Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

BPS Meeting, 21. September 2023, 14:15 – 15:30

Agenda

- BPS Activity Report (Detlef Angermann et al.)
- Some thoughts on the definition of EGVs (Thomas Gruber, remote)
- Working Group "Towards a consistent set of parameters for the definition of a new GRS" (Urs Marti, remote)
- Committee "Contributions to Earth System Modelling" (Maik Thomas, remote)
- Discussion

GGOS Days 2023, Alcalá de Henares, Spain, September 20-22, 2023

GGOS Bureau of Products and Standards (BPS) – Activity Report

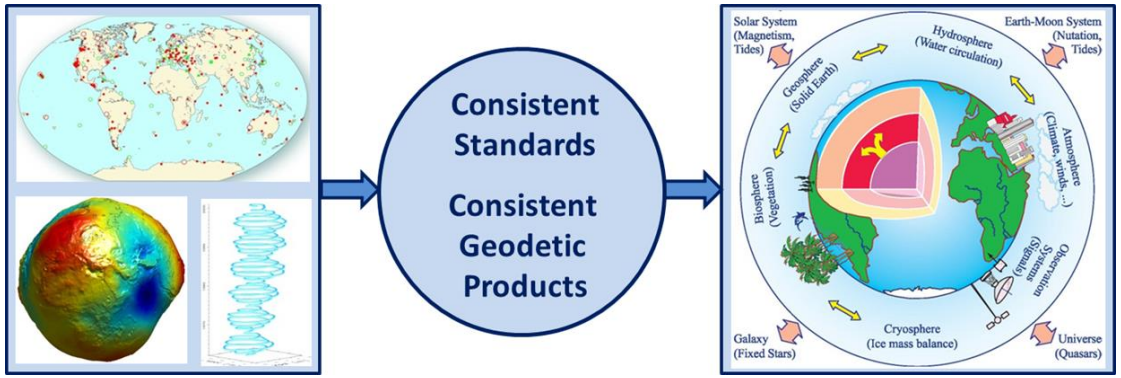
- BPS is chaired by the Technical University of Munich

  D. Angermann (Director), T. Gruber (Deputy Director), M. Gerstl (retired), R. Heinkelmann (GFZ), U. Hugentobler (TUM), L. Sánchez (DGFI-TUM), P. Steigenberger (DLR)

- **GGOS components associated to the BPS:**
  - Committee "**Contributions to Earth System Modelling (ESM)**" (Chair: M. Thomas)
  - Committee "**Definition of Essential Geodetic Variables (EGVs)**" (Chair: R. Gross)
  - Working Group **"Towards a consistent set of parameters for the definition of a new GRS**" (Chair: U. Marti)

- **Objectives:**
  - contact and coordinating point for homogenization of IAG standards and products
  - keep track of the adopted geodetic standards and conventions across all IAG components
  - motivate the development of new geodetic products
  - describe and promote geodetic products

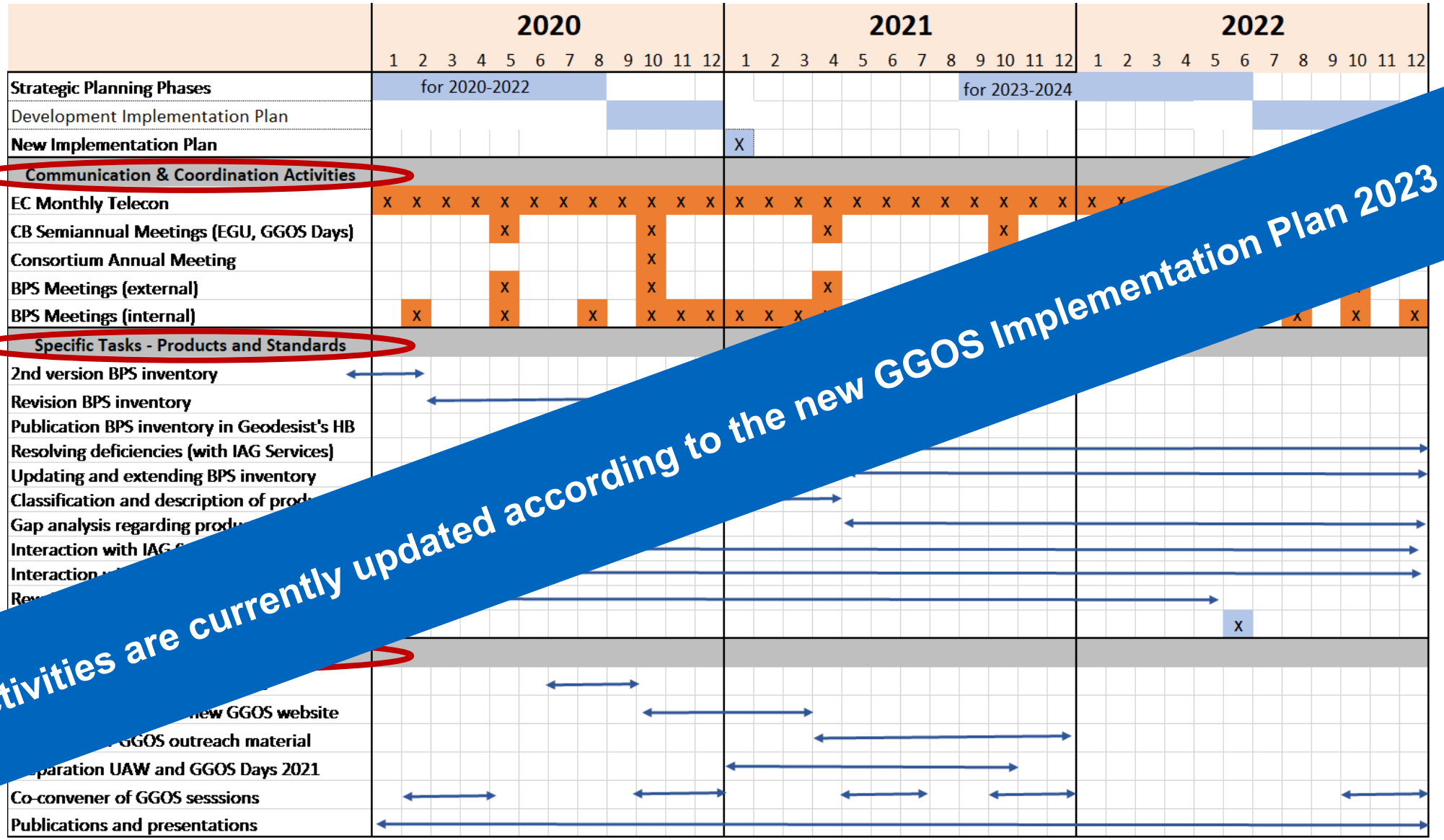
The BPS supports GGOS in its key goal to integrate the three pillars geometry, gravity field and rotation of the Earth



Representatives of IAG Services and other entities

R. Heinkelmann, Germany	International Earth Rotation and Reference Systems Service (IERS)	geometry
N. Stamatakos, USA	International Earth Rotation and Reference Systems Service (IERS)	
U. Hugentobler, Germany	International GNSS Service (IGS)	
E. Pavlis, USA	International Laser Ranging Service (ILRS)	
J. Gipson, USA	International VLBI Service for Geodesy and Astrometry (IVS)	
P. Štěpánek, Czech Republic	International DORIS Service (IDS)	
R. Barzaghi, Italy	International Gravity Field Service (IGFS)	gravity
S. Bonvalot, France	Bureau Gravimétrique International (BGI)	
M. Reguzzoni, Italy	International Service for the Geoid (ISG)	
E. S. Ince, Germany	International Center for Global Earth Models (ICGEM)	
K. M. Kelly, Germany	International Digital Elevation Model Service (IDEMS)	
H. Wzointek, Germany	International Geodynamics and Earth Tide Service (IGETS)	
J. Kusche, Germany	Representative of gravity community	
J. Ferrandiz, Spain	IAU Commission A3 Fundamental Standards	other entities
M. Craymer, Canada	Chair of Control Body for ISO Geodetic Registry Network	
L. Hothem, USA	Vice-Chair of Control Body for ISO Geodetic Registry Network	
S. Rózsa, Hungary	IAG Communication and Outreach Branch	
M. Sehnal, Austria	GGOS Coordinating Office	

BPS Implementation Plan 2020 – 2022



Activities are currently updated according to the new GGOS Implementation Plan 2023 – 2025

Overview of BPS tasks

- Keep track of adopted geodetic standards and conventions (BPS inventory)
- Contribute to the re-writing/revising of the IERS Conventions (in the function as Chapter Expert for Chapter 1 “General definitions and numerical standards“)
- Motivate development of integrated geodetic products (interact with GGOS Focus Areas)
- Classification and description of geodetic products (see www.ggos.org)
- Contribute to the definition of Essential Geodetic Variables (EGVs)

Mainly within IAG/GGOS

- Contribute to IAG/GGOS outreach (e.g. GGOS Website, Portal, Videos, Brochures,…)
- Interact with external stakeholders (e.g. IAU, ISO, UN-GGIM SCoG/GGCE,…)
- BPS representation in IAU Commission A3 “Fundamental Standards“
- IAG representative to ISO/TC 211
- IAG representative to UN-GGIM SCoG WG “Standards, Data Sharing and Policies“

External (outside IAG)

BPS Inventory of Standards and Conventions

Inventory of standards and conventions used for the generation of IAG products (*Angermann et al. 2016 and 2020*)

- Introduction (Chapter 1)
- GGOS Bureau of Products and Standards (Chapter 2)
- Evaluation of numerical standards (Chapter 3)
- Product-based review (Chapter 4)
  - Six IAG products/topics have been evaluated (see right)
  - Consider other products (e.g. atmosphere products, sea level, ice melting, terrestrial water storage, …)
- Assess the present status, identify gaps and deficiencies, provide recommendations (interaction with IAG Services, IERS Conventions Center, IAU, ISO, UN-GGIM SCoG/GGCE, …)
- Goal: Improve consistency of geodetic products

Contents

Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P. (2020): ***GGOS Bureau of Products and Standards: Inventory of standards and conventions used for the generation of IAG products****. The Geodesist's Handbook 2020, Eds: Poutanen M., Rózsa S., Journal of Geodesy, https://doi.org/10.1007/s00190-020-01434-z.*

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External (outside IAG)

BPS recommendations for IERS Conventions Chapter 1 update

- Outcome of Unified Analysis Workshop 2022 (Thessaloniki, Greece, October 21-23, 2022) "Session: Standards, Conventions, and Formats (Chairs: D. Angermann, N. Stamatakos)"
- Section 1.1 Permanent Tide
  - Include the IAG Resolution (2015) on the International Height Reference Frame (IHRF) demanding the mean-tide system for heights
  - Update references (e.g., Drewes et al. 2016; Ihde et al. 2017; Mäkinen 2021; Sánchez et al. 2021)
  - Add a short paragraph or a footnote summarizing the strategy for the implementation of the IHRF concerning the handling of the permanent tide (to be discussed within IERS)
- Section 1.2 Numerical Standards
  - Update Table 1.1 "IERS numerical standards" (see next slide)
  - Notes on Table 1.2 "Parameters of the GRS80"; Towards a new GRSXX (see presentation by Urs Marti)
- General recommendations of the BPS
  - **REC-1**: The used numerical standards including time and tide systems must be clearly documented for all geodetic products (*across all IAG components*)
  - **REC-2**: The BPS recommends that the necessity of a new Geodetic Reference System (GRSXX) should be further clarified (*WG: Urs Marti*)

IERS Conventions Section 1.2 Numerical Standards

(Table taken from IERS Conventions)

Table 1.1: IERS numerical standards.

	Constant	Value	Uncertainty	Ref.	Description
		Natural defining constants			
CODATA	c	$299792458\ \mathrm{ms}^{-1}$	Defining	[1]	Speed of light
		Auxiliary defining constants			
IAU	k	$1.720209895 \times 10^{-2}$	Defining	[2]	Gaussian gravitational constant
IAU	L_G	$6.969290134 \times 10^{-10}$	Defining	[3]	1−d(TT)/d(TCG)
IAU	L_B	$1.550519768 \times 10^{-8}$	Defining	[4]	1−d(TDB)/d(TCB)
IAU	TDB_0	-6.55×10^{-5} s	Defining	[4]	TDB−TCB at JD 2443144.5 TAI
IAU	θ_0	0.7790572732640 rev	Defining	[3]	Earth Rotation Angle (ERA) at J2000.0
IAU	$d\theta/dt$	1.00273781191135448 rev/UT1day	Defining	[3]	Rate of advance of ERA
		Natural measurable constant			
CODATA	G	$6.67428 \times 10^{-11}\ \mathrm{m^3kg^{-1}s^{-2}}$	$6.7 \times 10^{-15}\ \mathrm{m^3kg^{-1}s^{-2}}$	[1]	Constant of gravitation
		Body constants			
DE421	$GM_\odot$ #	$1.32712442099 \times 10^{20}\ \mathrm{m^3s^{-2}}$	$1 \times 10^{10}\ \mathrm{m^3s^{-2}}$	[5]	Heliocentric gravitational constant
DE421	$J_{2\odot}$	2.0×10^{-7}	(adopted for DE421)	[5]	Dynamical form factor of the Sun
DE421	μ	0.0123000371	4×10^{-10}	[6]	Moon-Earth mass ratio
		Earth constants			
Groten 2004	$GM_\oplus$ †	$3.986004418 \times 10^{14}\ \mathrm{m^3s^{-2}}$	$8 \times 10^{5}\ \mathrm{m^3s^{-2}}$	[7]	Geocentric gravitational constant
Groten 2004	a_E †‡	6378136.6 m	0.1 m	[8]	Equatorial radius of the Earth
Groten 2004	$J_{2\oplus}$ ‡	1.0826359×10^{-3}	1×10^{-10}	[8]	Dynamical form factor of the Earth
Groten 2004	$1/f$ ‡	298.25642	0.00001	[8]	Flattening factor of the Earth
Groten 2004	g_E †‡	$9.7803278\ \mathrm{ms^{-2}}$	$1 \times 10^{-6}\ \mathrm{ms^{-2}}$	[8]	Mean equatorial gravity
2017/11/06	W_0	$62636853.4\ \mathrm{m^2s^{-2}}$	$0.02\ \mathrm{m^2s^{-2}}$	[10]	Potential of the geoid
IAG 2015	R_0 †	6363672.6 m	0.1 m	[8]	Geopotential scale factor ($GM_\oplus/W_0$)
IAG 2015	H	3273795×10^{-9}	1×10^{-9}	[9]	Dynamical flattening
		Initial value at J2000.0			
	ϵ_0	84381.406″	0.001″	[4]	Obliquity of the ecliptic at J2000.0
		Other constants			
IAU	au ††	$1.49597870700 \times 10^{11}$ m	3 m	[6]	Astronomical unit
IAU	L_C	$1.48082686741 \times 10^{-8}$	2×10^{-17}	[3]	Average value of 1−d(TCG)/d(TCB)

TCB-compatible value, computed from the TDB-compatible value in [5].

† The value for $GM_\oplus$ is TCG-compatible. For a_E, g_E and R_0 the difference between TCG-compatible and TT-compatible is not relevant with respect to the uncertainty.

‡ The values for a_E, $1/f$, $J_{2\oplus}$ and g_E are "zero tide" values (see the discussion in Section 1.1 above). Values according to other conventions may be found in reference [8].

†† TDB-compatible value. An accepted definition for the TCB-compatible value of au is still under discussion.

[1] Mohr *et al.*, 2008.

[2] Resolution adopted at the IAU XVI General Assembly (Müller and Jappel, 1977), see http://www.iau.org/administration/resolutions/general_assemblies/

[3] Resolution adopted at the IAU XXIV General Assembly (Rickman, 2001), see http://www.iau.org/administration/resolutions/general_assemblies/

[4] Resolution adopted at the IAU XXVI General Assembly (van der Hucht, 2008), see http://www.iau.org/administration/resolutions/general_assemblies/

[5] Folkner *et al.*, 2008.

[6] Pitjeva and Standish, 2009.

[7] Ries *et al.*, 1992. Recent studies (Ries, 2007) indicate an uncertainty of $4 \times 10^5\ \mathrm{m^3s^{-2}}$.

[8] Groten, 2004.

[9] Value and uncertainty consistent with the IAU2006/2000 precession-nutation model, see (Capitaine *et al.*, 2003).

2017/11/06 [10] Resolution No. 1 adopted at the IAG (2015), see https://iag.dgfi.tum.de/fileadmin/IAG-docs/IAG_Resolutions_2015.pdf

BPS recommendations for Table 1.1 updates:

- IAU Res. B1.9 (2000): L_G declared as defining constant => L_G should not change with new updates of W_0 ($L_G = W_0/c_2$)
- IAU Res. B2 (2012): Gaussian gravitational constant ***k*** to be deleted from the system of astronomical constants
- IAU Res. B2 (2012): astronomical unit (**au**) => exact value
- L_C is a derived quantity => should be deleted from the table
- CODATA (2018): New value ***G*** = 6.67439 x 10^{-11} m^3 kg^{-1} s^{-2}
- New JPL planetary and lunar ephemerides (DE440 and DE441, Park et al. 2021)
- New value: GM_0 = 1.32712440042 x 10^{20} m^3 kg^{-1} s^{-2} (Pitjeva 2015)

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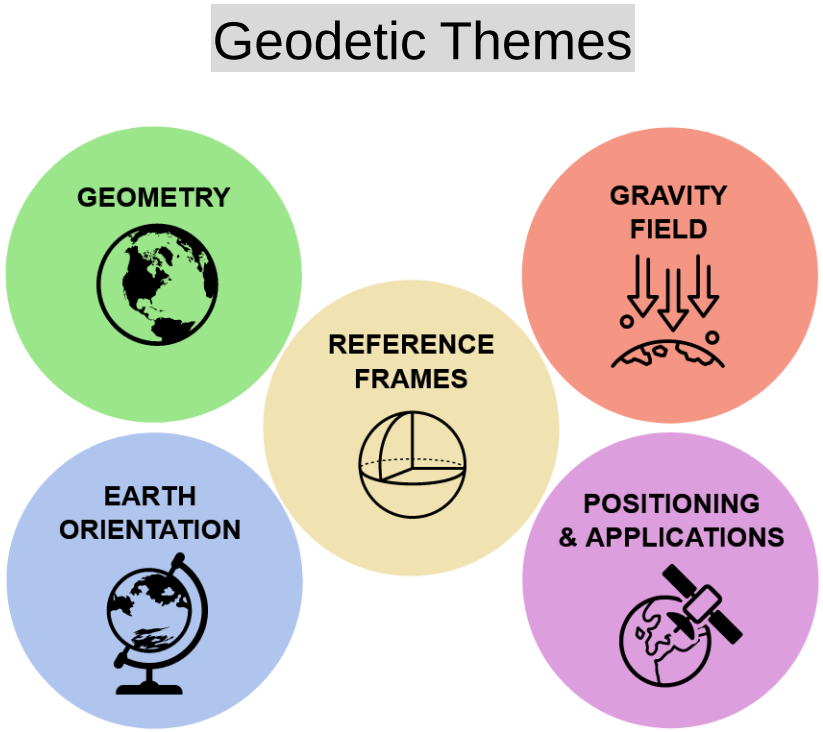
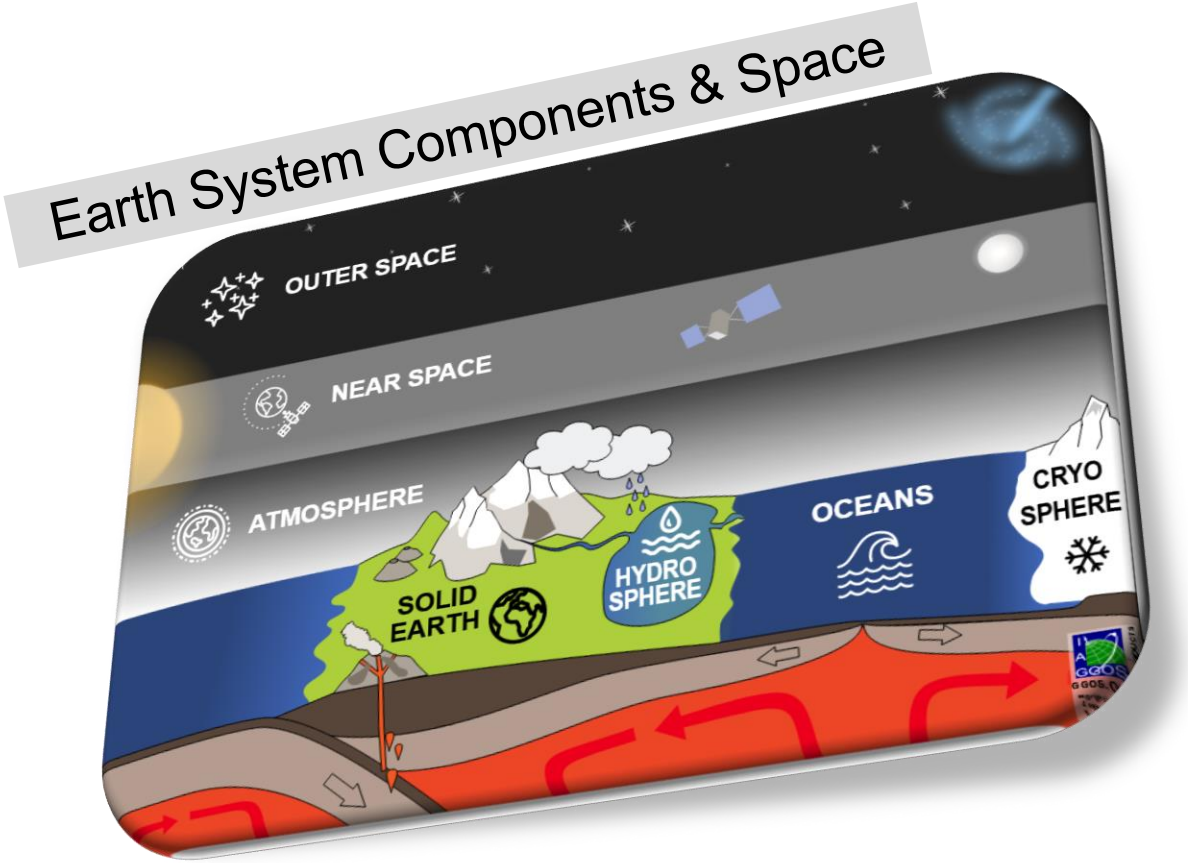
External (outside IAG)

Classification and description of geodetic products

Two classifications for geodetic products:

- ***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, and solid Earth





Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P., Gross R., Heki K., Marti U., Schuh H., Sehnal M., Thomas M.: **GGOS Bureau of Products and Standards: Description and Promotion of Geodetic Products**. In: (Eds. J. Freymueller, L. Sánchez), IAG Symposia, 10.1007/1345_2022_144, 2022

List of geodetic products and “appetizer“ questions (some examples)

Reference Frames

- Height Reference Frame
- Celestial Reference Frame
- Gravity Reference Frame
- Terrestrial Reference Frame

How can we link Earth and space?

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

Geometry

- Surface Deformation Models
- Ocean Topography Models
- Sea Level Change
- Digital Elevation Model
- Ice Sheets & Glaciers – Variations
- Station Positions & Variations
- Tide Gauge Records
- Sea Surface Heights

Why is the Earth‘s surface in constant change?

How fast is the sea level rising?

How fast is the ice being lost in Greenland and Antarctica?

How can the height of oceans be observed?

Earth Orientation

- Earth Orientation Parameters

Why are the days getting longer and the Earth is wobbling?

Gravity Field

- Global Gravity Field – Models
- Gravity Field – Temporal Variations
- Terrestrial Gravity Data
- Regional / Local Geoid Models
- Ice Sheets & Glaciers – Variations
- Height Systems

Why is the Earth‘s gravity field variable?

What is a geoid and why is it needed?

Why are height systems so important?

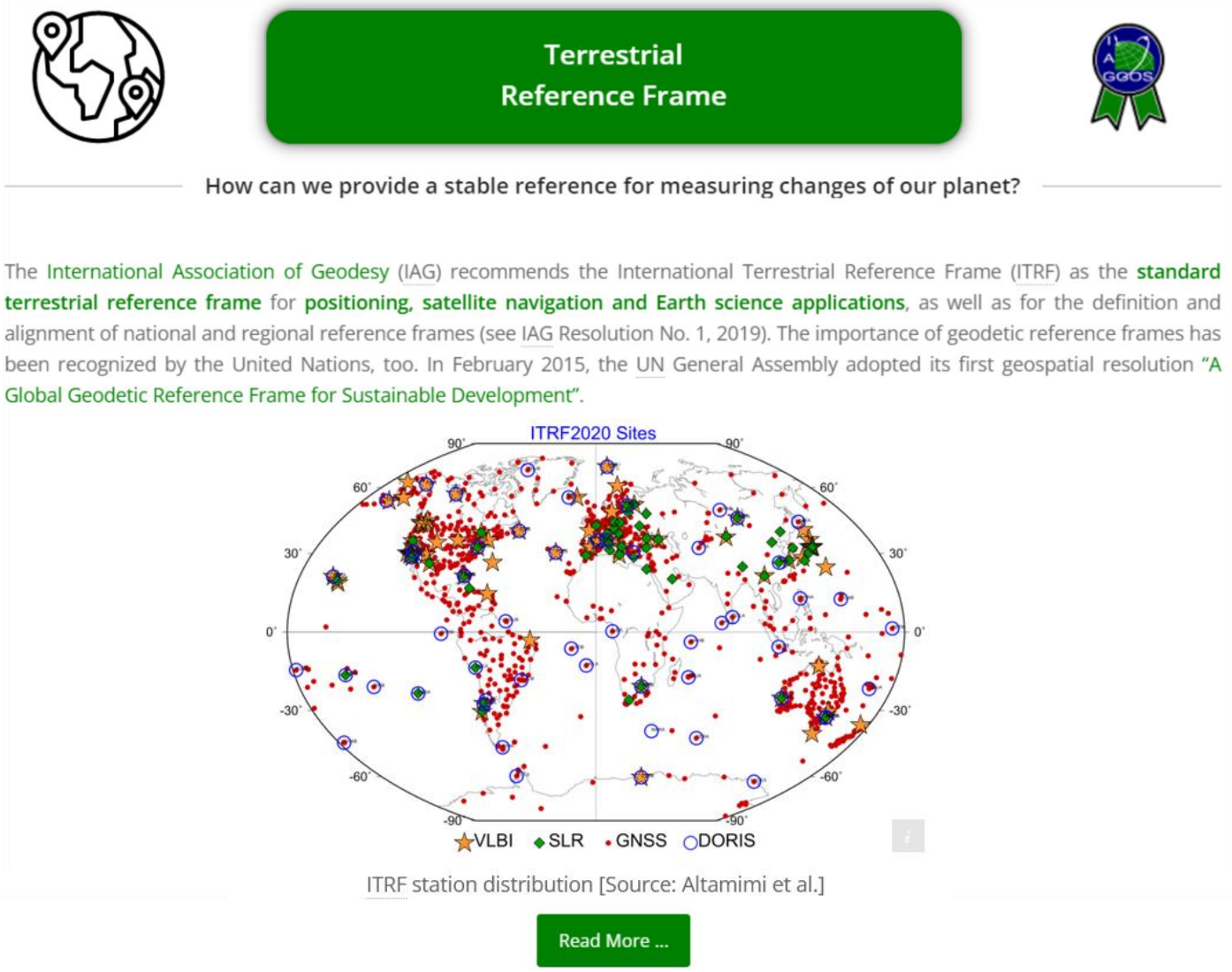
Positioning & Applications

- Thermosphere
- Ionosphere
- Lower Neutral Atmosphere
- Atmospheric Products
- GNSS Satellite Orbits and Clocks

How does the atmosphere influence low-flying satellites?

How can geodesy contribute to weather prediction?

Product descriptions at GGOS Website (www.ggos.org)

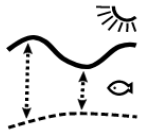


- 23 product descriptions finished
- Further descriptions will follow (e.g. terrestrial water storage, …)

Status: July 2023

Top Products	Visits
Sea Surface Heights	4951
EOP – Earth Orientation Parameters	4582
TRF – Terrestrial Reference Frame	3468
CRF – Celestial Reference Frame	3297
GNSS Satellite Orbits and Clocks	2501
GRF - Gravity Reference Frame	1986
Global Gravity Field Models	1791
Height Systems	1664

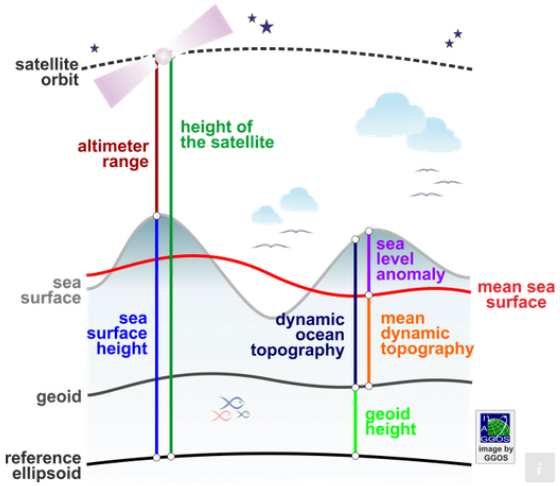
Sea surface heights (www.ggos.org)



Sea Surface Heights

How can the height of oceans be observed?

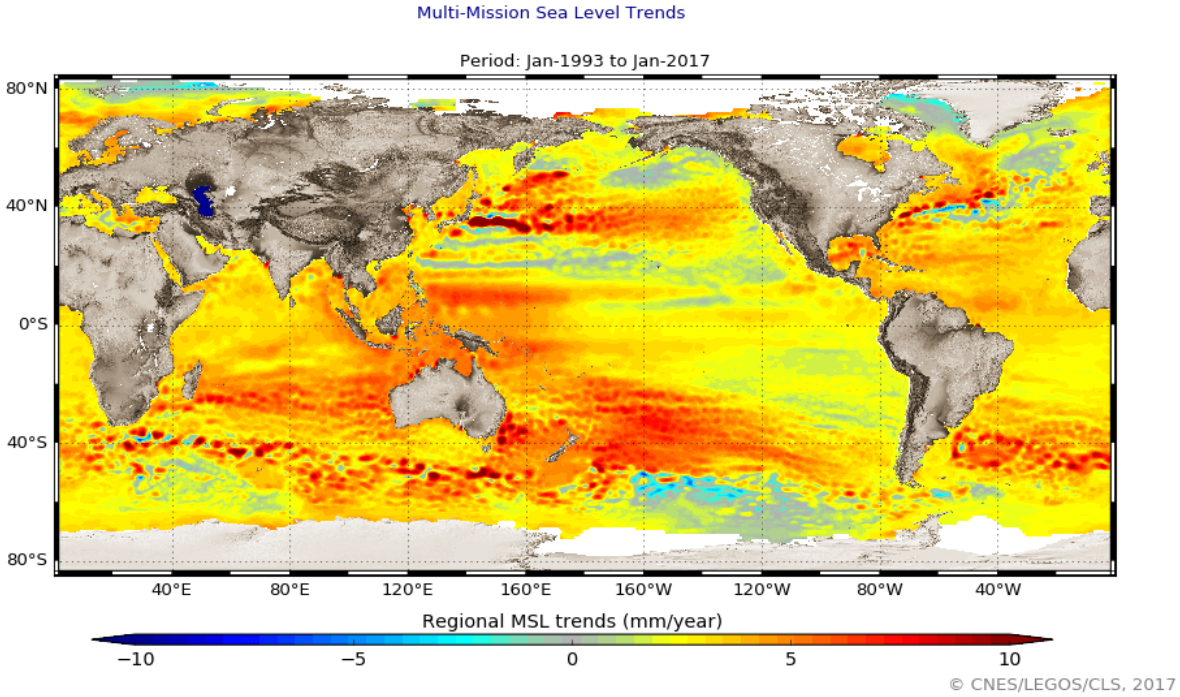
Satellite altimetry systems are designed to map the sea surface. These systems **measure the satellite-to-sea surface** round-trip travel time of radar or light pulses to determine the height of the satellite (altimetric range) above the instantaneous sea surface. The difference between the satellite altitude above a reference surface and the altimetric range provides the sea surface height with respect to the same reference surface. The range from the satellite to the sea surface is **corrected for various components** of the atmospheric refraction and to mitigate effects caused by instrumental biases and sea state induced systematics. A number of corrections due to different geophysical effects are also taken into account. **Different products are distinguished**:



Definition of various quantities related to sea-surface-heights

- + Sea Surface Height (SSH)
- + Mean Sea Surface (MSS)
- + Sea Level Anomalies (SLA)
- + Dynamic Ocean Topography (DOT)
- + Mean Dynamic Topography (MDT)
- + Mean Sea Level (MSL)
- + Global Mean Sea Level (GMSL)

Read More ...



Selected Data Sources

RADAR ALTIMETRY TUTORIAL AND TOOLBOX
at the European Space Agency (ESA) and Centre National d'Etudes Spatiales (CNES)

OCEAN SURFACE TOPOGRAPHY
from Space at the US National Aeronautics and Space Administration (NASA)

AVISO+ SATELLITE ALTIMETRY DATA
at the Centre National d'Etudes Spatiales (CNES) and the Center for Topographic studies of the Ocean and Hydrosphere (CTOH)

ALTIMETRIC AND OCEAN SURFACE TOPOGRAPHY DATA INFORMATION
at the US National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA)

COPERNICUS
European Union's Earth Observation Programme Copernicus

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External (outside IAG)

BPS contributions to GGOS outreach activities

GGOS Website (www.ggos.org)

- About GGOS (Organization)
- Information Portal
  - Descriptions & Links
  - Observations, Services, Products
- Events, Blog, Social Media, …
- GGOS Cloud (Documents)

GGOS Videos (https://www.youtube.com/c/GGOSGlobalGeodeticObservingSystem)

- Discover GGOS and Geodesy (12 languages, ~14.000 views on YouTube)
- New Film about Terrestrial Reference Frames (8 languages)
- More videos about geodetic products will follow (e.g. Geoid, EOPs, …)
- Social media posts about products (e.g. appetizer questions + illustrations)

Ongoing and future activities

- Update BPS activities for new GGOS Implementation Plan 2023 – 2025
- Keep track of standards and conventions across all IAG components
  - Regular update of the BPS Inventory of Standards and Conventions
  - Interaction with IAG Services, IERS Conventions Center, IAU, ISO, …
- Activities related to geodetic products
  - Accuracy assessment, gap analysis and requirements for geodetic products (link to EGV definition)
  - Motivate the development of integrated geodetic products (interact with GGOS Focus Areas)
  - Prepare further product descriptions (e.g. terrestrial water storage, time series of inland water, …)
- Activities related to GGOS outreach activities
  - Contribute to GGOS Website updates, Outreach Material (Brochures, Social Media Posts, …)
  - Contribute to GGOS Portal developments
  - Contribute to further GGOS Films (e.g. more videos about geodetic products will follow)
- Focus on the definition of Essential Geodetic Variables (next presentation by Thomas Gruber)
- …