Evaluation of GOCE- and GRACE-based global geoid models in Finnish territory

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Abstract

The gravity satellite mission GOCE made its final observations in the fall of 2013, by then it had exceeded its expected lifespan of one year with more than three additional years. The mission collected more data from the Earth's gravitational field than expected, and more comprehensive global geoid models have been derived ever since. The ESA High-level Processing Facility (HPF) has published the GOCE data annually. We compared all of the released HPF-models and some other GOCE and GRACE models with GPS–levelling data and gravity observations in Finland.

First, the geoid models were used to their full degrees. Then, the models were evaluated up to a common maximum degree, to be able to fully compare the models. Differences between height anomalies and free-air anomalies measured on the ground and those calculated from the models show a clearly improving pattern between the GOCE data levels. The standard deviations are getting smaller with all of the modeling methods when the GOCE data level is increased. Standard deviation of 17 cm and 15 cm for height anomalies in the Finnish territory can be reached for the GOCE-only gravity solution (TIM) and the GRACE-enhanced gravity solution (DIR), respectively.

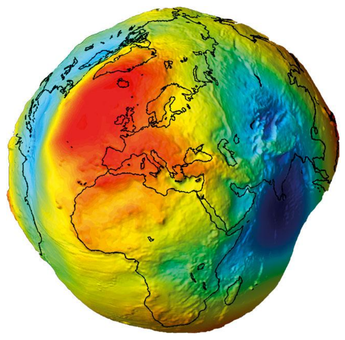

Figure 1. Global geoid (image credit: European Space Agency)

GOCE models

GOCE DIR (max degree/order 300)

- 5 data levels
- Released data 01/11/2009 – 20/10/2013
- A priori data (EIGEN-5C, ITG-GRACE2010s)
- LAGEOS + GRACE

GOCE TIM (max degree/order 280)

- 5 data levels
- Released data 01/11/2009 – 20/10/2013
- GOCE-only models

GOCE SPW (max degree/order 240)

- 2 data levels
- Released data 11/2009 – 7/2010
- GOCE-only model, a priori models used e.g. in ocean tide and signal covariance modelling

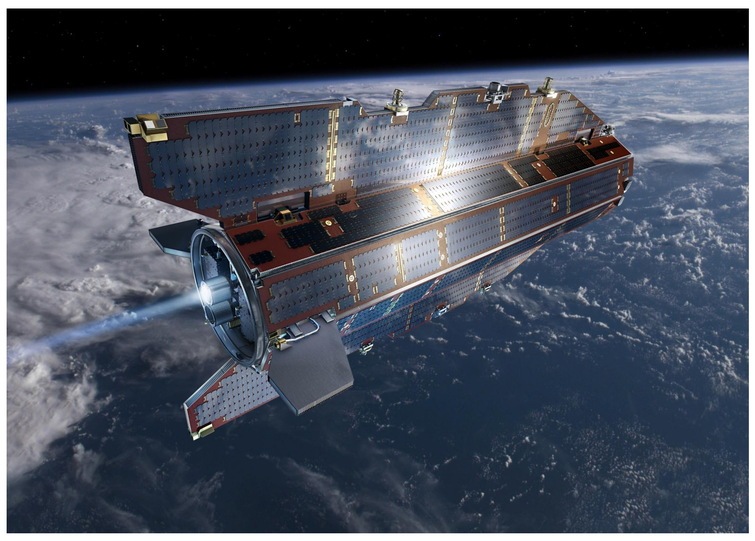

Figure 2. Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) (image credit: European Space Agency)

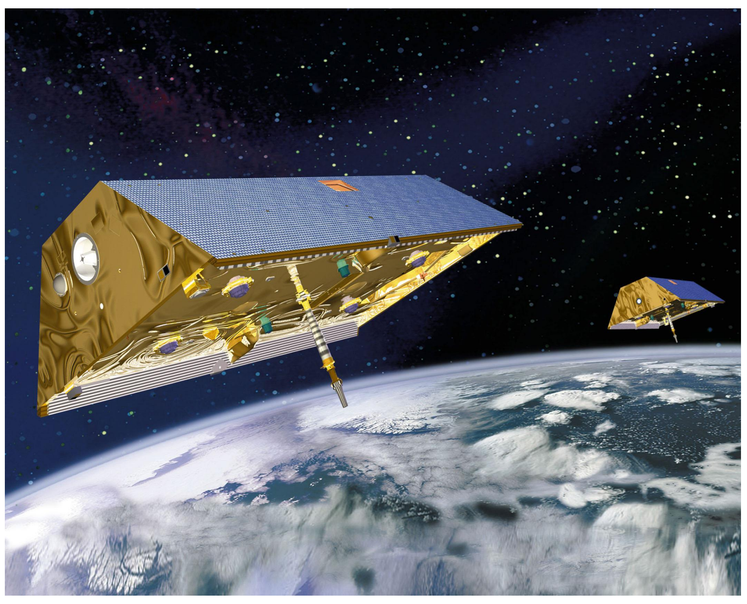

Figure 3. Gravity Recovery And Climate Experiment (GRACE) (image credit: National Aeronautics and Space Administration)

GRACE models

GRACE AIUB (max degree/order 160)

- Data 7/2003 - 8/2009
- EGM96 a priori

GRACE EIGEN5 (max degree/order 150)

- Data 8/2002 – 1/2007
- LAGEOS data 1/2002 – 12/2006

GRACE ITG (max degree/order 180)

- Data 8/2002 – 8/2009
- GRACE-only

GRACE GGM (max degree/order 180)

- Data 3/2003 – 5/2013
- GRACE-only

GRACE TONGJI (max degree/order 160)

- Data 2003 – 2007 (49 months)
- GRACE-only

Datasets of the ground truth in Finland

The FGI's gravity database and two GPS-levelling datasets were used as a ground truth. Both the gravity data and the GPS data were corrected for the land uplift (vertical velocities from the NKG2005LU land uplift model) and converted to the epoch 2000.0. The used datasets:

- The FGI's gravity database containing observations from 1938 to present.
- The EUVN-DA dataset (Figure 4) containing 50 GPS–levelling points (class 1) in Finnish territory. The points have EUREF-FIN GPS coordinates as well as levelled heights in the Finnish height system N2000.
- The GPS-levelling dataset by the National Land Survey of Finland (Figure 5) containing 526 GPS–levelling points (classes 1 to 3). The accuracy and distribution of the points is not homogenous and the dataset partly overlaps with the EUVN-DA dataset.

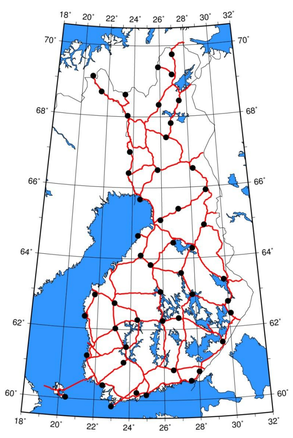

Figure 4. EUVN-DA -points

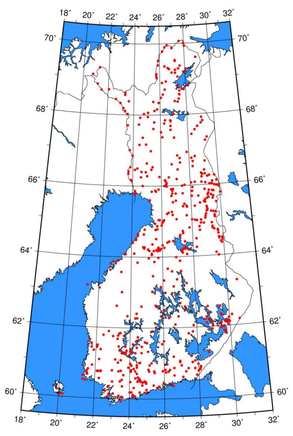

Figure 5. NLS-points

Results

The results of the evaluations of the GOCE and GRACE models are shown in the graphs above. Generally, all of the GOCE and GRACE modelling methods show an improvement of the later models over earlier models, since they include more data.

- Overall, the DIR models performed the best (± 0.218 – 0.153 m, ± 12.06 – 9.91 mgal, Figure 7).
- Major improvement can be seen with the TIM5 dataset (± 0.163 m, ± 10.14 mgal) over earlier TIM models (± 0.236 – 0.209 m, ± 12.30 – 11.08 mgal) (Figure 7 & 9).
- The results of the GOCE models are comparable with the results of the latest GRACE models when only coefficients up to degree and order 150 are used (Figure 6).
- When evaluating the models up to the maximum degree and order, the standard deviations of the height anomalies of the GOCE models are nearly half of those from the GRACE models (Figure 8).
- The residuals of the gravity anomalies show similar improvement between the datasets, although the differences between the GOCE and GRACE models are more restrained (Figure 9).

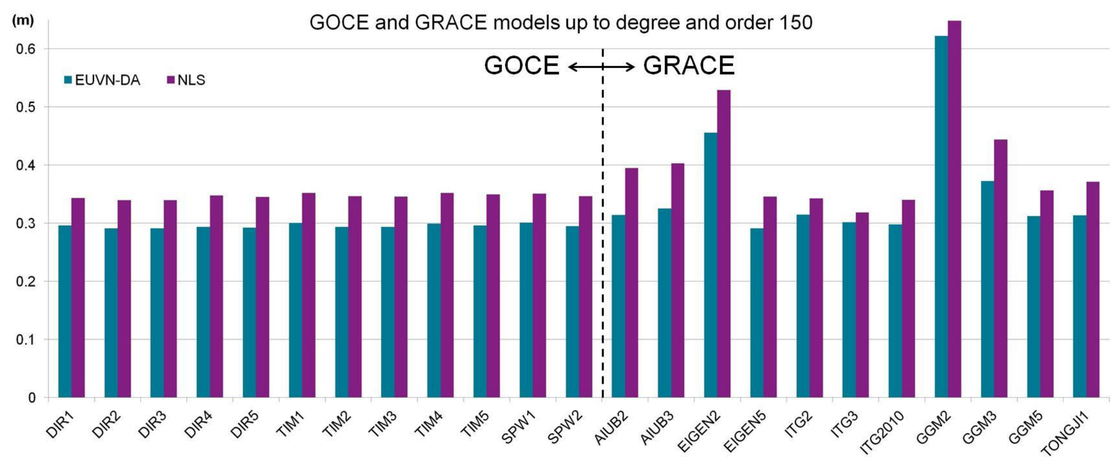

Figure 6. Comparison of the height anomalies from the GOCE and GRACE models up to degree and order 150 and GPS-levelling: Standard deviations of the differences (m)

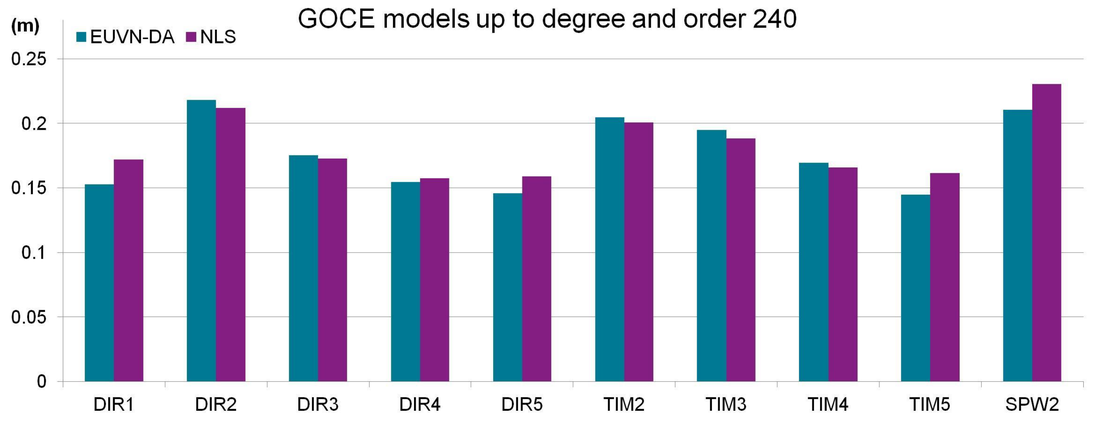

Figure 7. Comparison of the height anomalies from the GOCE models up to degree and order 240 and GPS-levelling: Standard deviations of the differences (m)

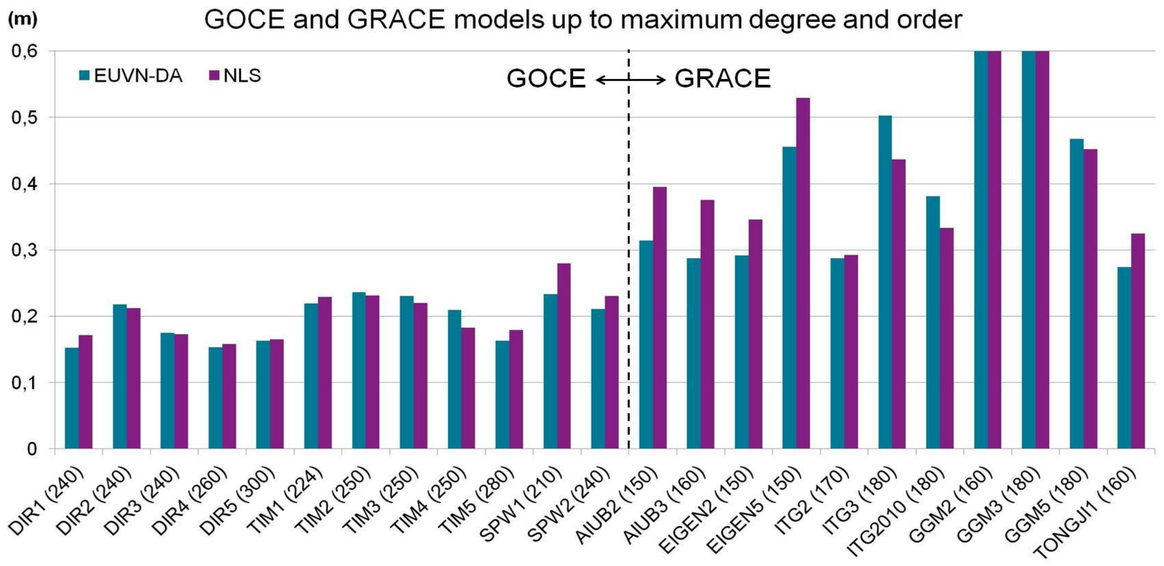

Figure 8. Comparison of the height anomalies from the GOCE and GRACE models using all available coefficients and GPS-levelling: Standard deviations of the differences (m)

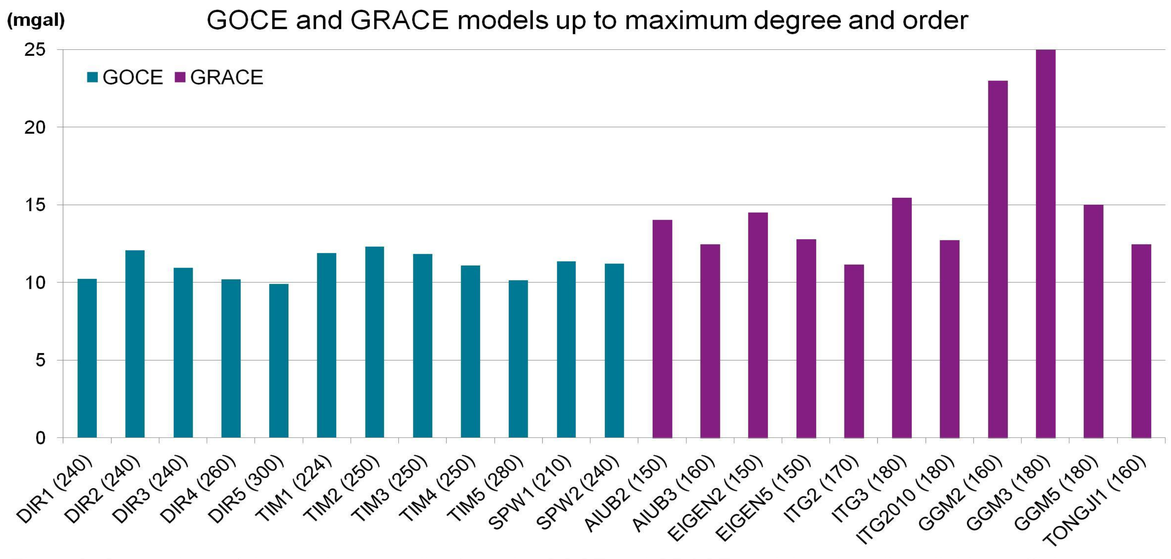

Figure 9. Comparison of the gravity anomalies from the GOCE and GRACE models using all available coefficients and gravity observations: Standard deviations of the differences (mgal)

Acknowledgements

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