GOCE Quality Analysis Using Cross-Overs

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Introduction

The GOCE (Gravity field and steady-state Ocean Circulation Explorer) mission is currently operating for about three and a half years and its initially expected mission duration is exceeded by far. GOCE's main measurement quantity is the gravitational gradients. To ensure high qualitative final GOCE products including highly accurate gravity field models, various methods are examined to assess the gradient quality. One of these is investigated here, the cross-over approach in which gravitational gradients are compared in satellite track cross-overs (XO).

The principle of the XO analysis is explained briefly. The effect of partly used synthetic model gradients on various tensor components due to a necessary tensor rotation is evaluated. Finally, results of the XO analysis are shown, wherein data is compared before and after reprocessing.

The cross-over (XO) approach

The XO approach is based on the idea that GOCE senses the same gravitation when crossing the identical point on the Earth's surface twice. This situation occurs in satellite track XOs, in which two three-dimensional measurements, the gravitational gradient tensors (V_{ij}), are compared.

Due to attitude and altitude differences between the two satellite positions (see Fig.1), a transformation of V_{ij} from GRF1 to GRF2 is performed:

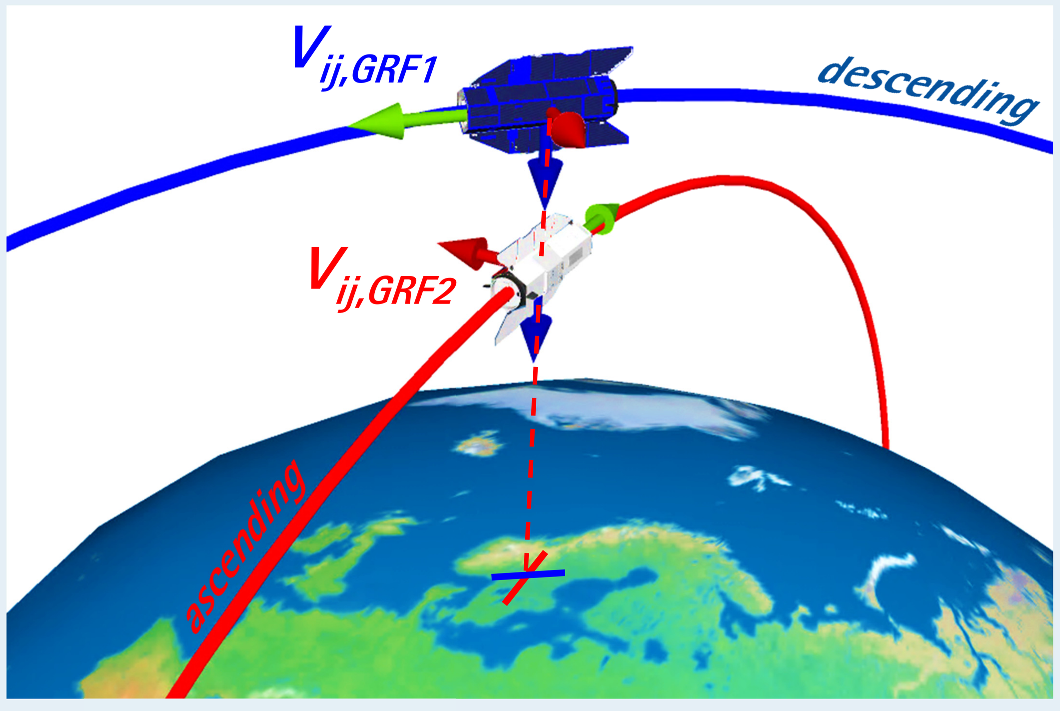


Fig.1: Sketch of XO over Scandinavia

$$\Delta V_{ij} = V_{ij,GRF2} - \left(R_{GRF1\rightarrow GRF2} \bullet V_{ij,GRF1} \bullet R_{GRF1\rightarrow GRF2}^{T} + \Delta V_{ij,\Delta h}^{synth}\right) \qquad (1)$$

Remark on required transformations:

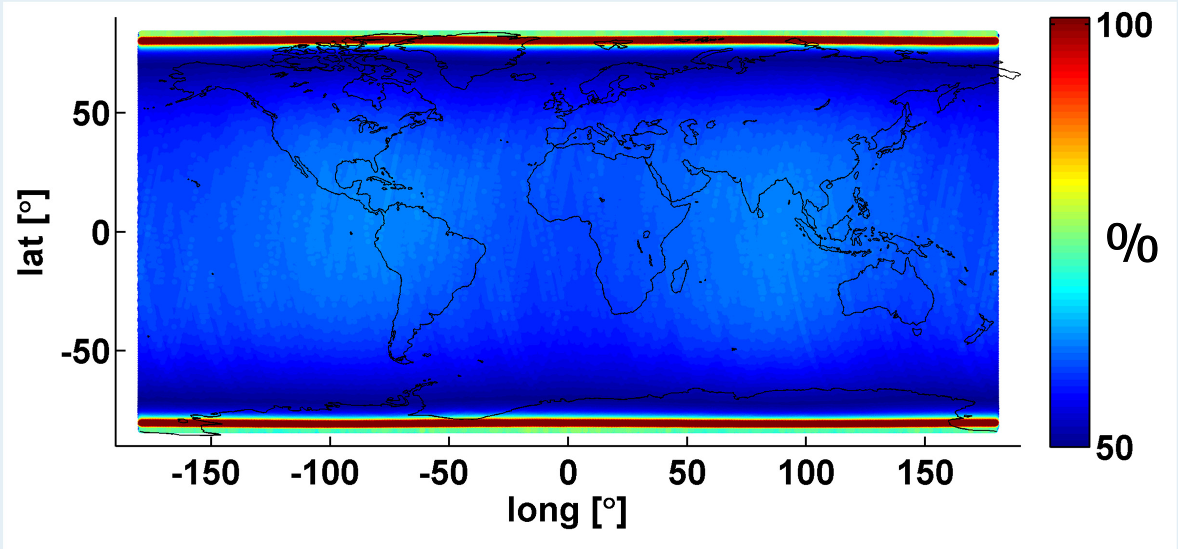
- To 'allow' for tensor rotation without mixing of less and highly accurate tensor components, the following component (parts) are replaced by synthetic V_{ij} (here from GOCO03S):
  - ➢ long wavelengths of $V_{xx}, V_{yy}, V_{zz}, V_{xz}$
  - ➢ V_{xy}, V_{yz} completely

$$V_{ij} = \begin{bmatrix} V_{xx} & V_{xy} & V_{xz} \\ & V_{yy} & V_{yz} \\ & & V_{zz} \end{bmatrix} \Leftrightarrow \begin{bmatrix} S+G & S & S+G \\ & S+G & S \\ & & S+G \end{bmatrix}$$

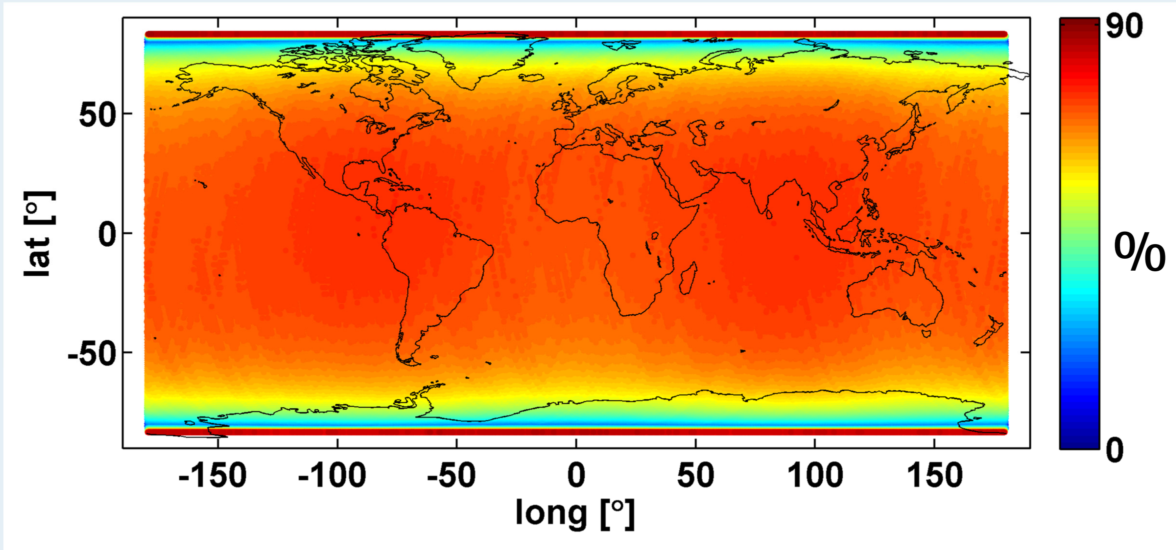
S – synthetic model gradients; G – GOCE gradients

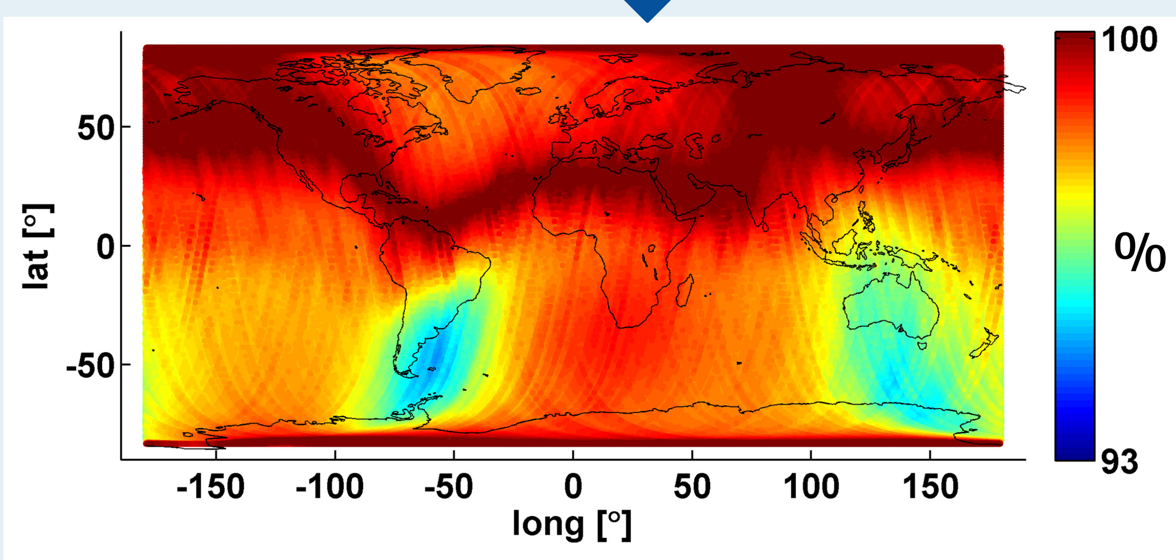
- Altitude dependent differences $\Delta V_{ij,\Delta h}^{synth}$ derived from synthetic V_{ij}

Signal shift due to tensor rotation



GOCE information [%] in V_{xx} (similar for V_{yy}) V_{xz} and V_{zz} after rotation.

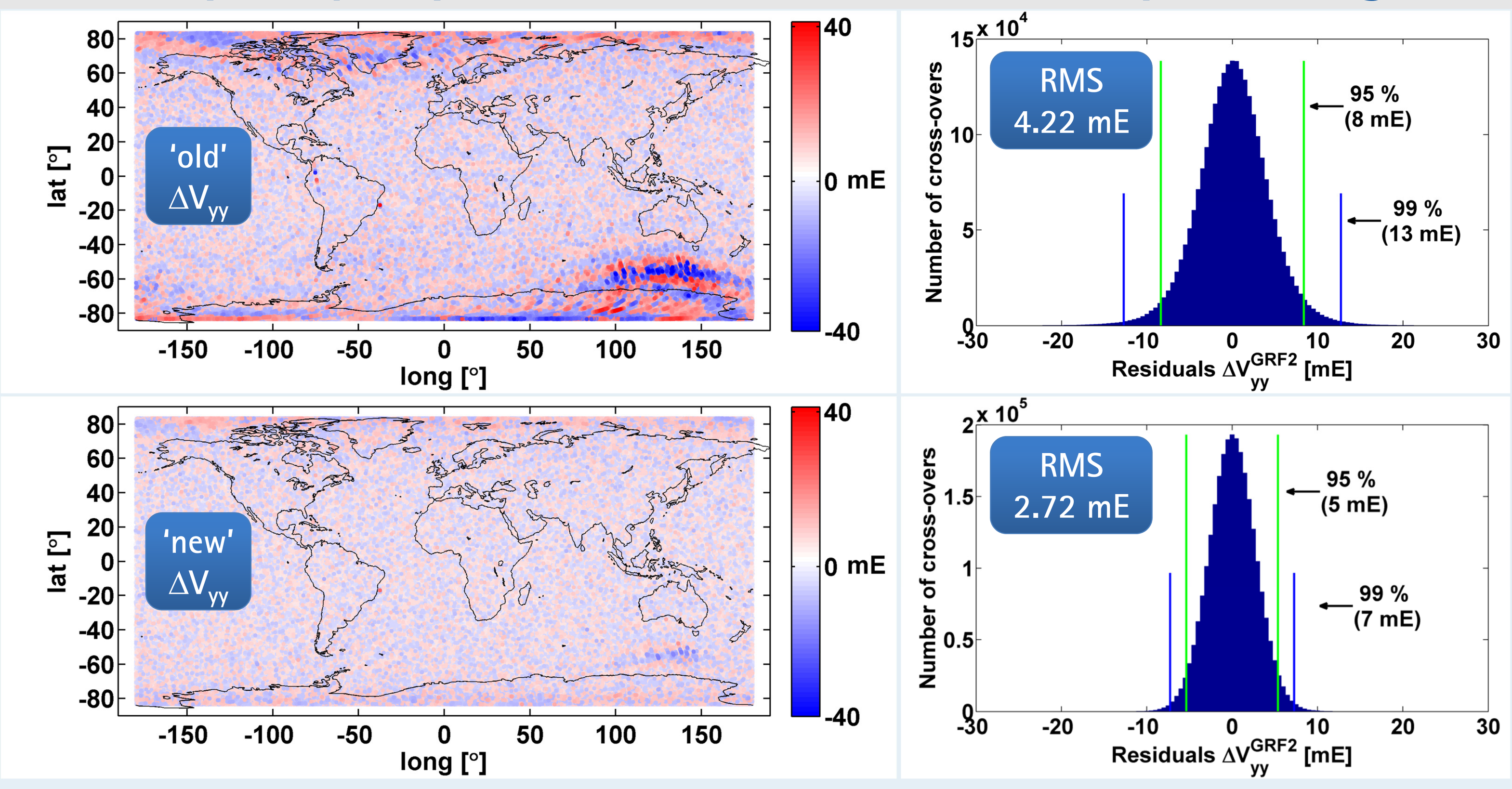




As mentioned in the previous section, synthetic gradients are included in the GOCE gravitational gradient tensor. The less accurate V_{xy} and V_{yz} are completely replaced by synthetic data. Due to tensor rotation, parts of these synthetic gradients shift to highly accurate tensor components. In order to establish how much synthetic data is incorporated into the high-precision gradient components, the signal shift due to rotation from GRF1 to GRF2 is derived from $R_{GRF1\rightarrow GRF2}$.

The figures show the contribution of GOCE gradients that remains from the original V_{xx}, V_{yy}, V_{zz} and V_{xz} (containing GOCE data above 4 mHz).

Gradient quality improvement after EGG-data reprocessing



In 2012 ESA updated its EGG-data processor. Main changes are:

- Linear interpolation of calibration matrices,
- Combination of attitude information of up to 3 star sensors,
- Combination of angular rates using Wiener Filter.

Here, the XO-approach is used to evaluate the improvement of the 'new' processor compared to the 'old' one. Figures show the nicely reduced artifacts in the V_{yy} component. From the histograms of the residuals ΔV_{yy} (see Eq. 1) one can see that 99 % of all residuals are below 7 mE ('old': 13 mE). The RMS comparison reflects the greatly improved data quality of about 30 % for V_{yy}.

Conclusion

- XO approach is a useful tool for gradient quality assessment.
- The mixture of synthetic and GOCE gradients is caused by tensor rotation. GOCE content in V_{zz} remains over 93 %.
- The XO approach confirms the high quality of the GOCE gradients: RMS of XO residuals ΔV_{xx}=2.9 mE, ΔV_{yy}=2.7 mE, ΔV_{zz}=6.6 mE. Improvements due to reprocessing up to 30 %.

Outlook

- Analysis for a sure method for the handling of altitude-related gradient differences in the XOs.
- Evaluation of a 'better' coordinate system in which the XO comparison can be performed → minimize synthetic data.
- Integration of consistent variance information in the XO software operations.

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