on long-standing collaboration between both countries and aims to serve as a unified voice to communicate scientific findings in an accessible way, allowing the public and policymakers to better understand changes occurring on our planet. By highlighting geodesy's contributions, GGOS IberAtlantic seeks to help attract new projects, funding, and skilled professionals to the field.

Since October 2024, GGOS IberAtlantic has continued to strengthen its presence and impact across the Iberian Peninsula and Atlantic region through strategic planning, scientific contributions, and regional engagement. A key milestone during this period was the completion of the Strategic Action Plan for 2024–2028, which defines the priorities and roadmap for the affiliate over the next four years.

GGOS IberAtlantic has participated in several conferences during this period, including:

- AGU Fall Meeting 2024,
- the 2024 EVGA Meeting, where a joint poster with RAEGE received the Best Poster Award,
- and the EGU General Assembly.

In terms of recognition, GGOS IberAtlantic was a finalist in the 2024 Spanish Meeting on Innovation in Public Services, in the category of projects led by young civil servants. This achievement highlights the growing relevance of geodesy and GGOS initiatives in public administration and innovation.

Capacity building has been a major focus, exemplified by the success of the GGOS Summer School, especially aimed at students of geodesy in Spain and Portugal. The 1st GGOS IberAtlantic Summer School offers a unique educational opportunity focused on GGOS-related topics. It will take place from July $13^{\text{th}}$ to July $18^{\text{th}}$, 2025, at the Yebes Observatory. Over five days, participants will engage in theoretical and practical sessions covering techniques such as VLBI, GNSS, SLR, DORIS, gravimetry, and local tie measurements. The event will showcase the RAEGE project and provide hands-on exposure to operations in fundamental geodetic stations worldwide. The call for this edition has been a great success, receiving numerous applications. Interest from other countries has been notable, prompting the team to consider opening the event internationally in the future, depending on the availability of resources, materials, and funding.

As part of upcoming initiatives, preparations are underway for participating in a geodetic training course at the San Juan Observatory in Argentina, from October $27^{\text{th}}$ to $31^{\text{st}}$, 2025, hosted by SIRGAS. Participation in a GGOS Affiliates meeting in Japan, hosted by GGOS Japan, is also being explored. In support of regional outreach, a new multilingual leaflet (in Spanish, Portuguese, and English) is planned, and efforts continue to involve more organizations and potentially expand participation to other countries.