Combination Service for Time-variable Gravity Fields (COST-G) – operations

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EGU 2020
G2.1 The Global Geodetic Observing System
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• Introduction to COST-G

• Products of COST-G
  – Combined GRACE gravity fields
  – Combined Swarm gravity fields

• Components of COST-G

• COST-G workflow, exemplified by a prototype GRACE-FO combination:
  – Quality control (Noise/Signal content)
  – Combination applying variance component estimation

• External validation (COST-G GRACE RL01)
### Introduction

#### Gravity and geoid metadata
Online applications for the creation of metadata for gravity and geoid data. Service for searching the metadata database.

**g-meta**
*the gravity metadata editor (v0.2.6 – beta edition)*

**N-meta**
*the geoid metadata editor (v0.1.3 – alpha edition)*

#### Gravity data
Lend, marine, airborne gravity data as point and gridded values. Absolute and relative gravity data, WGM

#### Geoid
Geoid models and geoid determination software, geoid modeling processing methodologies

#### SG and Earth tide data
Temporal variations of the Earth gravity field through long-term records from ground gravimeters, SG data, Earth tide data.

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**COST-G** is a product center of the


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**INTERNATIONAL ASSOCIATION OF GEODESY**

**IGFS**

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**EGU 2020**

**G2.1: Global Geodetic Observing System**
Welcome to COST-G

The International Combination Service for Time-variable Gravity Fields (COST-G) is a product center of the International Gravity Field Service (IGFS) and is dedicated to the combination of monthly global gravity field models. COST-G stems from the activities of the former H2020 project European Gravity Service for Improved Emergency Management (EGSIEM).

Please use the top menu to visit the various parts of our website!

The service started its work in 2019 and the website is still under construction. More features will be available soon! We apologize for any inconvenience. For any questions, please contact us.

Best regards,
Your COST-G Team.

https://cost-g.org/
COST-G and the H2020 G3P-project

COST-G is further developed within the frame of the Horizon 2020 project: G3P - Global Gravity-based Groundwater Product.
Products: Combined GRACE/GRACE-FO Gravity Fields

Improved and consolidated product integrating the strengths of all ACs
Products: Combined Swarm Gravity Fields

Combination Service of Time–variable Gravity Field Solutions (COST–G)

For Swarm
- Operational continuation is already running
- Will be funded by Swarm/DISC for two more years

funded by contract SD–ITT–1.1,
part of contract 000109587/13/I–NB
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

• **Level-3 Center (L3C)**
  – GFZ

• **Validation Centers (VCs)**
  – GRGS, GFZ

• **Product Evaluation Group (PEG)**
  – A. Eicker, A. Groh, B. Meyssignac

**Candidate ACs:** LUH, Chinese ACs

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

### Combination Process

<table>
<thead>
<tr>
<th>Harmonization</th>
<th>Quality Control</th>
<th>Combination</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC 1</td>
<td>Signal content</td>
<td>Solution combination</td>
<td>Internal and External Validation</td>
</tr>
<tr>
<td>AC 2</td>
<td>- hydrological cycle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- ice mass trend</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>--&gt; exclude biased solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rescaling</td>
<td>Noise content:</td>
<td>Weighting: VCE</td>
<td>L2 products</td>
</tr>
<tr>
<td>Mean Pole</td>
<td>- spectral domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tide System</td>
<td>- spatial domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truncation</td>
<td>--&gt; remove outliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC 3</td>
<td></td>
<td>NEQ-Combination</td>
<td>L3 products</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- AC: Acquisitions
- NEQ-Combination: Normalized Error Quotient combination
- VCE: Vector Component Estimation

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**COST-G**

G2.1: Global Geodetic Observing System
Quality Control – Noise Levels (spectral domain)

Degree-wise comparison of spherical harmonic coefficients to a deterministic signal model derived from the monthly means of all time-series (GRACE-FO).

GRACE-FO time-series:
- COST-G ACs:
  - AIUB
    - continuation of RL02
  - GFZ
  - GRGS (delayed)
  - ITSG
- COST-G candidate AC:
  - LUH
- COST-G partner ACs:
  - CSR-RL06
  - JPL-RL06
Degree-wise comparison of spherical harmonic coefficients to a deterministic signal model derived from the monthly means of all time-series (GRACE-FO).

GRACE-FO time-series:
COST-G ACs:
- AIUB
  - continuation of RL02
  - G3P project
- GFZ

If not labeled differently, the AIUB time-series derived from alternative ACC transplant products in the frame of the G3P project is shown.
Quality Control – Noise Levels (spatial domain)

Comparison of monthly grids to a deterministic signal model derived from the monthly means of all time-series (GRACE-FO). Shown are the RMS-values per grid cell over a common subset of monthly solutions per time-series.
Quality Control – Signal Content (Hydrology)

Example: amplitude of seasonal variations in Amazon river basin (GRACE).
Quality Control – Signal Content (Hydrology)

Due to the short time span of the GRACE-FO time-series the quality control by comparison of signal amplitudes is still somewhat limited.

Example: amplitude of seasonal variations in Amazon river basin (GRACE-FO).
Comparison of amplitudes $\text{amp}_a$ of seasonal mass variations and their formal errors $\text{sig}_{\text{amp}}$ in 100 major river basins.
Quality Control – Signal Content (Ice Mass Loss)

Example: ice mass loss in Greenland (GRACE), compared to static reference field GOCC05S.
Quality Control – Signal Content (Ice Mass Loss)

Despite the short time span of the GRACE-FO time-series the mass loss trends in Greenland agree well, no signal attenuation in any of the time-series could be detected.
# COST-G – Combination

## Combination Process

<table>
<thead>
<tr>
<th>Harmonization</th>
<th>Quality Control</th>
<th>Combination</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC 1, AC 2</td>
<td>- Rescaling Mean Pole Tide System Truncation</td>
<td>- Solution combination</td>
<td>- Internal and External Validation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Weighting: VCE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- NEQ-combination</td>
<td></td>
</tr>
<tr>
<td>AC 3, …</td>
<td>- Signal content: - hydrological cycle, - ice mass trend, -&gt; exclude biased solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Noise content: - spectral domain, - spatial domain, -&gt; remove outliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L2 products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L3 products</td>
</tr>
</tbody>
</table>
Combination applying Variance Component Estimation

VCE-derived weights (normalized):

Noise over the oceans:
In the absence of systematic differences the VCE-derived weights are inversely proportional to the noise levels of the individual monthly gravity fields. The somewhat different evaluation of noise over the oceans therefore indicates systematic differences in the individual time-series (to be further investigated).
Internal Validation: spectral domain

Median degree amplitudes of anomalies wrt a linear and seasonal model (no filtering applied)

For the COST-G GRACE-FO combination no external validation is yet available, in the following slides we therefore provide examples on the validation of the COST-G GRACE combination released in July 2019.

The main gain of the combination is in the range of degrees 15-45.
Internal Validation: spatial domain

RMS of anomalies of CSR6 (geoid heights)  RMS of anomalies of GFZ6 (geoid heights)

RMS of anomalies of COMB (geoid heights)
Basin-integrated AIS/GIS mass changes based on the sensitivity kernel approach by TU Dresden

Trends agree fairly well for the Greenland Ice Sheet
Basin-Averaged AIS Mass Changes

Larger trend differences for Antarctic Ice Sheet

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Trends from GFZ seem to be different for East Antarctica. A slight influence on COST-G products may be seen (under investigation).

Basin numbers:
29: Ant. Peninsula (AP)
30: East Ant. (EAIS)
31: West Ant. (WAIS)
32: AIS
SIGNAL ASSESSMENT ➔ Comparison to Altimetry. Presently, two test areas for the signal assessment have been selected: the Caspian sea and the Black sea. Correlation coefficient with altimetry over the Caspian Sea: the COST-G solution presents a slight improvement over the TUGRAZ and CSR solutions.

<table>
<thead>
<tr>
<th>Correlation w. ALT</th>
<th>COST-G</th>
<th>TUGRAZ ITSG18</th>
<th>CSR RL06</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDK5 filter</td>
<td>97.2 %</td>
<td>97.0 %</td>
<td>96.9 %</td>
</tr>
<tr>
<td>DDK6 filter</td>
<td>96.6 %</td>
<td>96.5 %</td>
<td>96.3 %</td>
</tr>
</tbody>
</table>

**Method:** The time series of the TVG solutions are compared with the time series of altimetric heights (from Hydroweb for the Caspian Sea or AVISO+ for the Black Sea). One bias (irrelevant) and one scale factor are adjusted. The criteria are the **scale factor** and **correlation coefficients**. Both should be as close as possible to 1.
GRACE solutions up to d/o 90 filled up with DIR-6 up to d/o 240:

- Table shows RMS of orbit fits (cm) for the different test cases (3D residuals, mean values from the 30 individual arcs in question)

<table>
<thead>
<tr>
<th>Gravity model</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009/11</td>
</tr>
<tr>
<td>GFZ_RL06</td>
<td>7,38</td>
</tr>
<tr>
<td>AIUB_RL02</td>
<td>8,69</td>
</tr>
<tr>
<td>CSR_RL06</td>
<td>6,88</td>
</tr>
<tr>
<td>GRGS_RL04f</td>
<td>5,88</td>
</tr>
<tr>
<td>ITSG_2018_tide_free</td>
<td>5,51</td>
</tr>
<tr>
<td>COSTG_RL01</td>
<td>5,03</td>
</tr>
</tbody>
</table>
Level-2 Product Availability

- Monthly combined GRACE gravity field models:
  - from Apr. 2002 to Jun. 2017 available at ICGEM
  - http://icgem.gfz-potsdam.de/series/02_COST-G/GRACE

- Monthly combined Swarm gravity field models:
  - from Dec. 2013 to Dec. 2019 available at ICGEM
  - http://icgem.gfz-potsdam.de/series/02_COST-G/Swarm
Level-2 Product Availability

<table>
<thead>
<tr>
<th>GRACE and Grace-FO solutions from the Science Data System centers CSR, GFZ and JPL</th>
<th>expand all</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ CSR</td>
<td>Center for Space Research at University of Texas, Austin</td>
</tr>
<tr>
<td>+ GFZ</td>
<td>Helmholtz Centre Potsdam German Research Centre for Geosciences</td>
</tr>
<tr>
<td>+ JPL</td>
<td>Jet Propulsion Laboratory</td>
</tr>
</tbody>
</table>

The processing standards to generate the GRACE Level-2 products of CSR, GFZ and JPL are also available in the Document Section of the GRACE archives at GFZ ISDC or JPL PO.DAAC

<table>
<thead>
<tr>
<th>COST-G (International Combination Service for Time-variable Gravity Field)</th>
<th>collapse all</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRACE</td>
<td>monthly</td>
</tr>
<tr>
<td>Swarm</td>
<td>DOI monthly</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GRACE / CHAMP solutions from other groups</th>
<th>expand all</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ AIUB</td>
<td>Astronomical Institute University Bern</td>
</tr>
<tr>
<td>+ CNES</td>
<td>Centre national d’études spatiales</td>
</tr>
<tr>
<td>+ DMT</td>
<td>Delft University of Technology</td>
</tr>
<tr>
<td>+ EGSIEM</td>
<td>European Gravity Service for Improved Emergency Project</td>
</tr>
</tbody>
</table>
# Level-2 Product Availability: GRACE

**Gravity Field Solutions for dedicated Time Periods**

**GRACE**

You can download all the models in this set as zip (22.4 MiB) or you can find subsets and single model files below. It can take a moment to generate the zip file for you.

You can also find these files at ftp://igem.gfz-potsdam.de/02_COST-G/GRACE.

<table>
<thead>
<tr>
<th>GAX_products</th>
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<tbody>
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<table>
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<th>zip</th>
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<th>388.8 KiB</th>
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<td></td>
<td>GSM-2_2002213-2002243 GRAC COSTG BF01 0100.gfc</td>
<td>389.0 KiB</td>
</tr>
</tbody>
</table>
Gravity Field Solutions for dedicated Time Periods

Swarm


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You can download all the models in this set as zip (1.1 MiB) or you can find subsets and single model files below. It can take a moment to generate the zip file for you.
You can also find these files at ftp://igcigem.gfz-potsdam.de/02_COST-G/Swarm.
Summary and Outlook

- COST-G RL01 Level-2 products for GRACE and Swarm are available from ICGEM.
- COST-G RL01 Level-3 products for GRACE are currently being processed and will be made available via GFZ's GravIS portal (http://gravis.gfz-potsdam.de/).
- Operational GRACE-FO combination will start shortly after EGU.
- CSR and JPL are listed as Partner Analysis Centers in the COST-G ToR.
- Inclusion of candidate Analysis Centers (LUH, Chinese ACs) is envisaged in the near future.