# GGOS Bureau of Products and Standards: Description and Promotion of Geodetic Products

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**Abstract**

The Bureau of Products and Standards (BPS) is a key component of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). It supports GGOS in its goal to provide consistent geodetic products needed to monitor, map, and understand changes in the Earth's shape, rotation, and gravity field. In its present structure, the two Committees "Earth System Modeling" and "Essential Geodetic Variables" as well as the Working Group "Towards a consistent set of parameters for the definition of a new Geodetic Reference System (GRS)" are associated to the BPS. This paper presents the structure and role of the BPS and it highlights some of the recent activities. A major focus is on the classification and description of geodetic products and their representation at the renewed GGOS website (www.ggos.org). This website serves as an "entrance door" to geodetic products to satisfy different user needs and communities (e.g., geodesists, geophysicists, other geosciences and further customers) in order to make geodesy more visible to other disciplines and to society.

**Keywords**

BPS inventory · Bureau of Products and Standards (BPS) · Geodesy · Geodetic products · GGOS · GGOS website · Standards and conventions

## 1 Introduction

The GGOS Bureau of Products and Standards (BPS), formerly known as Bureau for Standards and Conventions (BSC), was established as a component of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) in 2009. The organizational structure of GGOS and a description of its components is given in Miyahara et al. (2020), published in the Geodesist's Handbook 2020 (Poutanen and Rozsa 2020).

The BPS is chaired by the Technical University of Munich (TUM) within the Research Group Satellite Geodesy (Forschungsgruppe Satellitengeodäsie, FGS). Further

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involved partners are GFZ (Helmholtz Centre Potsdam, German Research Centre for Geosciences, Potsdam) and DLR (German Aerospace Centre, Oberpfaffenhofen). The organizational structure and further information about the BPS can be found in Angermann et al. (2018, 2020), and at the GGOS website (www.ggos.org).

The work of the BPS is fundamentally built on the IAG Scientific Services and the products they derive on an operational basis for Earth monitoring making use of various space geodetic observation techniques such as Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS), Doppler Orbitography and Radiopositioning Integrated on Satellite (DORIS), satellite altimetry, gravity satellite missions, gravimetry, etc.

With the ongoing technological improvements of the Earth observing systems, geodesy provides the potential to determine unambiguously and with utmost precision the geometric shape of land, ice and ocean surfaces as well as the rotation and gravity field of the Earth as global functions of space and time. Thus, geodesy provides the metrological basis for Earth system research and for reliably monitoring climate change phenomena (e.g., sea level variations, melting of ice sheets, continental water storage). To ensure consistent results and to fully benefit from the technological improvements and high accuracy of the geodetic observations, reliable reference frames as well as common standards, conventions and models are essential for the data analysis and product generation.

A key objective of the BPS is to keep track and to foster homogenization of adopted geodetic standards and conventions across all components of the IAG as a fundamental basis for the generation of consistent geometric and gravimetric products. Towards reaching these goals, the BPS has compiled an inventory of standards and conventions used for the generation of IAG products (Angermann et al. 2016 and 2020), published in the Geodesist's Handbook 2016 and 2020 (Drewes et al. 2016; Poutanen and Rozsa 2020). This inventory presents the current status, identifies gaps and inconsistencies as well as interactions between different products. It also provides open issues and recommendations regarding standards and conventions used for the generation of IAG products. In this way, the BPS supports IAG in its goal to obtain geodetic products of highest accuracy and consistency. Moreover, the Bureau contributes to the development of new geodetic products, needed for Earth sciences and society. In the framework of the renewing of the GGOS website, the BPS closely interacts with the GGOS Coordinating Office regarding the representation of geodetic products. In cooperation with the IAG Services, other data providers and the GGOS Science Panel members, user-friendly product descriptions have been generated and implemented at the GGOS website.

The scope of this paper is summarized as follows: Sect. 2 presents the objectives and tasks of the BPS as given in the BPS Implementation Plan 2020–2022, including its associated GGOS components. The main focus is on the recent BPS activities related to the representation of geodetic products at the renewed GGOS website, which is presented in Sect. 3. Finally, conclusions are provided in Sect. 4.

## 2 Objectives and Tasks of the BPS

The BPS supports GGOS in its goal to obtain geodetic products of highest accuracy and consistency. Thereby, the focus is on the evaluation of adopted geodetic standards and conventions across all IAG components to further improve the consistency of products describing the geometry, rotation and gravity field of the Earth. The work is primarily built on the IAG Service activities in the field of data analysis, combination and product generation. The BPS acts as contact and coordinating point regarding homogenization of standards and IAG products.

Figure 1 represents an overview and schedule of the BPS tasks as specified in the latest BPS Implementation Plan 2020–2022. The activities of the BPS are divided into three main categories: Coordination activities, specific tasks of the BPS, and outreach activities.

The first category comprises GGOS Consortium meetings (annually), GGOS Coordinating 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.

Among the specific tasks of the BPS, a recent key activity was the updating of the BPS inventory of standards and conventions used for the generation of IAG products (Angermann et al. 2020). The tasks also comprise the interaction with IAG and other entities in the field of standards and conventions such as the contribution to the rewriting/revising of the IERS Conventions, mainly in the function as Chapter Expert for Chapter 1 "General definitions and numerical standards". Moreover, the BPS director acts as representative to ISO/TC 211 and to the UN-GGIM Subcommittee on Geodesy (SCoG) Working Group "Data Sharing and Development of Geodetic Standards". The BPS also cooperates with the newly established Global Geodetic Centre of Excellence (GGCE) of the UN and the International Astronomical Union (IAU).

The third category includes various outreach activities, such as supporting the GGOS Coordinating Office concerning the renewing of the GGOS website, in particular regarding the description and representation of geodetic products

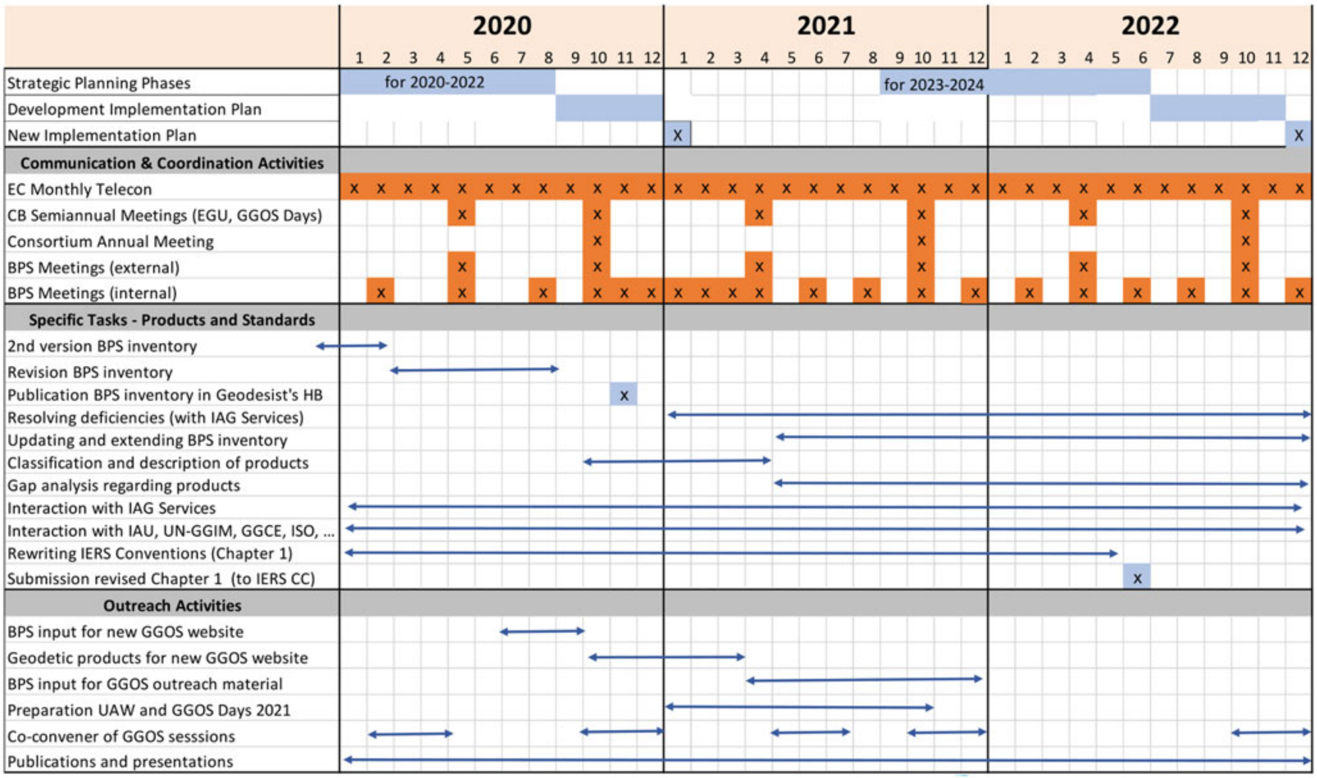



**Fig. 1** Overview and schedule of BPS activities

(see Sect. 3) as well as the presentation of BPS activities and results at workshops, conferences, and to publish them in scientific journals.

In its current structure, the following GGOS components are associated to the BPS:

- Committee "Contributions to Earth System Modeling" (see Sect. 2.1)
- Committee "Definition of Essential Geodetic Variables" (see Sect. 2.2)
- Working Group "Towards a consistent set of parameters for the definition of a new GRS" (see Sect. 2.3)

## 2.1 Committee "Contributions to Earth System Modeling"

The major goal of this committee is the preparation of a physically consistent numerical Earth system model for near-surface dynamics. Such a modular model approach is expected to allow for homogeneous processing, interpretation, and prediction of geodetic parameters, i.e., Earth rotation, gravity field and surface deformation, and thus, to finally contribute to a better understanding of dynamical processes in the Earth system reflected in geodetic observables.

Traditionally, various independent models tailored to specific spatial and temporal scales and to specific dynamical processes in individual sub-systems of the Earth are applied in order to estimate particular contributions to observed variations of geodetic parameters. Although it is well known that the individual sub-systems are coupled via fluxes of mass, energy and momentum, these interactions are generally not adequately considered or even neglected, and the total amount of geophysical excitation is mostly described by a simple linear addition of the individual contributions. Another deficiency results from the fact that the various estimates are based on different standards and parameters and use diverse analysis strategies and formats.

Thus, in order to ensure physical consistency, such as mass conservation, and to consider feedbacks, a modular model approach with individual elements representing sub-systems or components interacting through boundary conditions is mandatory. The envisaged system model approach has to be designed in such a way that it (i) ensures consistent interactions and physical fluxes among sub-systems, (ii) is applicable to all geodetic quantities, (iii) allows self-consistent predictions of geodetic parameters, and (iv) can be used for interpretation, cross-validation and integration of different observational data sets.

### 2.2 Committee "Definition of Essential Geodetic Variables"

The Committee on the Definition of Essential Geodetic Variables (EGVs) was formed with the objective of compiling a list of observed variables that describe the essential geodetic properties of the Earth. Since geodesy encompasses the rotation, gravity, and shape of the Earth, the list of EGVs should include Earth orientation parameters, gravity harmonics, positions of reference objects (ground stations, radio sources) and surface topography coefficients amongst others. Besides the primary variables needed to characterize the geodetic properties of the Earth, a hierarchy of other variables associated with or derived from the primary variables could also be compiled.

For example, the time rate-of-change of polar motion could be considered sub-variables of polar motion; the period and Q of the Chandler wobble could be considered supporting variables of polar motion; and the polar motion excitation functions could be considered variables derived from polar motion, its sub-variables of polar motion rate, and its supporting variables of the Chandler period and Q. Along with the hierarchical list of EGVs, information about the variables could also be given such as how they are observed, the accuracy and resolution with which they are observed, who is responsible for observing them, and where numerical values of them can be obtained.

### 2.3 Working Group "Towards a Consistent Set of Parameters for the Definition of a New GRS"

The main task of this WG is to define a consistent set of parameters and formulas for the definition of a new conventional Geodetic Reference System (GRS). This includes the geometry (size and shape of a reference ellipsoid), the gravity field (normal gravity field of this ellipsoid), terrestrial time and Earth rotation. More background information is provided in, e.g., Angermann et al. (2020), Ihde et al. (2017), Sánchez et al. (2021).

This new definition becomes necessary because, since the introduction of the GRS80 (Moritz 2000), the knowledge in geodesy has improved a lot (e.g. GNSS, gravity space missions) and the use of the parameters became inaccurate and inconsistent over time. The problem of the permanent Earth tide was not yet a topic at the epoch of the definition of GRS80. The acceptance of the IAG Resolution No. 1 released at the IUGG 2015 General Assembly (Drewes et al. 2016), which defines the potential at sea level ($W_0$) even increases the inconsistency in the geodetic parameters of the conventional GRS in use.

The new set of parameters is based on the four fundamental parameters: $W_0$ (potential at reference level), $J_2$ (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. Most of the defining parameters change with time. This includes seasonal variations and long-term trends. 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.

Besides the calculation of a new set of parameters, the main task will be to convince the users to adopt such a system as a new global reference. Since many users just consider GRS80 as a conventional model for the conversion of geocentric coordinates or for the calculation of gravity anomalies, such a replacement of the geodetic reference system needs to be further discussed within the community.

## 3 Description and Representation of Geodetic Products at the GGOS Website

In the last two years, the GGOS Coordinating Office worked intensively together with all GGOS components and other experts of the geodetic community to launch a new GGOS website (www.ggos.org). This new site now emphasizes more on the "Observing System" than on the "GGOS organization" itself. Therefore, the website was enhanced to provide an extensive information platform to bring the IAG observations, products and services into the focus, and to provide a unique information platform as a central access point. In this way, the new GGOS website serves now as an "entrance door" to make geodesy more visible to other disciplines and to society. Illustrative graphics guide the users to easily understandable descriptions about geodetic observations and products. For users who want to get more detailed information, links to the websites and data repositories of the IAG Services and other sources are provided.

In the framework of the renewing of the GGOS website, the BPS supports the GGOS Coordinating Office regarding the representation of geodetic products. With the success and engagement of the IAG Services and their contributing analysis and combination centers an extensive portfolio of geodetic products is routinely provided. This forms the basis to improve the understanding of our dynamic planet and to monitor global change phenomena as well as for a broad spectrum of various applications (e.g., satellite navigation, surveying, mapping, engineering, geo-information systems).

Two classifications for the geodetic products have been implemented at the GGOS website:

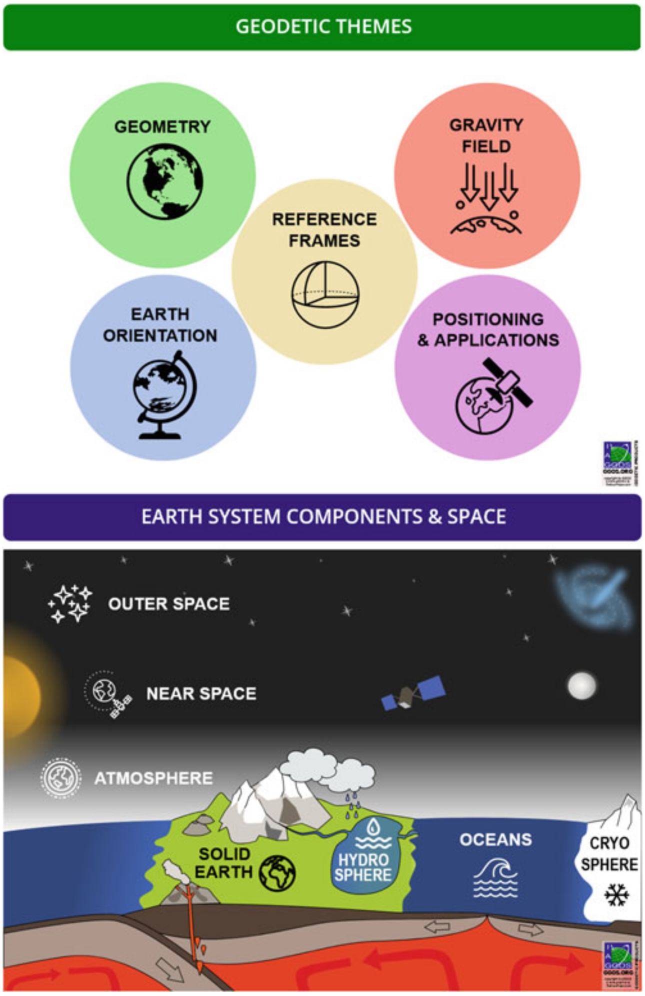



**Fig. 2** Screenshot of the GGOS website for the two classifications of geodetic products (www.ggos.org, screenshot taken on 2021-09-22)

– **Geodetic themes**: Reference frames, geometry, Earth orientation, gravity field, positioning and applications.
– **Earth system components and space**: Outer and near space, atmosphere, hydrosphere, oceans, cryosphere, solid Earth.

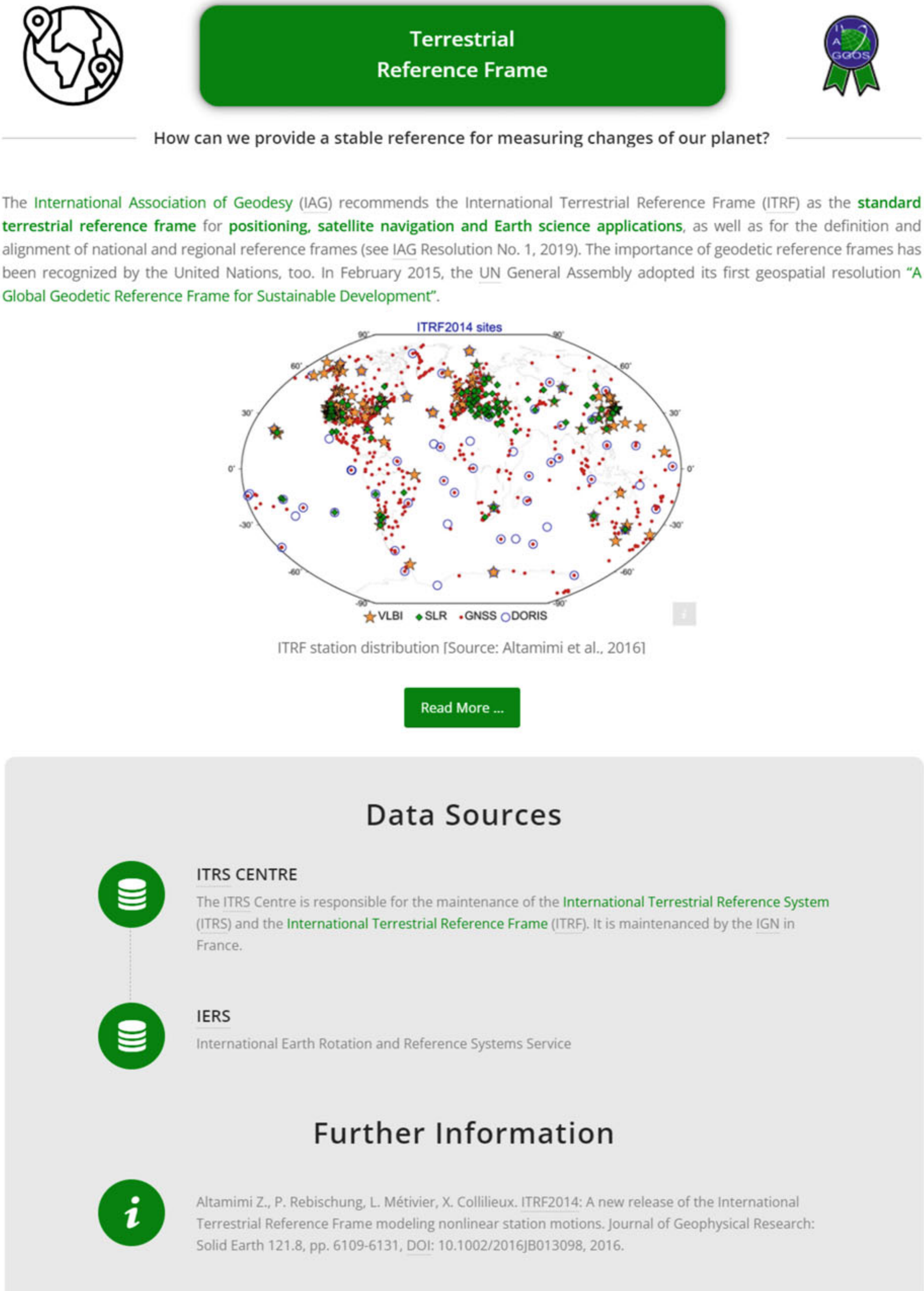
Option 1 provides the classical geodetic view, whereas users from other disciplines may prefer the second classification to discover the product descriptions. A screenshot of the GGOS website illustrates these two classifications of the geodetic products (see Fig. 2). With these visualization tools, users can navigate to a specific product description either via the geodetic themes or Earth system components. As an example, Fig. 3 shows a screenshot of the description for the terrestrial reference frame.

All geodetic product descriptions are structured in a similar way. At the top level, a typical symbol for a particular product is displayed (left), it's name is highlighted in a green box (middle) and the label (right) indicates if it's an official IAG product. Directly under the product's name, a so-called "appetizing question" is displayed to attract users to visit the GGOS website. As a next item, the descriptions comprise an easily understandable introduction with some general information and typical applications for the particular product, followed by an illustrative graphic. The "Read More ..." button provides the option to get further information for those users, who want to learn more about the geodetic product. And for those who would like to use this particular product for their studies, web links to the IAG Services and other data providers, as well as the respective data and product sources are displayed. Moreover, related references are provided to give more background information.

Until now, about 23 product descriptions have been prepared by the BPS members in cooperation with representatives of the IAG Services, other data providers and various experts in the field. The descriptions have been reviewed by the members of the GGOS Science Panel coordinated by its chair Kosuke Heki, and then implemented at the GGOS website by Martin Sehnal, the director of the GGOS Coordinating Office. Figure 4 provides a list of the currently available product descriptions, along with the so-called "appetizing question" for each particular product. With such an information portal, GGOS is contributing to advertise geodetic products also to other disciplines and to make geodesy more visible in the geoscientific community and beyond.

In addition to the product description of the terrestrial reference frame, we provide some further examples for geodetic products displayed at the GGOS website, representing geometry, gravity field and atmosphere.

Geodetic core products are station positions and their temporal variations at the Earth's surface. These products form the basis for many activities, ranging from classical geodetic tasks, disaster prevention and mitigation to the monitoring of geodynamic effects and climate change phenomena. In addition to official IAG products (e.g., ITRF station positions and velocities), the GGOS website also displays data products provided by other institutions such as the Nevada Geodetic Laboratory (NGL). Figure 5 shows a global GPS network of over 19,000 geodetic stations which are routinely processed to derive a variety of geodetic products (e.g., station positions and velocities, atmospheric water vapor). These products are openly available at NGL's comprehensive GPS products portal (http://geodesy.unr.edu/, Blewitt et al. 2018).



Terrestrial
Reference Frame

How can we provide a stable reference for measuring changes of our planet?

The International Association of Geodesy (IAG) recommends the International Terrestrial Reference Frame (ITRF) as the **standard terrestrial reference frame** for **positioning, satellite navigation and Earth science applications**, as well as for the definition and alignment of national and regional reference frames (see IAG Resolution No. 1, 2019). The importance of geodetic reference frames has been recognized by the United Nations, too. In February 2015, the UN General Assembly adopted its first geospatial resolution "A Global Geodetic Reference Frame for Sustainable Development".

ITRF2014 sites

VLBI SLR GNSS DORIS

ITRF station distribution [Source: Altamimi et al., 2016]

Read More ...

Data Sources

ITRS CENTRE

The ITRS Centre is responsible for the maintenance of the International Terrestrial Reference System (ITRS) and the International Terrestrial Reference Frame (ITRF). It is maintenanced by the IGN in France.

IERS

International Earth Rotation and Reference Systems Service

Further Information

Altamimi Z., P. Rebischung, L. Métivier, X. Collilieux. ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions. Journal of Geophysical Research: Solid Earth 121.8, pp. 6109-6131, DOI: 10.1002/2016JB013098, 2016.

**Fig. 3** Screenshot from the GGOS website for the product description of the terrestrial reference frame (www.ggos.org, screenshot taken on 2021-11-24)

| | | |
|---|---|---|
| **Reference Frames** | | |
| | Terrestrial reference frame | How can we provide a stable reference for measuring changes of our planet? |
| | Celestial reference frame | How can we link Earth and space? |
| | Gravity reference frame | How to refer gravity measurements at the Earth surface to a uniform reference? |
| | Height reference frame | What is a height above sea level? |
| **Geometry** | | |
| Land surface | Station positions & variations | Why do we need precise positioning and navigation on Earth and in space? |
| | Digital elevation model | How can the Earth's surface be represented? |
| | Surface deformation models | Why is the Earth's surface in constant change? |
| Ocean surface and lakes | Sea surface heights | How can the height of oceans be observed? |
| | Ocean topography models | What are dynamic ocean topography models and why are they needed? |
| | Sea level change | How fast is the sea level rising? |
| | Tide gauge records | What is the best sea level reference along the coasts? |
| Ice surface | Ice sheets and glaciers - variations | How fast is the ice being lost in Greenland and Antarctica? |
| **Gravity field** | | |
| | Global gravity field models | How and why does the Earth's gravity change with location? |
| | Gravity field temporal variations | Why is the gravity field variable? |
| | Regional / local geoid models | What is a geoid and why is it needed? |
| | Terrestrial gravity data | What is the purpose of measuring gravity on the Earth's surface? |
| | Ice sheets and glaciers - variations | How fast is the ice being lost in Greenland and Antarctica? |
| | Height systems | Why are height systems so important? |
| **Earth Orientation** | | |
| | Earth orientation parameters | Why are days getting longer and Earth is wobbling? |
| **Positioning and Applications** | | |
| Atmosphere | Atmospheric products | How can space geodetic techniques observe the atmosphere? |
| | Lower neutral atmosphere | How can geodesy contribute to weather prediction? |
| | Ionosphere | How does electron density affect positioning and navigation? |
| | Thermosphere | How does the atmosphere influence low-flying satellites? |
| GNSS products | GNSS satellite orbits and clocks | How positioning benefits from precise satellite orbits and clocks? |

**Fig. 4** List of product descriptions that are currently displayed at the GGOS website, including an "appetizing question" for each particular product, status: 2021-11-15

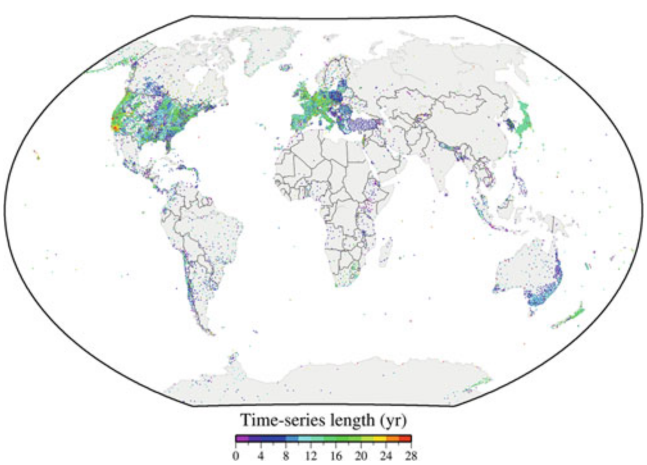



**Fig. 5** Global network of over 19,000 geodetic GPS stations processed by the Nevada Geodetic Laboratory (NGL) in USA (Source: Blewitt et al. 2018)

Also global gravity field models are fundamental geodetic products (see Fig. 6). These products provide information about the physical Earth's shape, its interior and fluid envelope. They are essential for many Earth system research areas such as quantifying mass distribution and mass transport, monitoring oceanic transport, continental hydrology, ice mass balance and sea level, and dynamics of mantle and crust. The GGOS website gives an overview about static and time-variable gravity field models and provides a link to the respective IAG Services, the International Centre for Global Earth Models (ICGEM, Ince et al. 2019), coordinated by the International Gravity Field Service (IGFS), as well as the International Combination Service for Time-Variable Gravity Fields (COST-G, Jäggi et al. 2020), which is the Product Centre of the IGFS for time-variable gravity fields. In addition to these official IAG Service products, the GGOS website also displays high-level products such as temporal

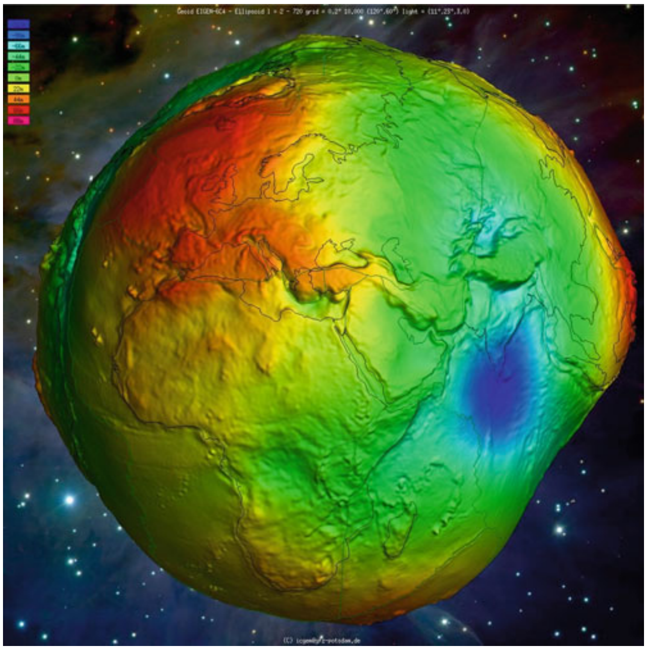


**Fig. 6** Geoid from combined global gravity field model EIGEN-6C4 (Source: Ince et al. 2019)

variations of ice sheets in Greenland and Antarctica (https://ggos.org/item/ice-sheets-glaciers/), including a link to the providers. These derived products are highly relevant to society, since phenomena such as the global sea level rise are largely driven by accelerated melting of the Greenland and Antarctica ice sheets and glaciers, and could be catastrophic for millions of people in the future.

A further example from the GGOS products pages is provided in Fig. 7. It shows the impact of the 2017 typhoon Noru on the distribution of atmospheric delay gradients and zenith wet delays (ZWD) in central Japan. The method for the calculation of the ZWD is described in Arief and Heki (2020). Routinely generated are such troposphere products by the International GNSS Service (IGS) and the International VLBI Service for Geodesy and Astrometry (IVS). Furthermore, the GGOS website provides a link to troposphere products at the regional level such as EUREF, the Regional Reference Frame for Europe, and SIRGAS, the Geocentric Reference Frame for the Americas. The ZWDs derived from space geodetic techniques provide important atmospheric information for weather models.

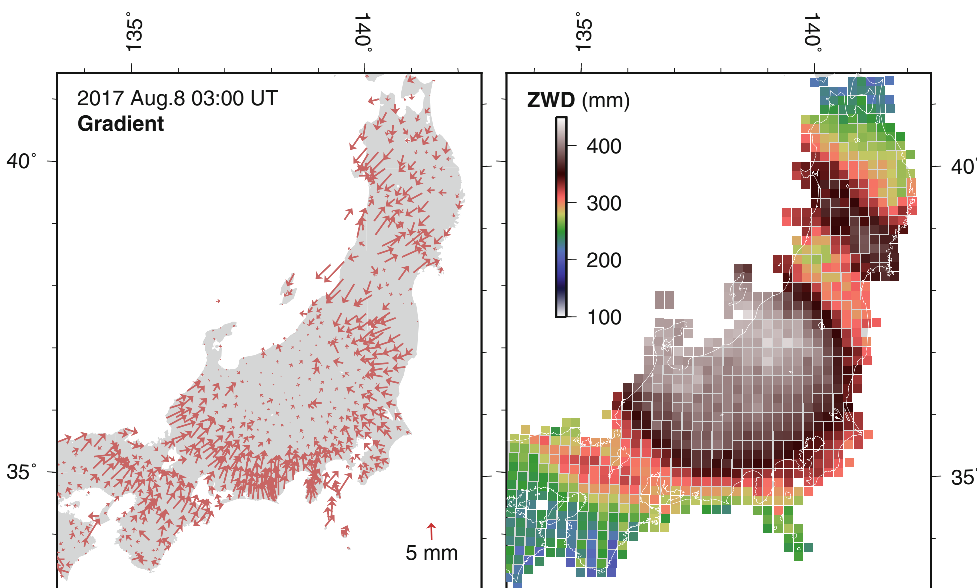



**Fig. 7** Distribution of atmospheric delay gradients (left) and wet delays (right) when the 2017 typhoon Noru made landfall in central Japan (for more details see Arief and Heki 2020)

## 4 Conclusions

The IAG strives to provide geodetic results at the highest level of precision and consistency, which fundamentally requires that the processing and combination of the contributing geometric and gravimetric observations are based on unified standards and conventions. In cooperation with the IAG Services and other entities involved, the BPS contributes to this goal by evaluating the adopted standards and conventions across all IAG components and by regularly updating the BPS inventory.

The recent BPS activities focused on the classification of geodetic products and on the generation of user-friendly descriptions, which have been implemented at the renewed GGOS website. With this, GGOS provides a unique information platform and a central access point for geodetic data and products, which should help to make them easier findable and which should also contribute to make other disciplines and society aware of geodesy and its beneficial products.

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