Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

The importance of highly-accurate and consistent geodetic products for reliable Earth system monitoring

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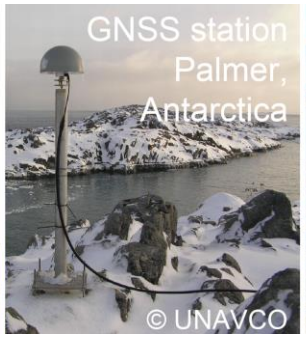
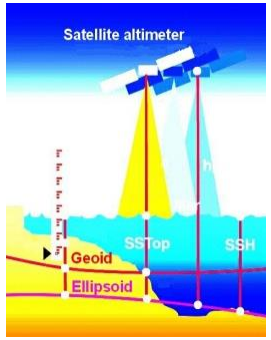
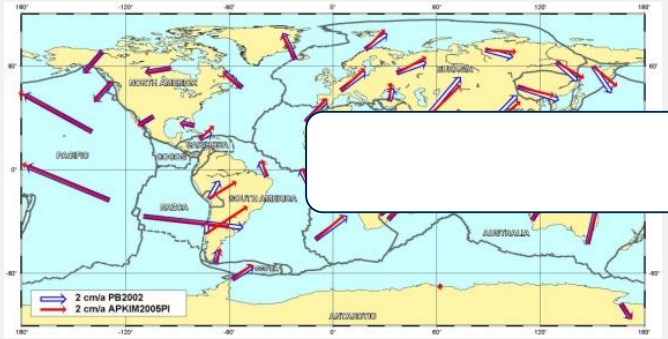
IUGG BERLIN 2023
THE 28TH GENERAL ASSEMBLY

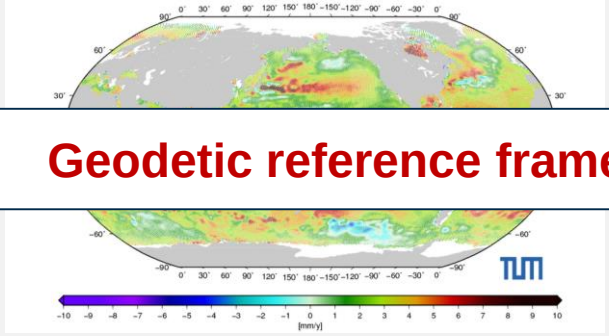
Symposium G06 ”Monitoring and Understanding the Dynamic Earth with Geodetic Observations”

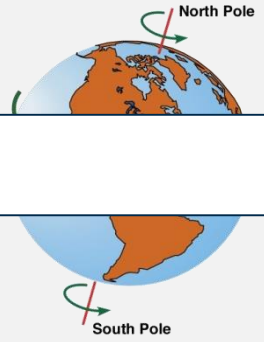
Introduction

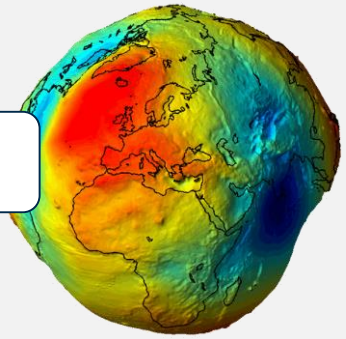




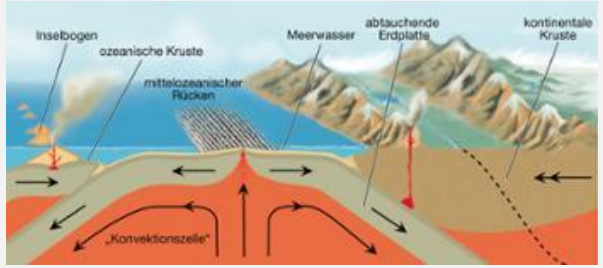




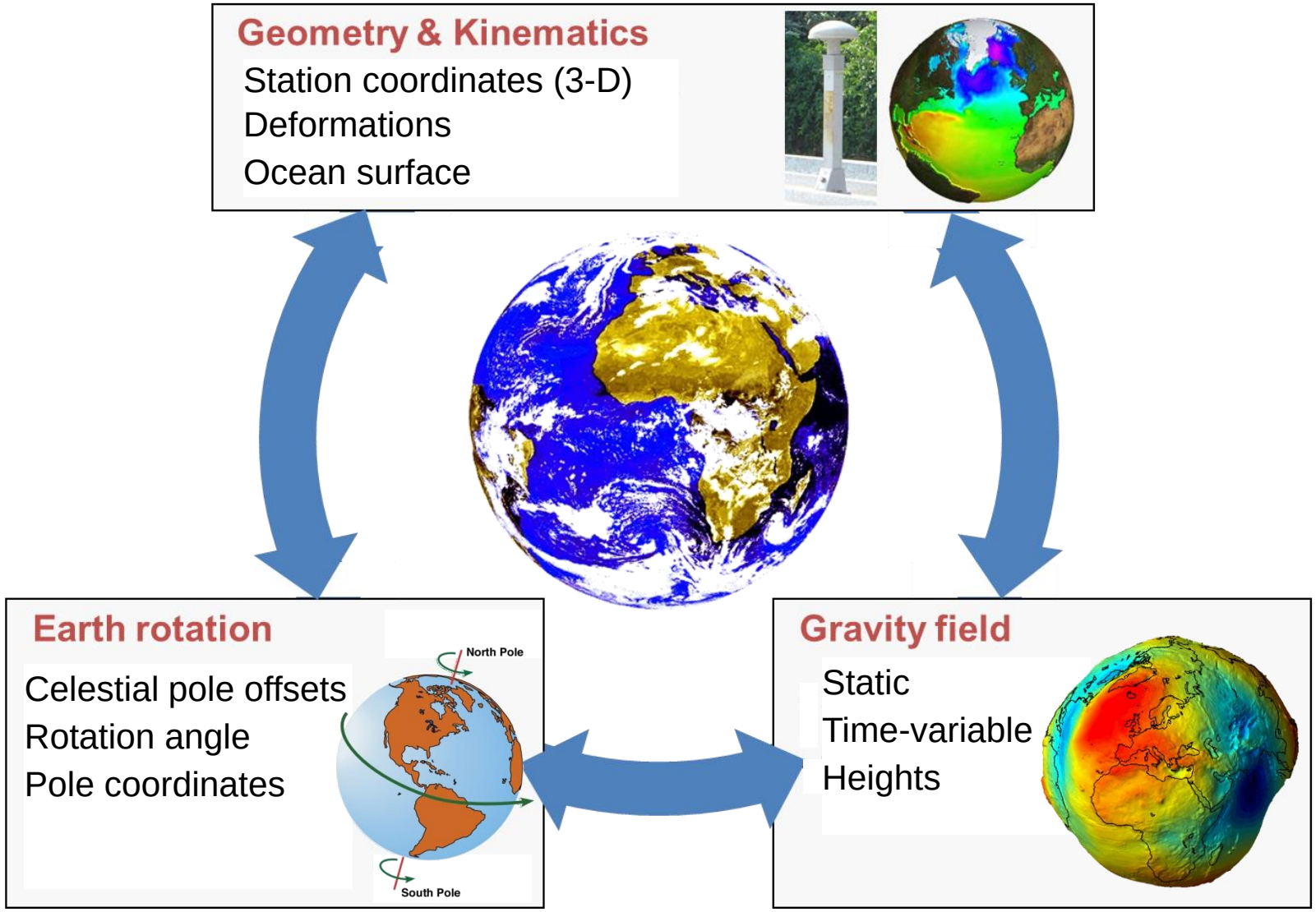




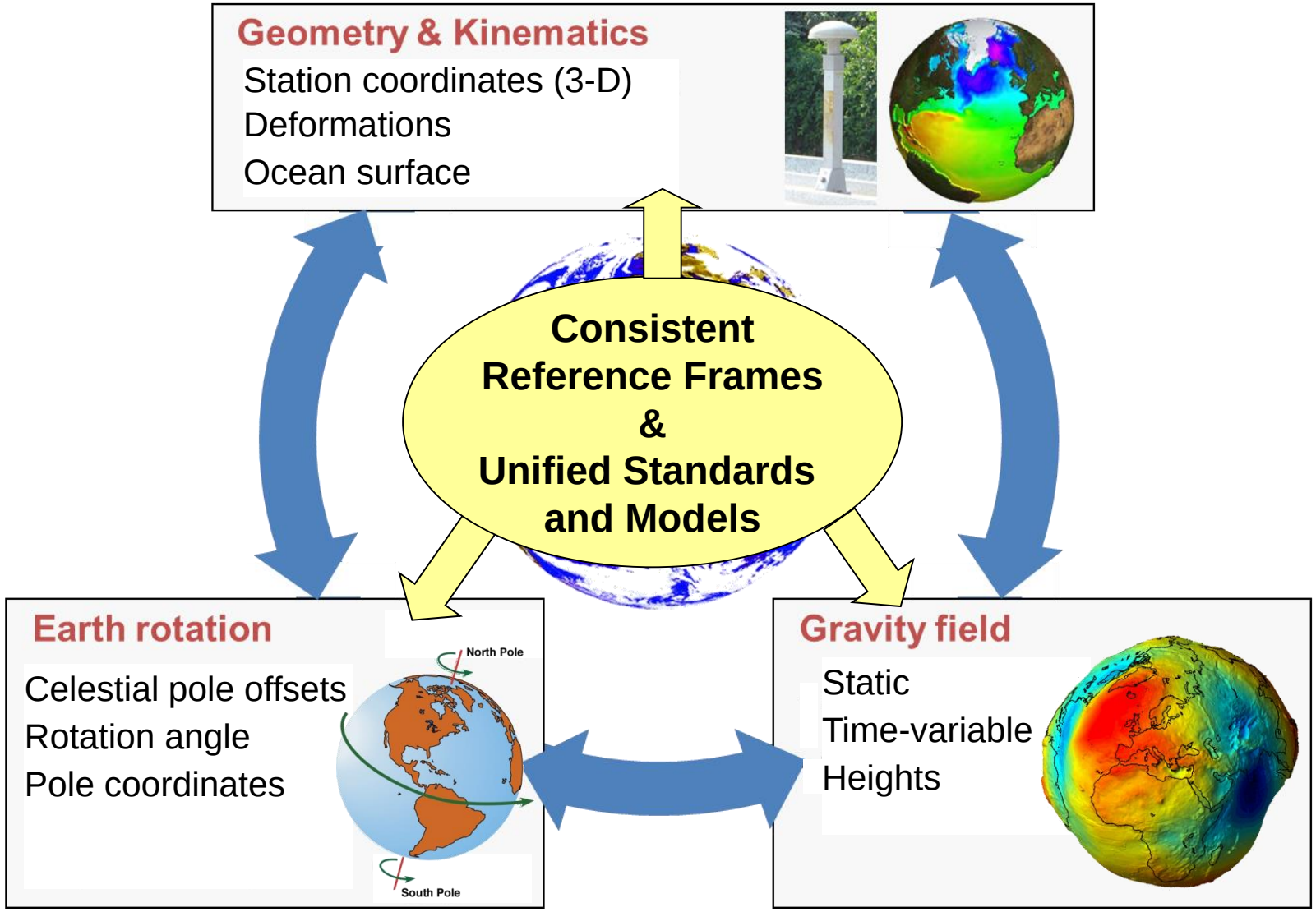
Geodetic reference frames



Introduction



Introduction



GGOS Bureau of Products and Standards (BPS)

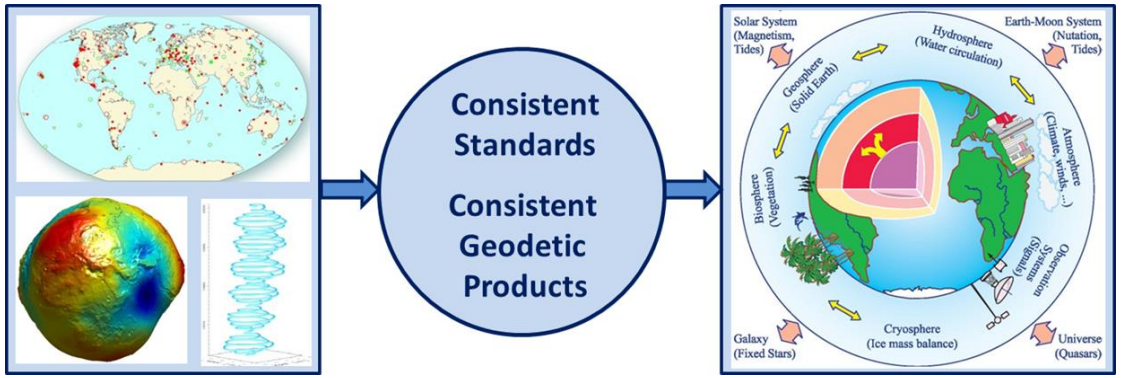
- BPS is chaired by Technical University of Munich

  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
  - stimulate the development of new geodetic products, needed for Earth sciences and society
  - description and promotion of 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, USA	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 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)
  - Consideration of other products (e.g., atmosphere products, sea level, ice melting, ground water storage, lakes, …)
- Assess the present status, identify gaps and deficiencies, provide recommendations (interaction with IAG Services, IERS Conventions Center, UN-GGIM SCoG, GGCE, IAU, ISO, …)
- Goal: Improve consistency of geodetic products

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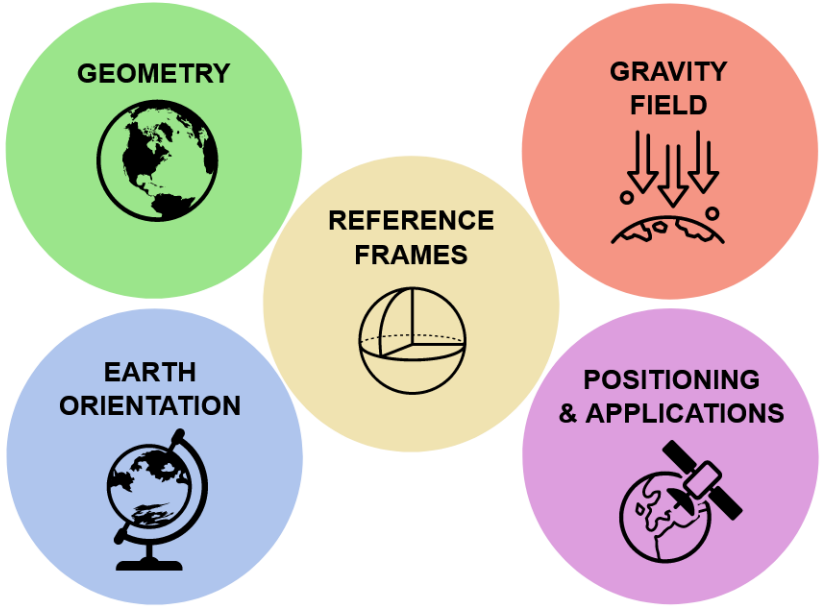
Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P. (2020): ***GGOS Bureau of Products and Standards: Inventory of standards and conventions used for the generation of IAG products****. The Geodesist's Handbook 2020, Eds: Poutanen M., Rózsa S., Journal of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

Classification and description of geodetic products

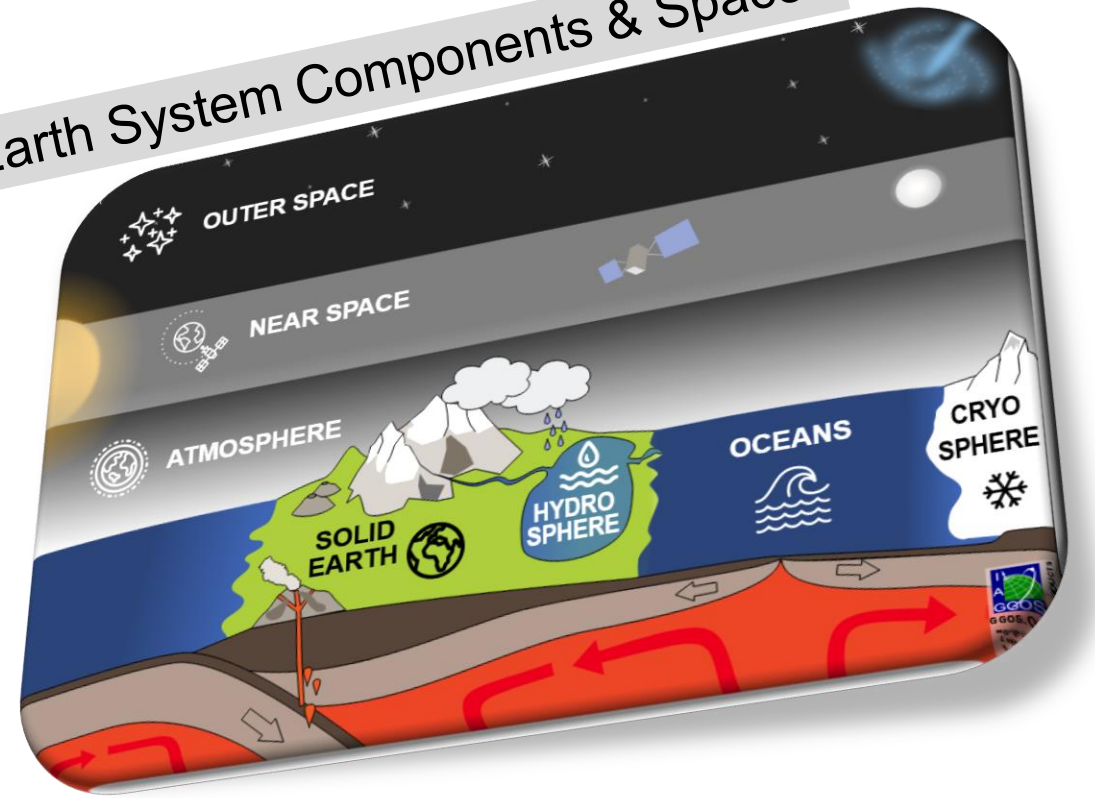
Two classifications for geodetic products:

- ***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

Geodetic Themes



Earth System Components & Space



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?

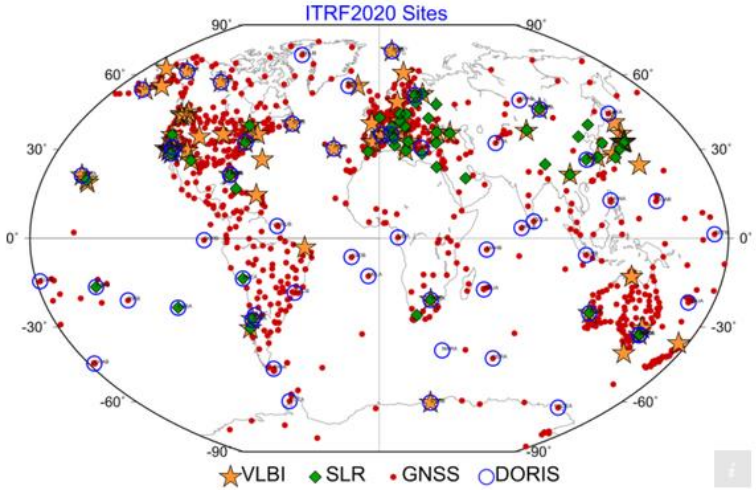
GFZ Helmholtz-Zentrum Potsdam · DLR · Federal Office of Metrology and Surveying

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

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".



ITRF station distribution [Source: Altamimi et al.]

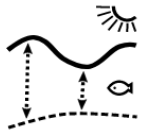
Read More ...

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

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

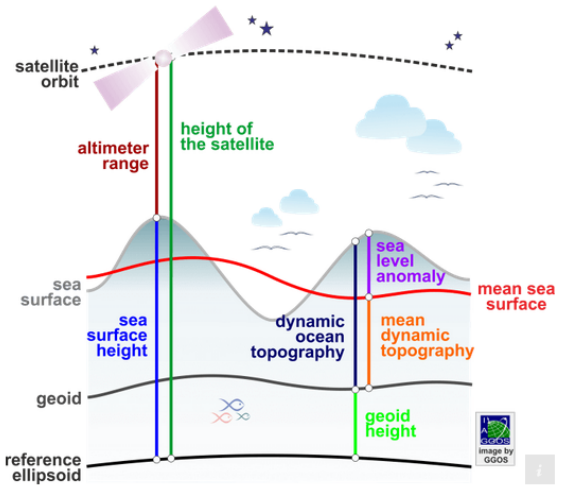
Sea surface heights (www.ggos.org)



Sea Surface Heights

How can the height of oceans be observed?

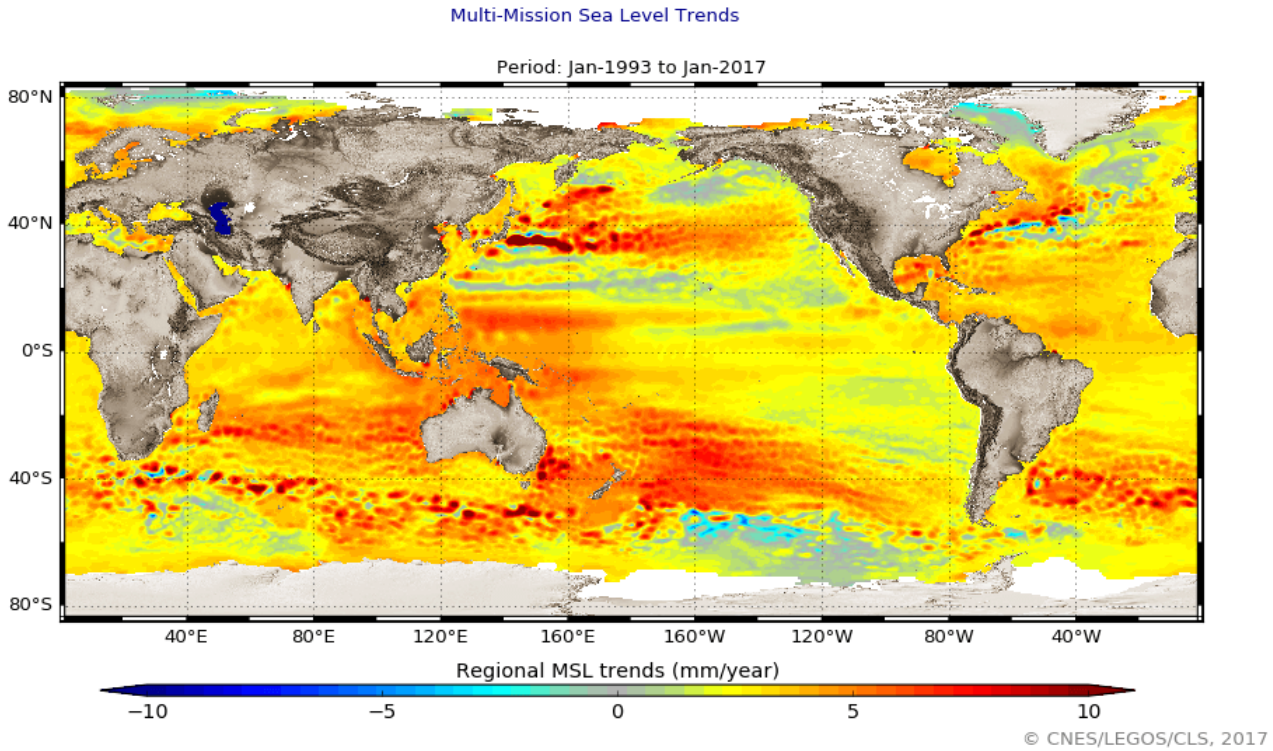
Satellite altimetry systems are designed to map the sea surface. These systems **measure the satellite-to-sea surface** round-trip travel time of radar or light pulses to determine the height of the satellite (altimetric range) above the instantaneous sea surface. The difference between the satellite 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 ...

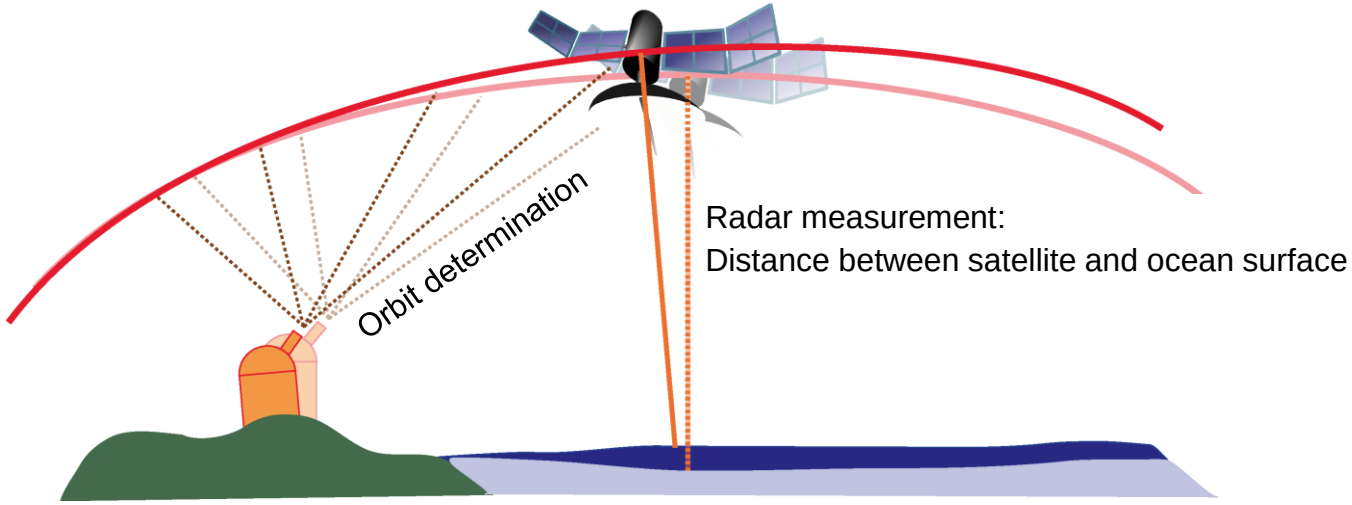


Enormous threat potential caused by rising sea level

IPCC's Special Report on the Ocean and Cryosphere in a Changing Climate. Credit: Julie G via Flickr.

Mean sea level variations from satellite altimetry

The key role of reference frames



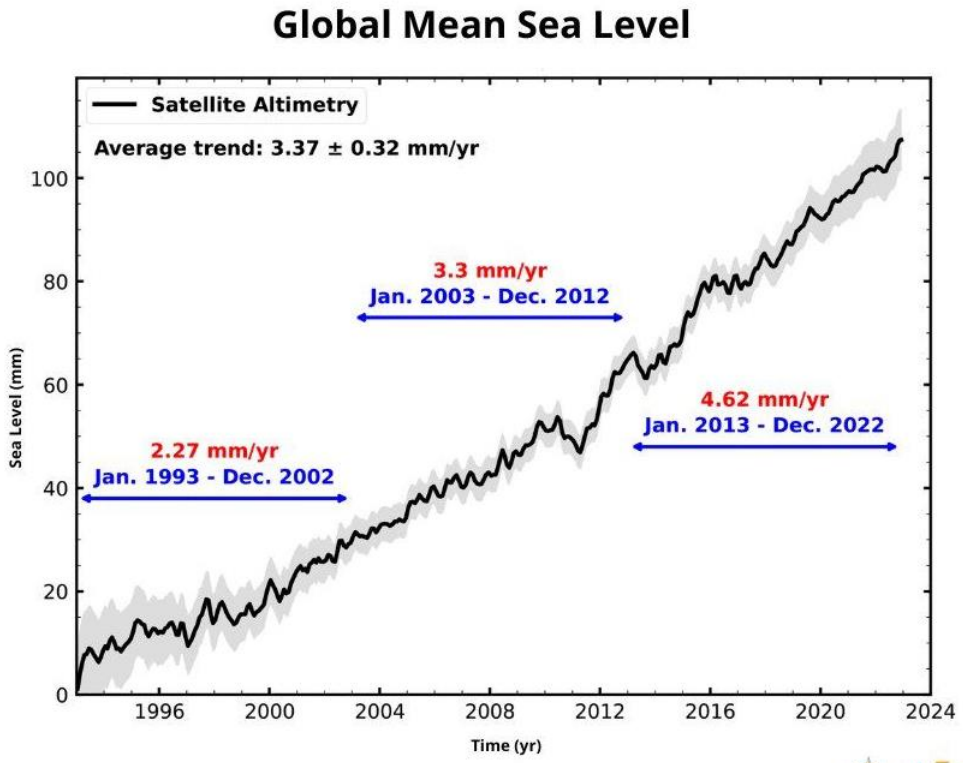
Source: Angermann et al.: "Mission Earth – Geodynamics and Climate Change Observed Through Satellite Geodesy", Springer, 10.1007/978-3-662-64106-4, 2022.

- Accurate and long-term stable reference frames
- Precise orbits of altimetry satellites
- IAG/GGOS accuracy requirement for the ITRF: **1 mm** and a stability of **0.1 mm/yr**
- Not yet reached, challenge for geodetic work
- Fundamental role of Geodesy (often) not visible

IPCC Report (2021):

Global mean sea level rise

- 1,3 mm/yr (1901-1971)
- 1,9 mm/yr (1971-2006)
- 3,7 mm/yr (2006-2018)



Source: State of the Global Climate 2022 (WMO-No. 1316), 2023

BPS contributions to GGOS outreach activities

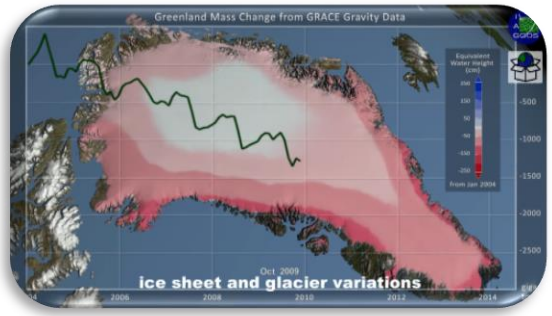
GGOS Website (www.ggos.org)

- 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)

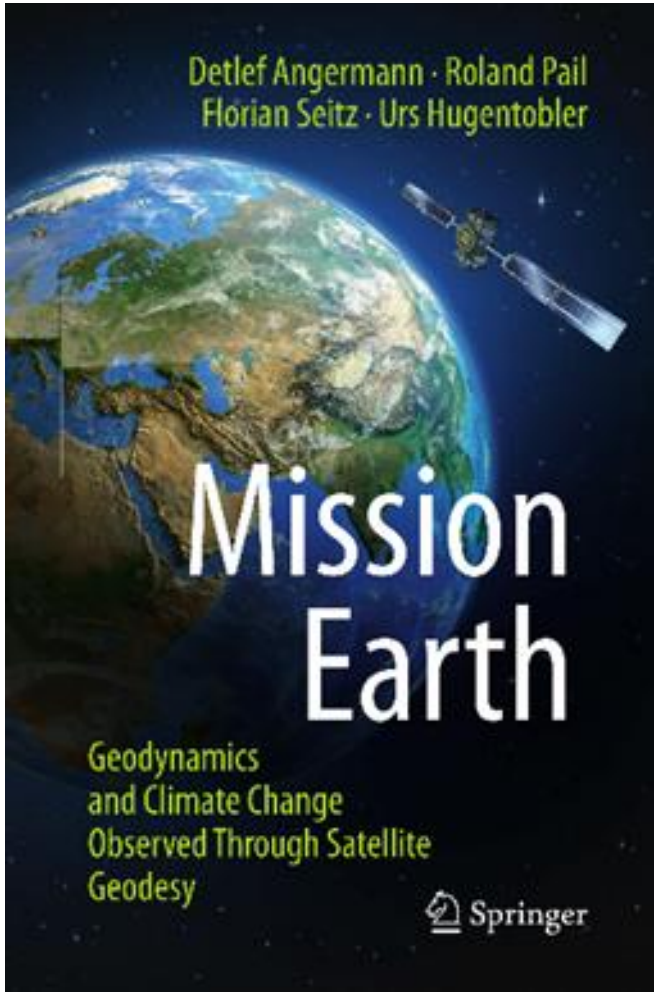
- Discover GGOS and Geodesy
  (short 2 min and long 8 min versions, 11 languages)
- Views on YouTube (Total: ~14.000, English: 5.740)
- Next step: Videos for geodetic products
  (e.g. Terrestrial Reference Frame in preparation)



Final remarks

- The work of the BPS, and of GGOS in general, is built upon the foundation provided by the IAG Services and the other IAG components
- The BPS serves as a GGOS component to identify and harmonize discrepancies between the standards and conventions used within IAG for the generation of geodetic products
- It supports IAG in its goal to obtain geodetic products of highest accuracy and consistency, which are essential for reliable Earth system monitoring
- Thanks to a strong collaborative work between the BPS, the GGOS Coordinating Office, the GGOS Science Panel, and the IAG Services, it has been possible to create a comprehensive description of the different geodetic products for the GGOS website
- With such an information platform and central access point for geodetic products, GGOS contributes to make geodesy more visible for its beneficial products

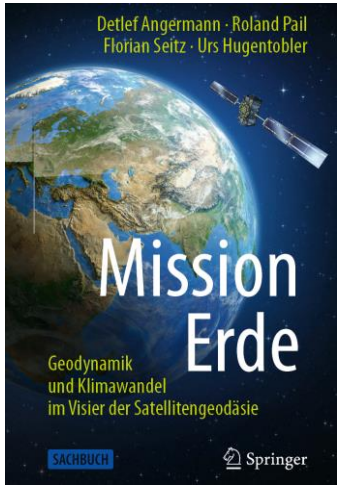
Thank you very much for your attention!



- **Geodesy - The science of measuring the Earth, presented in an exciting and easy to understand way**
- **Illustrative examples from satellite navigation to climate change**
- **How geodesy has become an integral part of our daily life**

With interview contributions by Günter Hein, Harald Lesch and Stefan Rahmstorf

Further editions: German, Dutch



Order here: