Cross-Overs for Evaluating GOCE Gravitational Gradients

Phillip Brieden, Jürgen Müller
Institut für Erdmessung, Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover, Germany
Phone: +49 511 / 762 – 17402, brieden@ife.uni-hannover.de

ife GEOTECHNOLOGIEN REAL GOCE GERMANY Leibniz Universität Hannover

Introduction

ESA's Gravity field and steady-state Ocean Circulation Explorer (GOCE) determines the Earth's gravity field with unprecedented accuracy and spatial resolution.
Beyond the original goal of determining the static gravity field, additional applications including approaches to study time-varying effects in the GOCE gravitational data are investigated at present. In all applications, data quality remains of paramount importance. To ensure the high quality of the GOCE products, a variety of validation and calibration approaches is applied to both 'raw' measurement quantities and final GOCE gravity field solutions. For the quality assessment of the 'raw' measurements, especially the GOCE gravitational gradients (GG), the cross-over (XO) approach has been developed. It is an approach in which almost exclusively GOCE measurements are used. It is based on the comparison of measured gravitational gradients in satellite track cross-overs (see Figure 1).

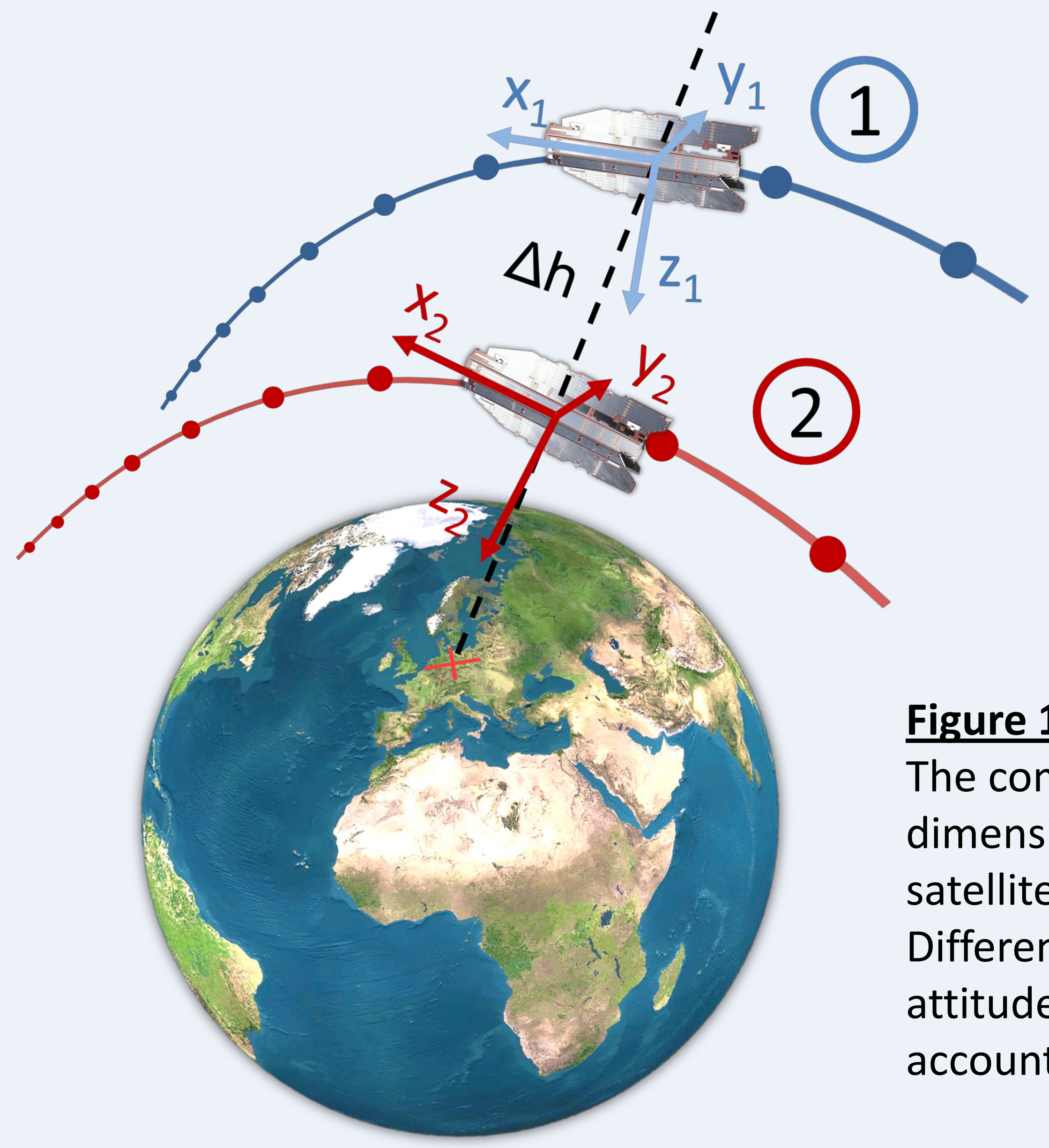

Figure 1: Cross-Over Approach
The comparison of two three-dimensional measurements in satellite track cross-overs. Differences in altitude Δh and attitude have to be taken into account.

Adaptation of XO analysis for GOCE GG validation

For the comparison of two three-dimensional measurements, namely the components of the gravitational gradient tensors (GGT), they have to be transformed into the same coordinate system. The rotational part of the transformation is affected by the following restrictions:

1) less accurate long-wavelength information in all GGT components, and
2) less accurate off-diagonal components in the GGT.

→ Effect: Shift of less accurate signal components into all GGT components because of rotation. All GGT components become less accurate.

→ Solution: Replacement of less accurate signal parts due to 1) and 2) by model information derived from a global geopotential model, here the GOCO02S [1].

Besides an approach allowing for tensor rotation, the translational part of the transformation has to be taken into account as well. In order to overcome the differences in altitude, model information is used. The gradient differences, caused by the vertical displacement of the two satellite positions, are corrected by again applying the GOCO02S model.
A more detailed description of the integration of model information and the necessary filtering procedures can be found in [2].

Final Comparison

After pre-processing as discussed in the previous section, the XO comparison is carried out using the following equation (colors according to Figure 1):

$$\Delta V_{ij} = \boxed{V_{ij}^{GRF\,2}} - \left(R_{GRF\,2 \leftarrow GRF\,1} \cdot \boxed{V_{ij}^{GRF\,1}} \cdot R_{GRF\,2 \leftarrow GRF\,1}^{T} + \Delta V_{ij}^{\Delta h} \right) \quad (1)$$

Finally, the residuals ΔV_{ij} are further analysed.

Results

Within the XO analysis, the residuals ΔV_{ij} from equation (1) are investigated in detail. One possible representation is shown in Figure 2, i.e. color-coded XO residuals ΔV_{ii} and their geographical distribution.
The observation period, from which GOCE gradients have been used, is February 11, 2011 until April 3, 2011.

The geographical distribution of the XO residuals (Figure 2) illustrates a different behavior of the three main diagonal components:

- The residuals ΔV_{xx} and ΔV_{yy} show similar, distinct accumulations of larger systematic differences towards the poles and south of Australia as well as south of Greenland. The maximum values are ± 40 mE. In a large band around the equator, the residuals are small (near zero) and show some random noise behavior.
- The residuals ΔV_{zz} show a slight accumulation of larger differences near the poles. They are in a range of about ± 30 mE, with a general noise level that is somewhat higher than for the other two main diagonal components.

Due to the rotation of the gravitational gradient tensor (see equation 1), anomalies only appearing in single GOCE gradient components are shifted to other tensor components. This effect is also evident in the XO residuals. The anomaly south of Australia, for instance, that is present in the GOCE V_{yy} gradient component, is shifted to V_{xx} due to rotation and becomes visible in the residuals ΔV_{xx}, too. The V_{zz} component, however, seems to be less affected by shifts.

For the quality analysis of the gradients, the RMS values of the residuals are determined. By limiting the latitudinal band around the equator, the anomaly-affected residuals at higher latitudes can be excluded. The results in Table 1 show a significant improvement for ΔV_{xx} and ΔV_{yy}. The residuals ΔV_{zz} do not show any effect, their noise performance remains unchanged.

Table 1: RMS values of XO residuals ΔV_{ii} determined in various latitudinal bands

latitude	RMS (V_{xx})	RMS (V_{yy})	RMS (V_{zz})
90°(all)	4.93 mE	5.48 mE	5.31 mE
50°	3.36 mE	3.32 mE	5.32 mE
20°	3.26 mE	2.97 mE	5.28 mE

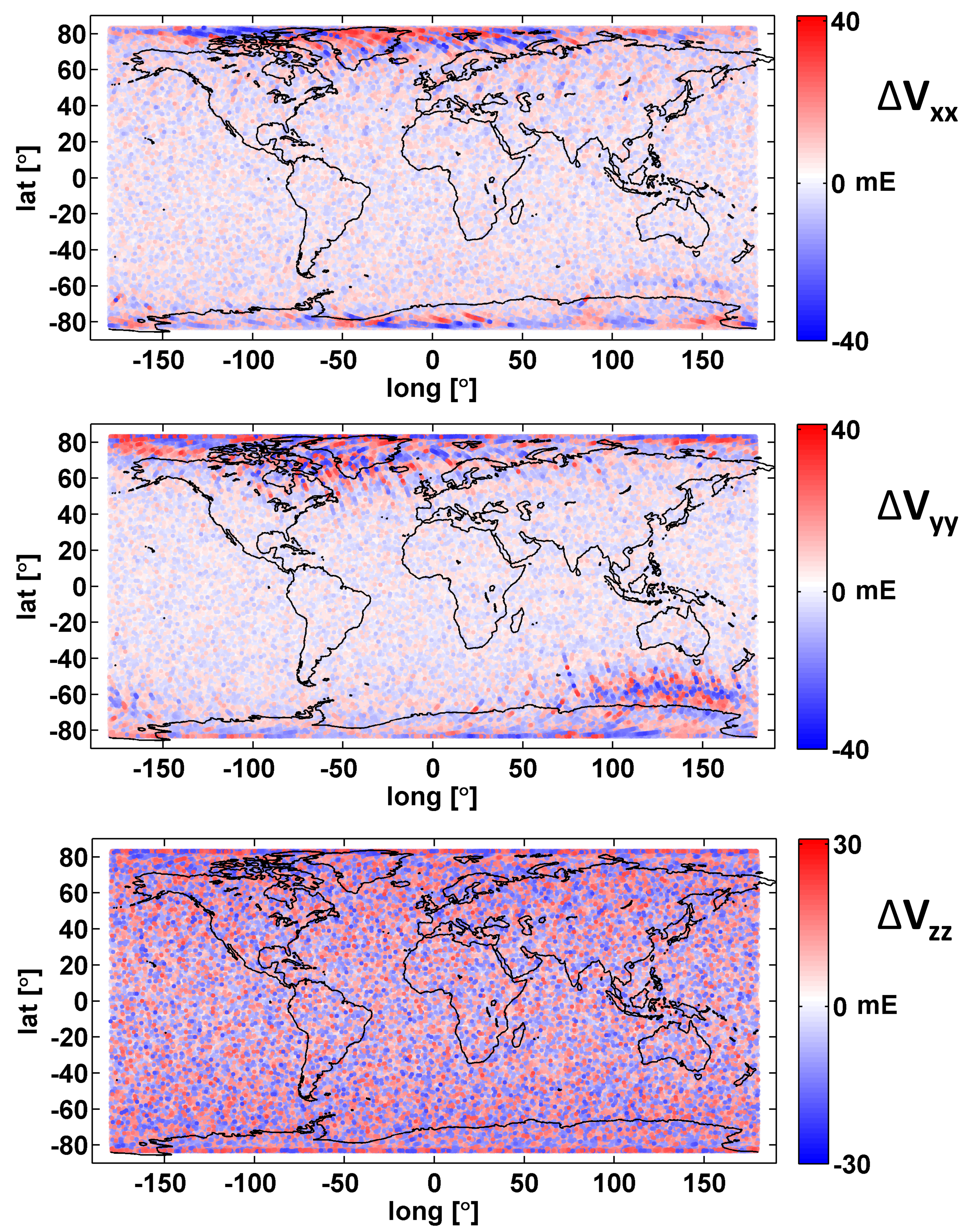

Figure 2: Geographical distribution of XO residuals ΔV_{ii}

Conclusion

The XO approach assesses the GOCE gravitational gradient quality, also including the gradients being affected by anomalies in single tensor components, especially V_{yy}. Excluding the identified anomaly areas, the evaluation of the random noise level of the GOCE gradients becomes possible. The results indicate a noise level of about 3.1 mE (RMS) for the V_{xx} and V_{yy} components. The noise of V_{zz} is at the level of 5.3 mE (RMS), this is larger by a factor of 1.7. This result is in very good agreement with the findings of other GOCE calibration/validation studies (e.g., [3]) confirming the high quality of the GOCE measurements.

References

[1] Goiginger H. et al.: *The combined satellite-only global gravity field model GOCO02S*. Presented at the GA of the EGU, Vienna, Austria, April 4-8, 2011.
[2] Brieden P., Müller J.: *Two methods for quality assessment of GOCE gradients*. Proceedings of the ESA Living Planet Symposium, ESA SP-686, Bergen, 2010.
[3] Yi W. et al.: *Performance analysis of GOCE gradiometer measurements*. Proceedings of the ESA Living Planet Symposium, ESA SP-686, Bergen, 2010.

EGU General Assembly 2012, Vienna, Austria , April 22-27, 2012 (Poster EGU2012-10964)