Combination Service for Time-Variable Gravity Models (COST-G) – current status

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IUGG General Assembly 2019
Montreal, Canada
8 – 18 July, 2019
COST-G is a new product center of the IGFS

http://igfs.topo.auth.gr/
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 steams 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/
Combination of GRACE Gravity Fields

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

Improved and consolidated product integrating the strengths of all ACs

AC 1

AC 2

AC 3

AC 4
Combination of 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
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, L. Longuevergne, B. Meyssignac

COST-G is very open for additional contributors.
COST-G Workflow

**Combination Process**

<table>
<thead>
<tr>
<th>Harmonization</th>
<th>Quality Control</th>
<th>Combination</th>
<th>Validation</th>
</tr>
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- **Harmonization**
  - AC 1
  - AC 2
  - Rescaling
  - Mean Pole Tide System Truncation
  - AC 3
  - ...

- **Quality Control**
  - Signal content:
    - hydrological cycle
    - ice mass trend
    --> exclude biased solutions
  - Noise content:
    - spectral domain
    - spatial domain
    --> remove outliers

- **Combination**
  - Solution combination
  - Weighting: VCE
  - NEQ-combination

- **Validation**
  - Internal and External Validation
  - L2 products
  - L3 products
Example: amplitude of seasonal variations in Amazon river basin.
Amplitude of seasonal variations and formal errors of amplitudes in major river basins. No systematic signal attenuation in any of the contributing gravity field time-series can be observed.
Quality Control – Signal Content (Ice Mass Loss)

Ice mass of Greenland

- ITSG18
- GRGS04
- AIUB
- CSR6
- GFZ6

mass (Gt)

2003 2005 2007 2009 2011 2013 2015 2017
Quality Control – Noise Levels

RMS of anomalies of CSR6 (geoid heights)

RMS of anomalies of GFZ6 (geoid heights)

RMS of anomalies of GRGS (geoid heights)

RMS of anomalies of ITSG (geoid heights)
Quality Control – Noise Levels

AIUB contribution is still based on L1B-RL02 and AOD1B-RL05.
## Combination Process

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<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>- weighting: VCE</td>
<td>L2 products</td>
</tr>
<tr>
<td>Rescaling</td>
<td>- ice mass trend</td>
<td>NEQ-combination</td>
<td>L3 products</td>
</tr>
<tr>
<td>Mean Pole</td>
<td>--&gt; exclude biased solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tide System</td>
<td>Noise content:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truncation</td>
<td>- spectral domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC 3</td>
<td>- spatial domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>--&gt; remove outliers</td>
<td></td>
<td></td>
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</table>

**IUGG General Assembly**
Montreal, 8 – 18 July, 2019
COST-G RL01 has been combined on the solution level iteratively applying variance component estimation.

The relative weights determined by VCE can directly be interpreted as quality indicators, they are inversely proportional to the noise levels of the individual contributions.
Internal Validation: spherical harmonics domain

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

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

For internal validation the noise content of the individual and the combined gravity fields is assessed by their non-secular, non-seasonal variability over the oceans.
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-Averaged GIS Mass Changes

- 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 GIS Mass Changes

- Noise measure for each basin time series and ratio to the noise measure of the COST-G time series (numbers indicate the median of all basin ratios). Basin 9 denotes the entire GIS.

![Graphs showing noise measures and ratios for different basins compared to COST-G.](image-url)
Basin-Averaged AIS Mass Changes

Larger trend differences for Antarctic Ice Sheet
Trends from GFZ seem to be different for East Antarctica. Influence on COST-G products may be seen.
Comparison to Altimetry

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.
## Orbit Tests with GOCE

- 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>2009/11</th>
<th>2009/12</th>
<th>2010/10</th>
<th>2010/11</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFZ_RL06</td>
<td>7.38</td>
<td>6.84</td>
<td>6.23</td>
<td>6.18</td>
</tr>
<tr>
<td>AIUB_RL02</td>
<td>8.69</td>
<td>8.56</td>
<td>7.39</td>
<td>7.21</td>
</tr>
<tr>
<td>CSR_RL06</td>
<td>6.88</td>
<td>9.09</td>
<td>6.65</td>
<td>6.20</td>
</tr>
<tr>
<td>GRGS_RL04f</td>
<td>5.88</td>
<td>7.30</td>
<td>5.47</td>
<td>5.83</td>
</tr>
<tr>
<td>ITSG_2018_tide_free</td>
<td>5.51</td>
<td>5.12</td>
<td>4.19</td>
<td>4.54</td>
</tr>
<tr>
<td>COSTG_RL01</td>
<td>5.03</td>
<td>5.54</td>
<td>4.52</td>
<td>4.72</td>
</tr>
</tbody>
</table>

- Good quality for COST-G, but not yet best for all months.
Product Availability

- **Monthly combined GRACE gravity field models:**
  - from Apr. 2002 to Jun. 2017 available at ICGEM
  - [http://icgem.gfz-potsdam.de/series/03_COST-G/GRACE](http://icgem.gfz-potsdam.de/series/03_COST-G/GRACE)

- **Monthly combined Swarm gravity field models:**
  - from Dec. 2013 to Mar. 2019 available at ICGEM
  - [http://icgem.gfz-potsdam.de/series/03_COST-G/Swarm](http://icgem.gfz-potsdam.de/series/03_COST-G/Swarm)
## Product Availability

**COST-G (International Combination Service for Time-variable Gravity Field)**

- **GRACE**
  - Monthly GRACE solutions from the International Combination Service for Time-variable Gravity Field (COST-G), see also [here](#).
  - (Monthly Swarm solutions, more information can be found here [here](#) and [here](#))

### GRACE weekly solutions
- **GFZ Release 05**
  - (GFZ GRACE Level-2 Processing, Revised Edition, January 2013)

### GRACE daily solutions
- **ITSG-Grace2014**
  - (more information can be found [here](#))
- **ITSG-Grace2016**
  - (more information can be found [here](#))
- **ITSG-Grace2018**
  - (more information can be found [here](#))

### SLR monthly
- SLR-only monthly solutions from AIUB

### Non-isotropic smoothing
- **AIUB Release 02**
  - (more information can be found [here](#))
- **CSR Release 05**
  - (UTC5R Level-2 Processing Standards Document, Rev 4.0 May 29, 2012)
- **GFZ Release 05**
  - (GFZ GRACE Level-2 Processing, Revised Edition, January 2013)
Summary and Outlook

- COST-G RL01 Level-2 products for GRACE and Swarm are available on ICGEM
- COST-G RL01 Level-3 products for GRACE will be made available soon on ISDC, GravIS
- Status of CSR and JPL in COST-G
- Inclusion of new candidate Analysis Centers
- Definition of further GRACE releases and timeline for operational GRACE-FO combinations
- Next COST-G ISSI Team Meeting: 13 – 17 January 2020
Thanks a lot for your attention!

Visit us on https://cost-g.org/