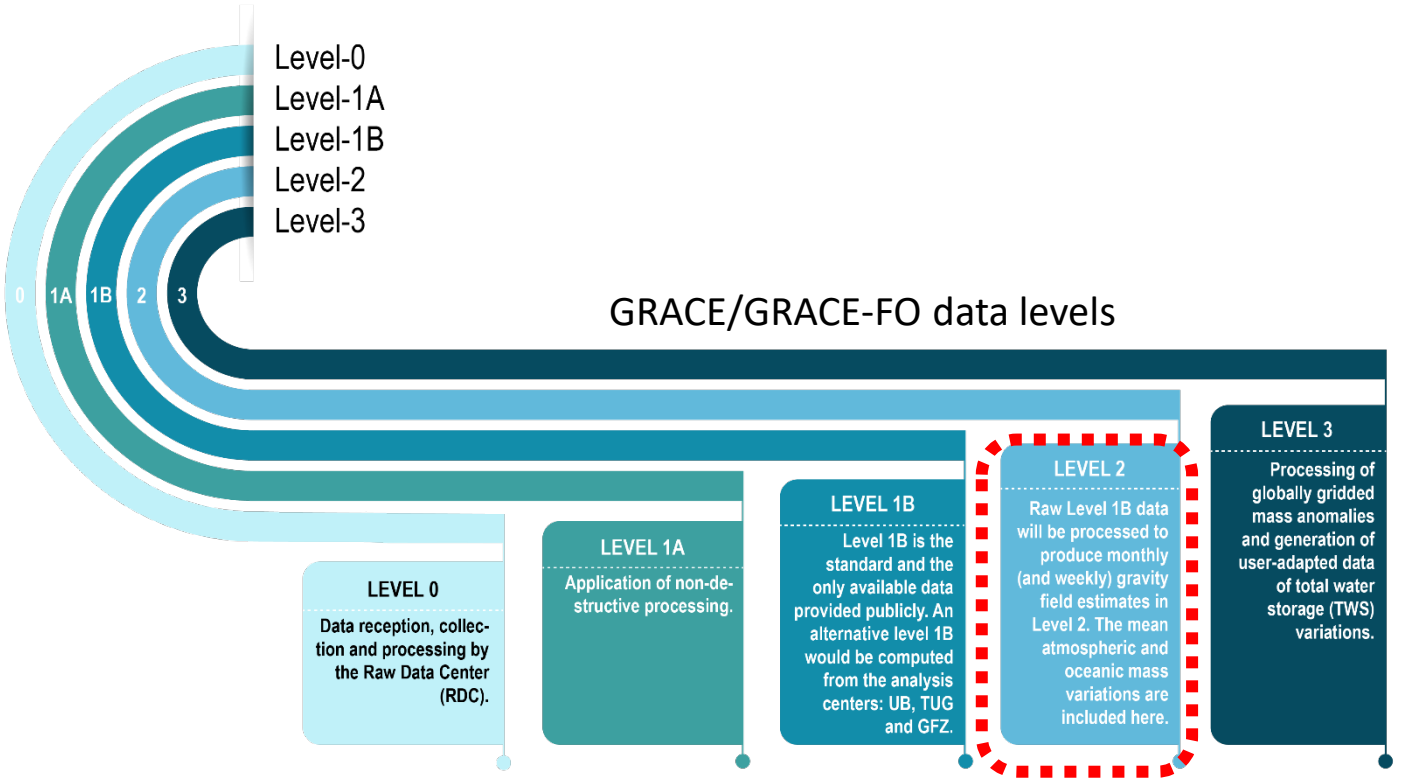
International Combination Service for Time-Variable Gravity Fields (COST-G)

Overview of Current Activities and
Future Perspectives for NGGM/MAGIC

A. Jäggi
on behalf of the COST-G team

Challenging Data Processing

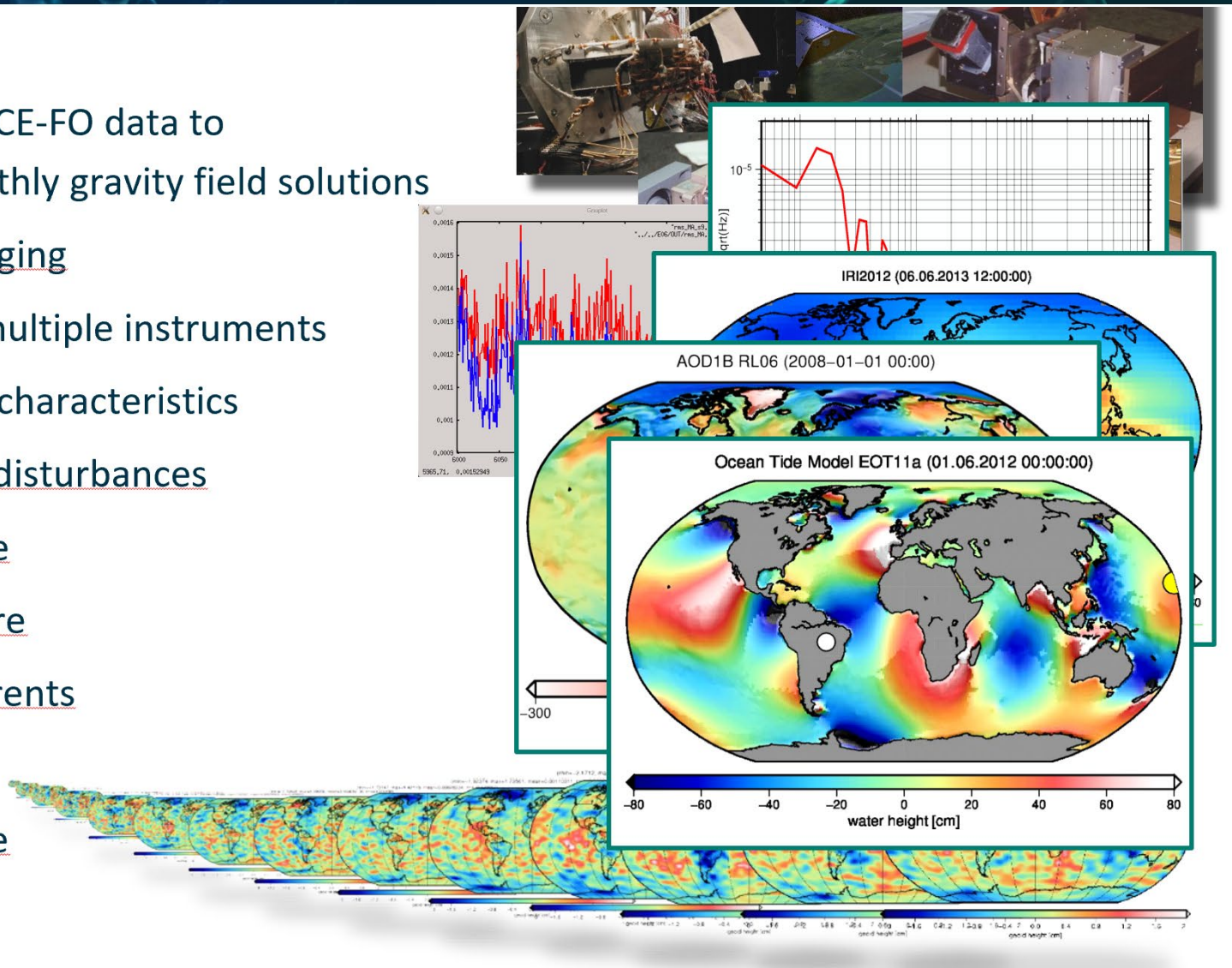
Terrestrial Water storage (**TWS**)



Efforts are needed to address **all Levels (1, 2, 3)** to exploit current and future space gravimetry missions. Feedback loops between the different levels are crucial.

Challenging Data Processing (Level 2)

- Process GRACE/GRACE-FO data to a time series of monthly gravity field solutions
- Processing is challenging
  - Interaction of multiple instruments
  - Different noise characteristics
  - Environmental disturbances
    - Ionosphere
    - Atmosphere
    - Ocean currents
    - Tides
  - There is not one „true“ solution



European Gravity Initiatives

The University of Bern (PI: Adrian Jäggi) coordinated the H2020 project **EGSIEM** (2015-2017). It was explicitly mentioned in NASA's Decadal Survey and paved the way for the current activities.

EGSIEM
European Gravity Service for Improved Emergency Management
http://egsiem.eu/

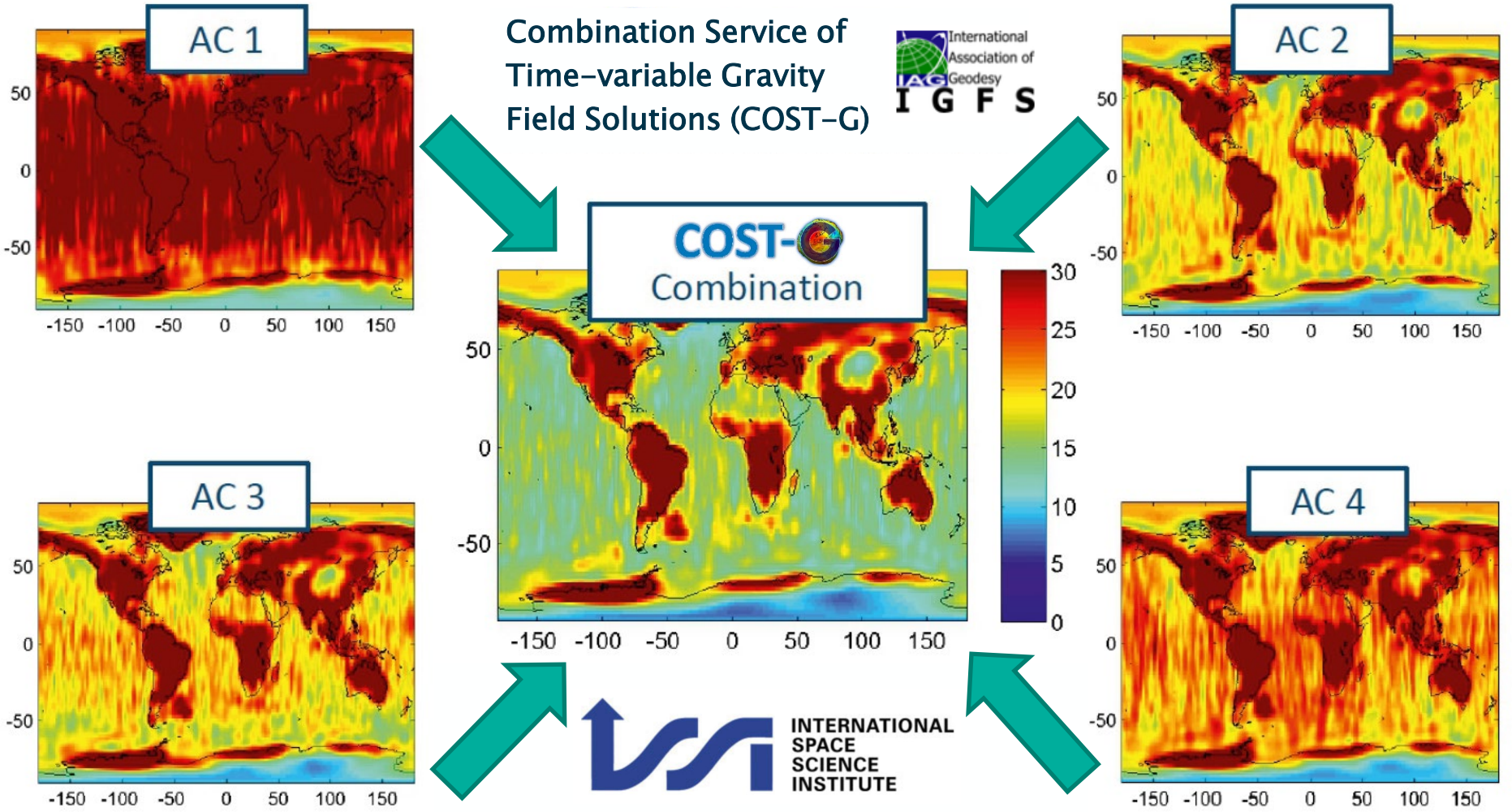
Parts of EGSIEM are continued since 2019 as an IAG service activity called **COST-G**, coordinated again by the University of Bern (Founding Chair: Adrian Jäggi).

COST-G
Combination Service for Time-variable Gravity Models
http://cost-g.org/

The University of Bern initiated to strive for a H2020 follow-up of EGSIEM with the same gravity core-group as in EGSIEM => **Global Gravity-based Groundwater Product (G3P)**, a H2020 project coordinated by GFZ Potsdam (2020-2022, PI: Andreas Güntner).

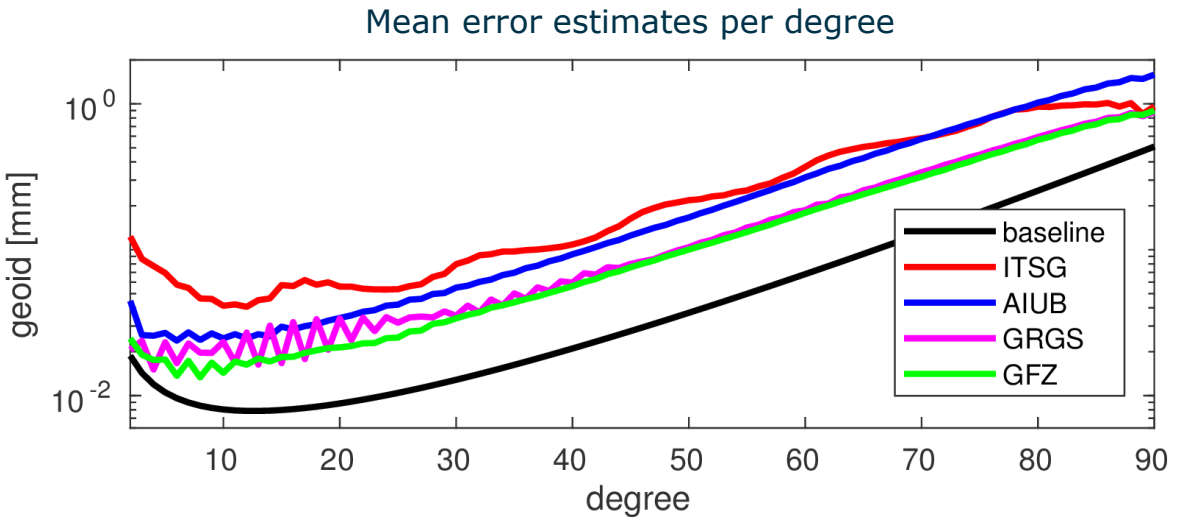
G3P
https://www.g3p.eu/

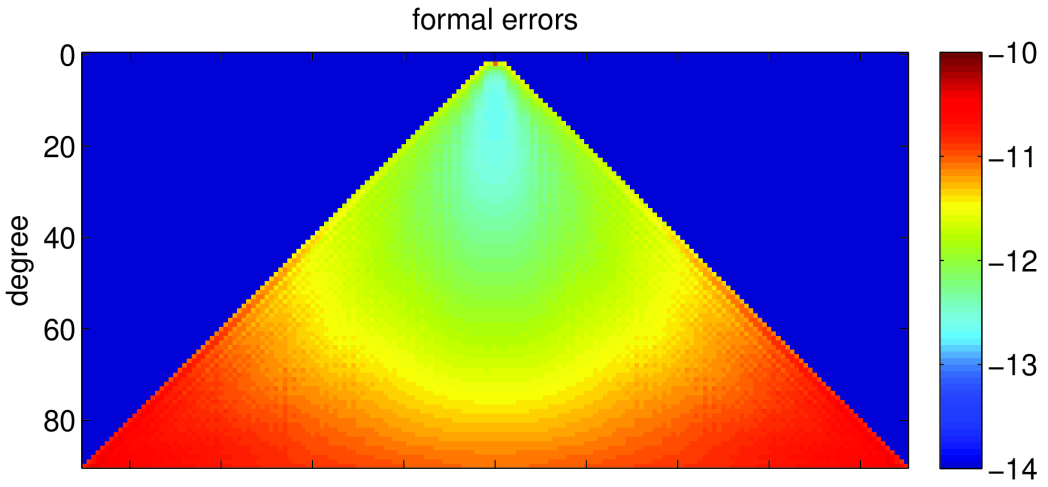
COST-G Principle

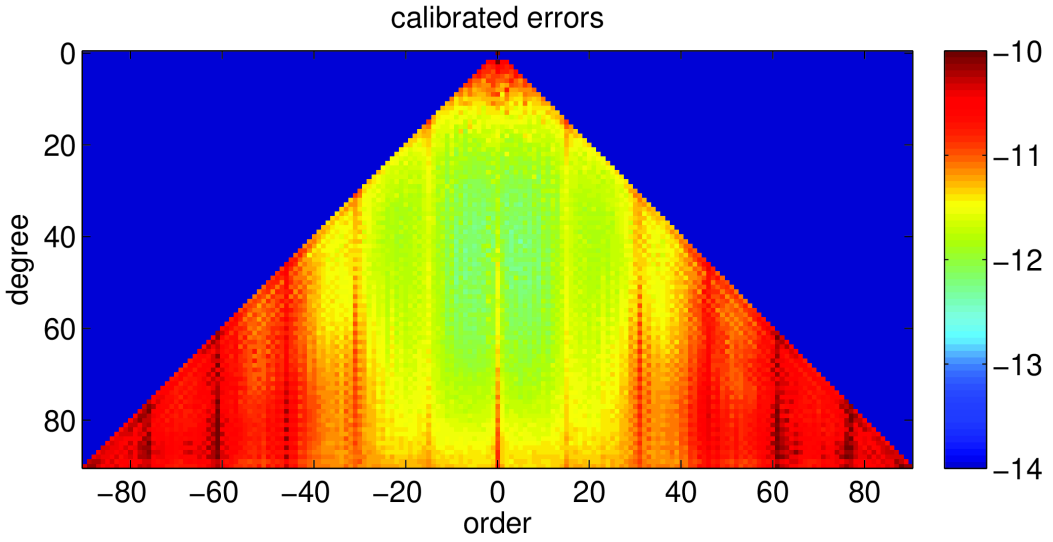


Improved and consolidated product integrating the strengths of all ACs

Challenging Combination







- Formal errors are **very diverse** and generally **too optimistic**
- **They cannot be used** in the combination process (neither on NEQ-level, nor on solution level)
- For the current COST-G (RL02) combination high-order coefficients (> 60) are not considered for the determination of relative weights on solution level using VCE
- **Consistent (realistic) weights** will most probably enable a **meaningful combination on NEQ-level**

Permanent Components of COST-G

COST-G accomplishes its objectives through the following permanent components and roles:

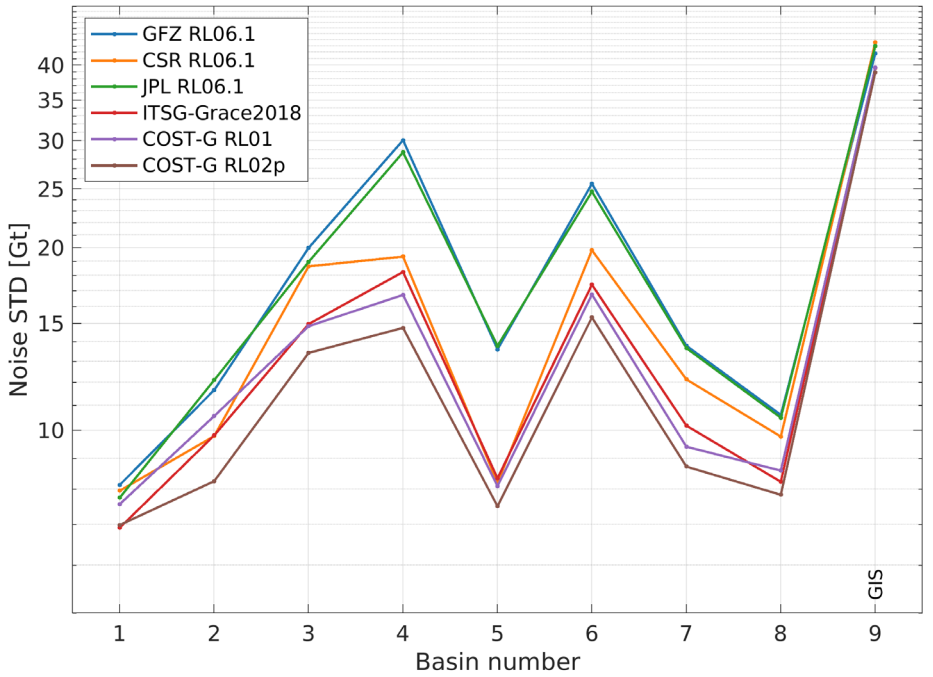
- **Central Bureau (CB) & Analysis Center Coordinator (ACC)**
  - AIUB
- **Analysis Centers (ACs)**
  - AIUB, CNES, GFZ, TUG, LUH
- **Level-3 Center (L3C)**
  - GFZ
- **Validation Centers (VCs)**
  - GRGS, GFZ
- **Product Evaluation Group (PEG)**
  - A. Eicker, T. Döhne, A.Blazquez

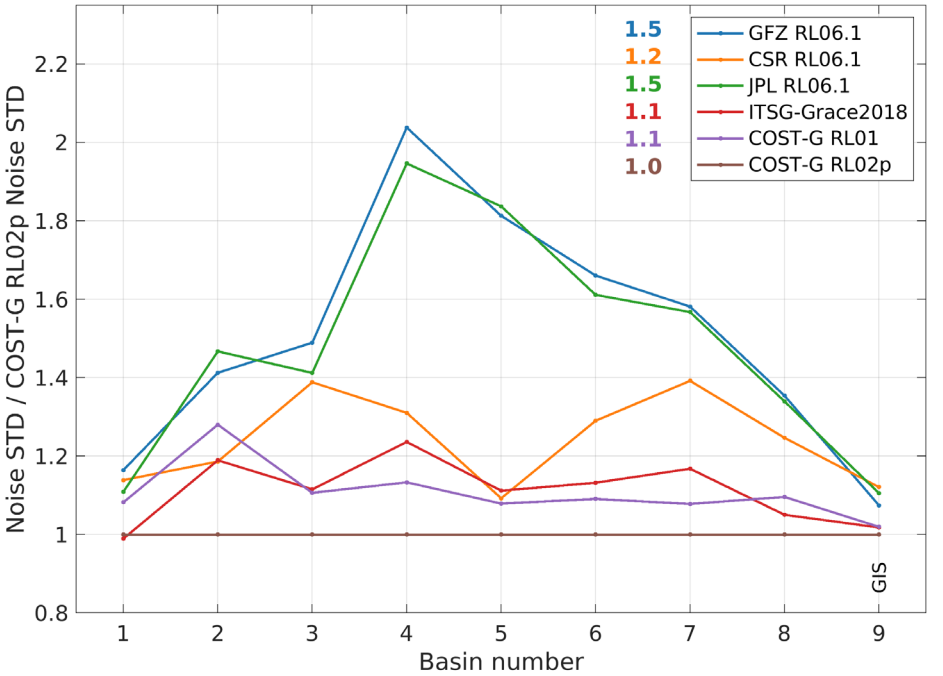
- **Candidate ACs:** Chinese ACs

GRACE/GRACE-FO SDS (CSR, JPL) contribute as partner ACs to COST-G combinations.

Meyer, U. et al. (2020): International Combination Service for Time-variable Gravity Fields (COST-G) Monthly GRACE-FO Series. V. 01. GFZ Data Services. https://doi.org/10.5880/ICGEM.COST-G.002

Noise Reduction in Ice Mass Loss



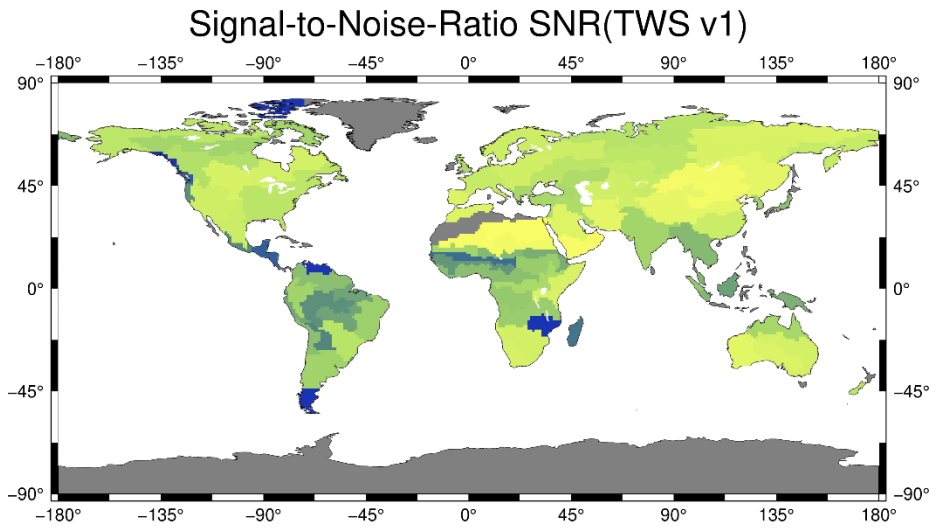


Noise measure for each basin time series for individual solutions and the 1st and 2nd releases of COST-G combined solutions.

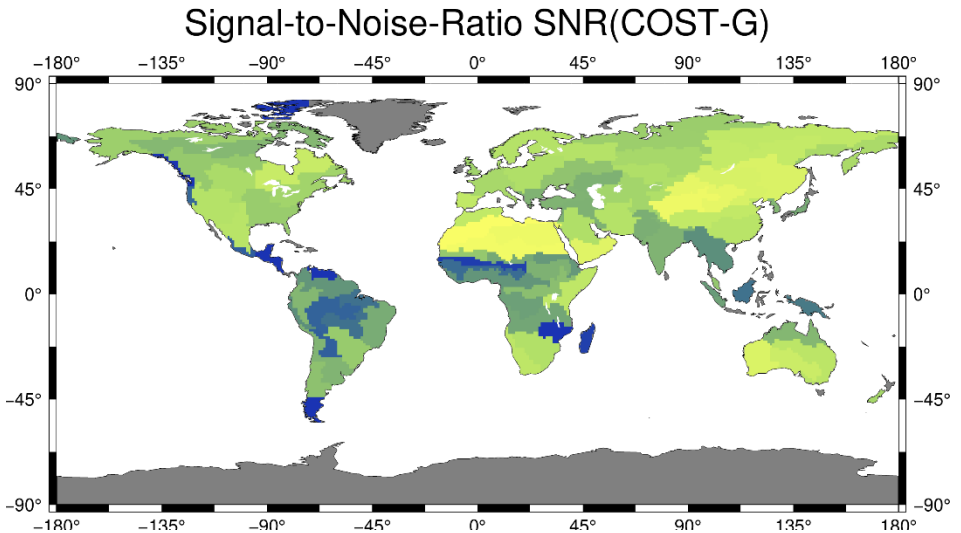
Ratio w.r.t. noise measure of the latest COST-G combined time series (numbers indicate the median of all basin ratios).

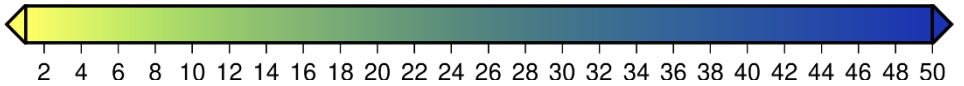
Noise Reduction in River Basins

GFZ v1



COST-G G3P





Percentage Differences in Signal-to-Noise Ratios may amount up to 100% for individual basins when comparing the Level 3 GFZ v1 Products with COST-G G3P Level 3 Products.

Boergens, E. et al. (2020): COST-G GravIS RL01 Continental Water Storage Anomalies. V. 0005. GFZ Data Services. https://doi.org/10.5880/COST-G.GRAVIS_01_L3_TWS

Product Uptake in Operational Activities

esa → opernicus Europe's eyes on Earth

EUMETSAT

COPERNICUS POD Service

Copernicus Sentinel-1 | Copernicus Sentinel-2 | Copernicus Sentinel-3 | Copernicus Sentinel-6 Michael Freilich

- Sentinel satellites are equipped with various Earth observation instruments
- Mission requirements demand high levels of orbital accuracy (**GPS**, DORIS+SLR only S-3 + S-6 (+GAL)) → **Copernicus POD Service**

Copernicus POD Service

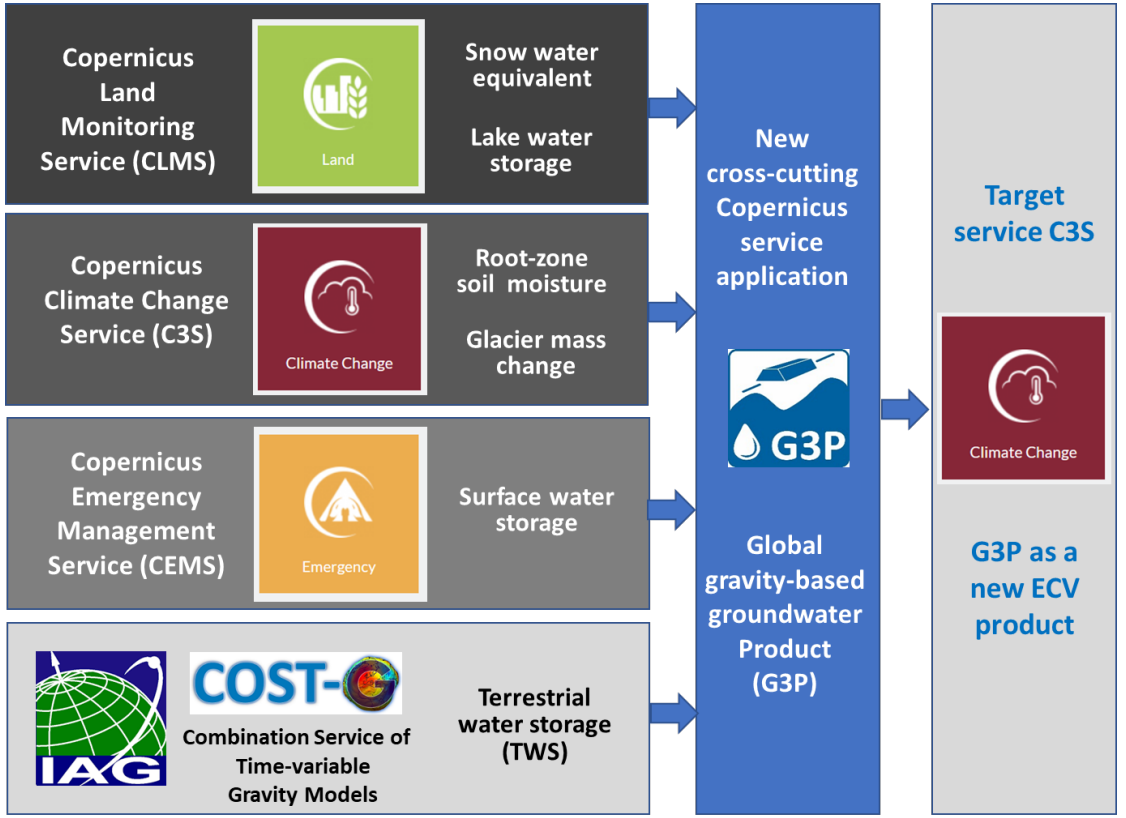
- Consortium led by **GMV**, Tres Cantos, Spain
- **magicGNSS**, external GPS orbit and clock provider (NRT, STC)
- **PosiTim**, QWG management, quality control, improvements, scientific outreach …
- **DLR, TUM, TUD, GFZ** quality control, QWG members

Copernicus POD QWG

- Additional members: **AIUB, CNES, GRGS, GSFC, JPL, ESOC, TUG**

Starting on 18 July 2023, the Copernicus POD Service deployed a new version of the system (3.3.0) which uses the **COST-G Fitted Signal Models** for gravity field modeling in all the operational chains.

Cross-cutting Copernicus Product



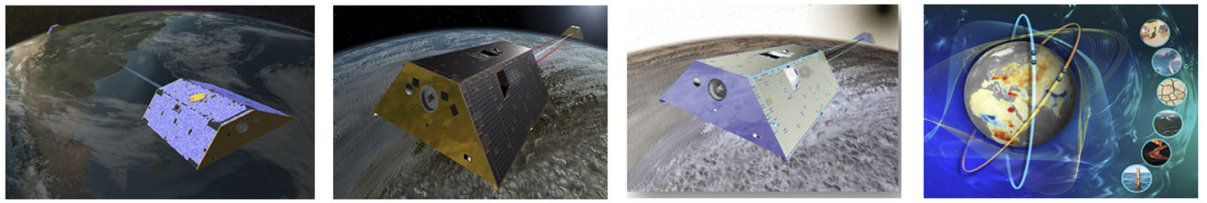
The H2020 project G3P developed a product of **groundwater storage variations** with global coverage and monthly resolution by a cross-cutting combination of GRACE/GRACE-FO satellite gravity data from COST-G with water storage data that are based on the existing portfolio of different Copernicus services.

The G3P prototype product is envisaged to move towards operational generation for the Copernicus Climate Change Service (C3S).

Güntner, A. et al. (2023): Global Gravity-based Groundwater Product (G3P). V. 1.11. GFZ Data Services. https://doi.org/10.5880/G3P.2023.001

Future Perspectives

Grounds are prepared for perpetuating COST-G and G3P data products by approved **future satellite gravimetry missions** for providing **long-term ECV climate data records** of
- TWS
- groundwater storage



GRACE (NASA, DLR)
2002 – 2017

First time enabling of mass change monitoring from space based on two-way micro-wave ranging.

GRACE-FO (NASA, GFZ)
2018 – 2028

Continued times series of mass change. Additionally operates a Laser Ranging Interferometer (LRI) as technology demonstrator for future missions.

GRACE-I/MC (NASA, DLR)
2028 – 2033

Data continuity based on LRI measurements.

NGGM/MAGIC (esa, NASA)
2032 – 2037

Improved spatial/temporal resolution based on combination of GRACE-I/MC with ESA´s NGGM to realize MAGIC.

NASA-DLR Implementation Arrangement signed in 10/2023

***Mass-change And Geoscience International Constellation (MAGIC):* ESA Member States Ministerial Meeting approved funding in 11/2022**

Recommendations from COST-G

Heritage and experience from GRACE and GRACE-FO ACs should be exploited to the extent possible and adapted to NGGM/MAGIC. Relying on the experience from GRACE/GRACE-FO this can be achieved by

- Several Analysis Centers computing monthly Level-2a products within a **High-Level Processing Facility (HPF).**
- Regularly **comparing** and **improving** the Level-2a products within the HPF.
- Generation of a **combined Level-2a** product to derive the Level-2b and Level-3 products.
- Doing the same for sub-monthly (e.g. 3 or 5 days) solutions.

COST-G has already realized similar structures within the IAG. In particular

- COST-G offers broad expertise covering **Level-1b**, **Level-2**, **Level-3 Real GRACE/GRACE-FO Data Processing,** i.e. covering the entire processing chains.

There is also a lot of heritage from the **GOCE mission** concerning the set-up, operation and benefits of running a **High-Level Processing Facility (HPF)**.

Summary from COST-G

COST-G is very much interested to be part of the upcoming activities to develop the necessary procedures for the NGGM/MAGIC mission.

COST-G offers broad expertise covering **Level-1b**, **Level-2**, **Level-3 Real GRACE/GRACE-FO Data Processing,** i.e. covering essentially the entire processing chains that will also be relevant for NGGM/MAGIC.

COST-G can serve as nucleus for a corresponding **High-Level Processing Facility (HPF)**.

A future HPF, but also already the related **preparatory scientific studies**, need to address **all Levels (1, 2, 3)** to enable crucial feedback between the different levels.

Thanks a lot for your attention !

COST-G Flyer

https://plot.cost-g.org/
http://gravis.gfz-potsdam.de/
http://icgem.gfz-potsdam.de/

COST-G Plotter

GravIS

Easy accessibility

The COST-G plotter is an easy and convenient way to look at and evaluate the data products of the ACs and other partner centres as well as the combined solutions generated at the University of Bern (AIUB).

GravIS, the Gravity Information Service of GFZ in collaboration with AWI and TUD, enables the usage of satellite gravimetry data for a broader community. **User-friendly and ready-to-use products ('Level-3') are generated and visualized based on the most recent GRACE and GRACE-FO data releases from GFZ and COST-G.** The products presented at GravIS are available for download at GFZ's Information System and Data Center (ISDC).

Partners

- GFZ German Research Centre for Geosciences, Germany (GFZ)
- Centre National d'Études Spatiales, France (CNES)
- University of Bern, Switzerland (AIUB)
- Graz University of Technology, Austria (TUG)
- Leibniz Universität Hannover, Germany (LUH)
- Alfred-Wegener-Institut, Germany (AWI)
- Technical University Dresden, Germany (TUD)
- Stellar Space Studies

IAG International Association of Geodesy

I G F S

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