Quality assessment of REAL GOCE gravitational gradients using cross-overs

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Introduction

ESA's Gravity field and steady-state Ocean Circulation Explorer (GOCE) determines the Earth's gravity field since November 2009. The satellite operates well, the group of users of the GOCE products grows month by month and the fields of application expand.
Regardless of the field of application, the data quality of the GOCE products remains of paramount importance. In addition to a multitude of calibration and validation approaches, the comparison of gravitational gradients in satellite cross-overs (XOs) is a very suitable method to be used for assessing the quality of GOCE gravitational gradients (GG).

Here, the main steps of XO analysis and its use for the validation of GOCE GGs is investigated. It is discussed which level of accuracy can be achieved.

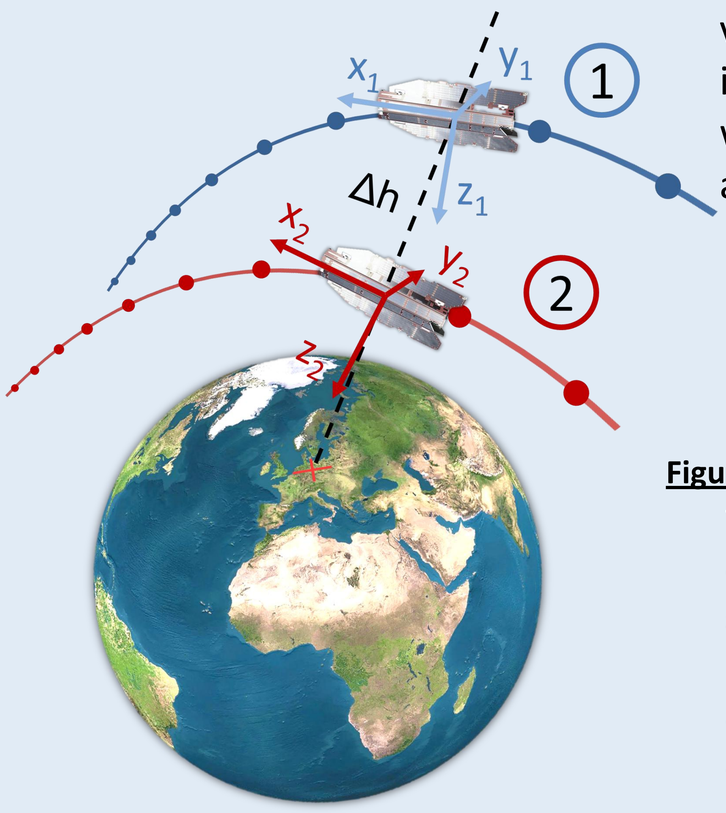

Figure 1: XO-Approach
The comparison of two three-dimensional measurements in satellite track cross-overs. Differences in attitude and altitude have to be taken into account.

Adaptation of XO analysis for GOCE GG validation

The comparison of GG tensors in satellite cross-overs has to be performed in one and the same coordinate system. In order to counteract a shift of less accurate tensor and signal components due to rotation, less accurate signal parts are replaced by gravity field models. The difference in altitude is corrected by model derived gradient differences ($\mathbf{V_{ij}}^{\Delta h}$). A more detailed description of the necessary data pre-processing can be found in [2].

$$\Delta \mathbf{V_{ij}}^{GRF2} = \mathbf{V_{ij}}^{GRF2} - \left(\mathbf{R}_{\mathbf{GRF\ 2 \leftarrow GRF\ 1}} \cdot V_{ij}^{GRF1} \cdot \mathbf{R}_{\mathbf{GRF\ 2 \leftarrow GRF\ 1}}{}^{\mathbf{T}} + \Delta \mathbf{V_{ij}}^{\Delta \mathbf{h}} \right)$$

Achievable accuracy

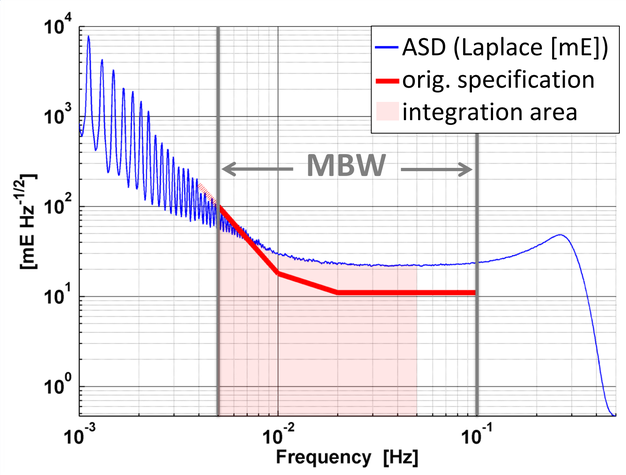

Figure 2: ASD of the Laplace equation ($V_{xx}+V_{yy}+V_{zz}$) and its original specification. After pre-processing, GOCE signal is only contained in the area that is marked light red.

$$\sigma^2_{observation} = \int_{5\,mHz}^{50\,mHz} ASD\left(V_{xx} + V_{yy} + V_{zz}\right) df$$

The achievable level of accuracy is derived from the amplitude spectral density (ASD) of the Laplace equation. The spectral density in the "integration area" (between 5 and 50 mHz) is integrated following the equation below.

The results obtained from GOCE measurements and from pre-mission specifications are compared:

- σ_{GOCE}: **5.71 mE**
- σ_{specs}: **4.17 mE**

Results

The observation period covers the period from February 11, 2011 until April 3, 2011. Model GGs are calculated from GOCO02S [1].

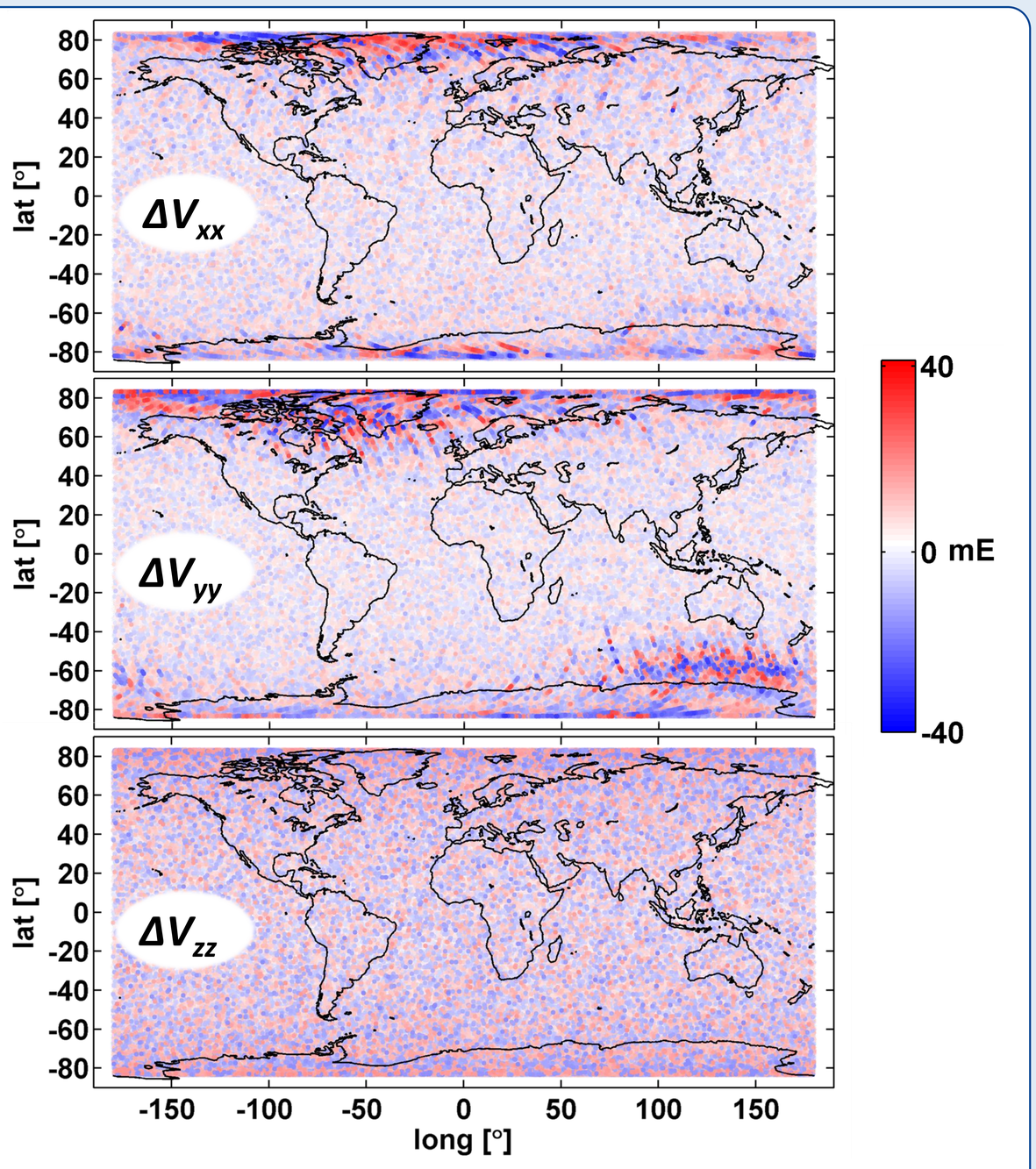

Figure 3: Geographical distributed XO-residuals ΔV_{ii}

In Figure 3 the geographical distribution of the color-coded XO residuals ΔV_{ii} are illustrated:

- ΔV_{xx} and ΔV_{yy} show a distinct accumulation of larger differences (up to ± 40 mE) towards the poles and south of Greenland as well as south of Australia. The latter are evident in the V_{yy}-component and become visible in ΔV_{xx} due to tensor rotation.
- The residuals ΔV_{zz} are more noisy and show a slight increase of the residuals towards the poles. Their maximum absolute value (less than ± 30 mE) is much smaller compared to ΔV_{xx} and ΔV_{yy}.

Solar winds are believed to be the reason for these effects.

As not to be affected by the systematics, the analysis area is limited to latitudinal bands around the equator. Root Mean Square (RMS) values of ΔV_{ii} are compared.

Longitude	RMS (V_{xx})	RMS (V_{yy})	RMS (V_{zz})
± 90° (all)	4.93 mE	5.48 mE	5.31 mE
± 50°	3.36 mE	3.23 mE	5.32 mE
± 30°	3.29 mE	3.00 mE	5.29 mE

factor 1.7

Conclusions

The XO approach is a very suitable tool to assess GOCE gravitational gradient quality. The determination of the achievable accuracy is driven by the noise level of the V_{zz} (RMS 5.3 mE), which is about a factor 1.7 higher compared to V_{xx} and V_{yy} (RMS 3.1 mE).
All in all the XO analysis confirms the excellent quality of the GOCE gravitational gradients.

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. Proceeding of the ESA Living Planet Symposium, ESA SP-686, 2010.

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