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COMBINED GLOBAL GRAVITY FIELD MODELS FROM GOCE DATA AND COMPLEMENTARY DATA TYPES

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INTRODUCTION

The main objective is the generation of high-resolution global gravity field models, by combining data from the satellite gravity missions GOCE, GRACE and CHAMP with complementary gravity field information represented by terrestrial data, satellite altimetry, and satellite laser ranging (SLR). These different data types are complementary with respect to their measurement principle, accuracy, spatial distribution and resolution, and spectral (error) characteristics. By means of data combination, benefit can be taken from their individual strengths and favourable features, and in parallel specific deficiencies can be reduced. A detailed global map of the Earth´s gravity field contributes to many branches of Earth sciences, e.g., geophysics, geodesy, oceanography, cryospheric and climate research.

ARCHITECTURAL DESIGN

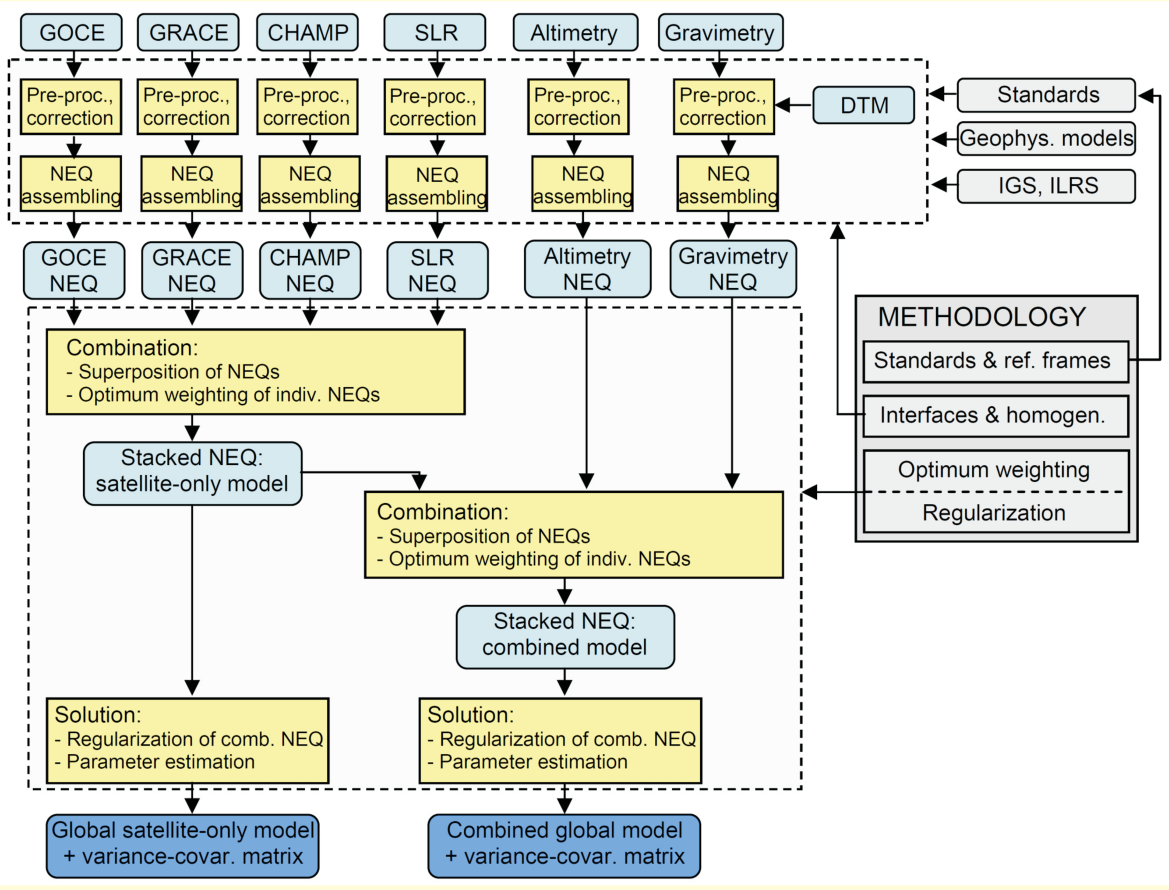

Fig. 1. Software architecture and data flow.

The final products are a satellite-only model and a combined model in terms of geopotential coefficients and the corresponding full variance-covariance matrices (cf. Fig. 1). The combination strategy is based on a weighted superposition of the normal equation (NEQ) matrices of each data type. Therefore, the NEQ matrices have to be assembled for each observation type. For the following consistent combination of the NEQ's, it is very important that they are based on common standards by means of defined constants, reference frame, background models for the reduction of temporal variations, etc. The key issue of the combination step is the determination of optimum weights for each data type with special emphasis on those spectral regions where the individual observation type contributes most to the optimum final solution. In future, also the problem of regularization has to be addressed because of the restricted spatial data distribution of ,e.g., GOCE.

DATA DESCRIPTION

An initial processing environment was implemented to compute a preliminary combined model based on satellite-only data and to demonstrate the impact of the different data types.

- **CHAMP:** 4 years of precise orbit data and acceleration measurements
- **GRACE:** full variance-covariance matrix of the ITG-GRACE03S model available on the website of the Institute of Geodesy and Geoinformation at the University of Bonn. This model comprises 4.5 years of data and has a resolution of degree and order (d/o) 180.
- **GOCE:** 1 month of satellite gravity gradiometry (SGG) data, which is available through the ESA GOCE data announcement of opportunity.

Reference frame and standards

In the present stage of this project the issue concerning an uniform reference frame and standards are not considered. Since each data type is observed and computed in its individual reference frame using different standards, the data sets have to be transformed into a common system for future project activities.

PROCESSING AND RESULTS OF THE INDIVIDUAL SOLUTIONS

In this part of the processing chain normal equation systems of each data type are assembled. To get an impression of the characteristics of each data type the gravity anomalies are shown in Fig. 2. Comparing the gravity anomaly maps, GRACE and GOCE are able to significantly identify more detailed structures than CHAMP. One has to keep in mind that the GOCE model is based on only 1 month of real SGG-only data whereas CHAMP is based on 4 years and GRACE even on 4.5 years of data.

CHAMP

The CHAMP-only model is based on precise orbit data for the period of 2004 to 2007 (4 years). To determine the spherical harmonic coefficients to degree and order (d/o) 90, the in-house software based on the energy integral approach was applied.

GRACE

The full variance-covariance matrix of the ITG-GRACE03S model has to be inverted to obtain the normal equation matrix. Next, the corresponding right-hand side of the normal equation system is computed on a cluster by multiplication of the normal equation matrix with the ITG-GRACE03S coefficients up to d/o 180.

GOCE SGG-only

The GOCE SGG-only model is based on 1 month (November 2009) of satellite gravity gradients (SGG). The SGG equation system is parametrized up to d/o 224 and a realistic stochastic model is incorporated by applying cascaded digital filters which are developed by the Institute of Geodesy and Geoinformation, University of Bonn. Finally Kaula regularization with constraints towards zero to (near-) zonal coefficients and to the coefficients of d/o 170 to 224 is applied to improve the signal-to-noise ratio.

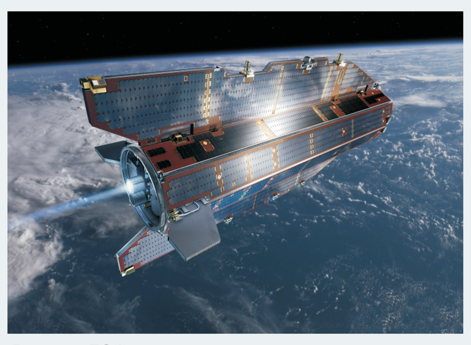

Image: ESA

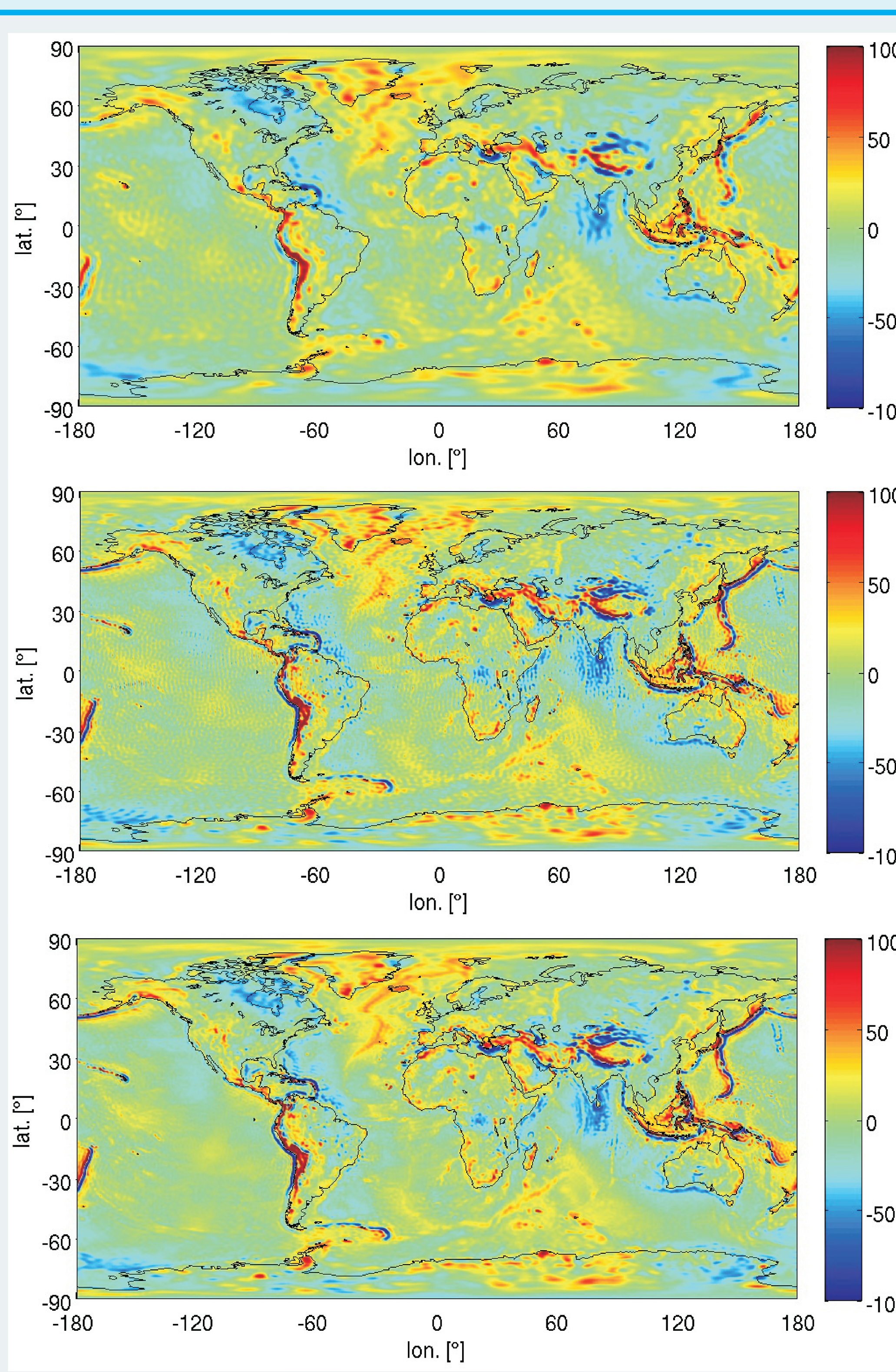

Fig. 2. Gravity anomalies [mGal] neglecting the zonal coefficients of degree 2, 4, 6, 8 derived from CHAMP up to d/o 90 (top), GRACE up to d/o 180 (center), and simulated GOCE data up to d/o 204 (bottom).

PROCESSING AND RESULT OF A PRELIMINARY COMBINED SOLUTION

The degree variances plot (cf. Fig. 3) of the solutions w.r.t. to the 'state-of-the-art' model EIGEN-5C illustrates that, in the present configuration, CHAMP has no impact on the combined solution, i.e. the coefficients up to d/o 90 are dominated by GRACE. Between d/o 90 and d/o 150 the GRACE coefficients can be confirmed by the GOCE SGG solution. From d/o 150 upwards the combined solution is clearly dominated by the GOCE SGG-only solution. To conclude it can be seen that the combined model benefits from the high accuracy of GRACE in the lower part of the spectrum and from the high accuracy of GOCE SGG-only in the upper part of the spectrum. Furthermore the difference curve of the combined model (dashed green) coincides with the cyan curve, representing the calibrated errors of EIGEN-5C, quite well. Note: it has to be kept in mind that GOCE is based on only 1 month of SGG data whereas GRACE is based on 4.5 years.

Figure 5 displays the gravity anomaly differences [mGal] between the combined model and EIGEN-5C up to d/o 200. As can be noticed the GOCE gradients deliver additional information especially in mountainous regions, like the Himalayas and the Andes, and in regions where only a few and less accurate terrestrial measurements are available, like parts of Africa and Antarctica.

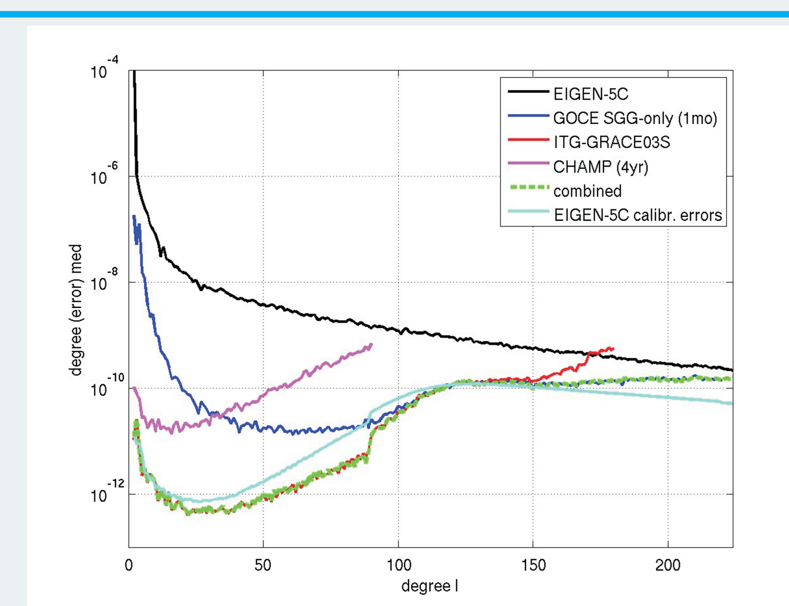

Fig. 3. Degree (error) median of individual solutions and combined sol.

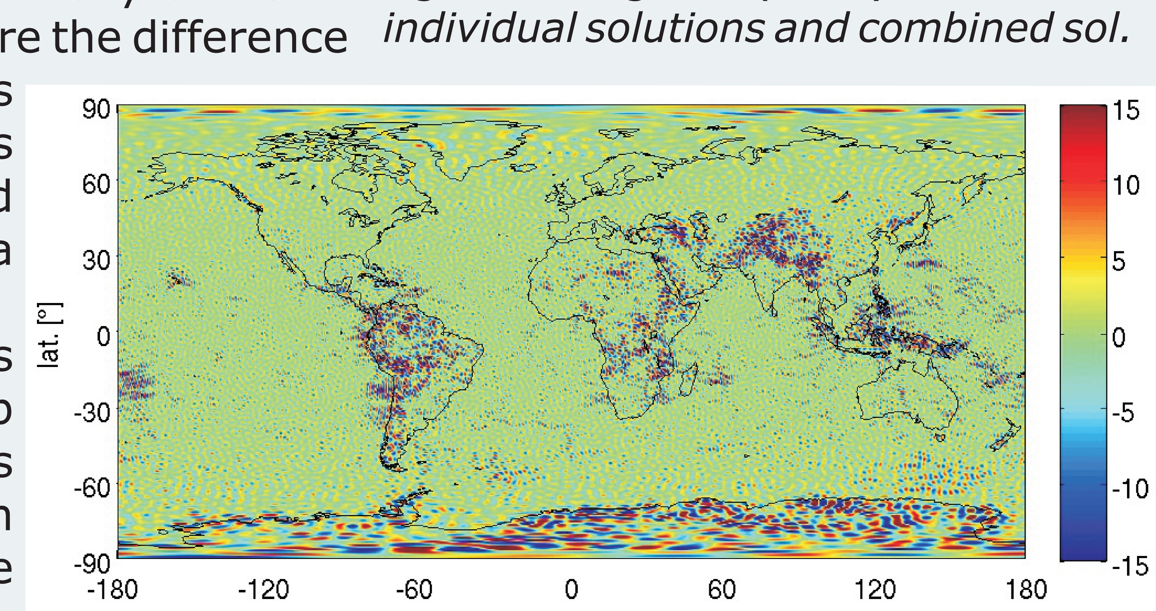

Fig. 4. Differences of gravity anomalies [mGal] derived from preliminary combined model w.r.t. EIGEN-5C.

SUMMARY AND OUTLOOK

The presented study clearly demonstrates the benefits of the different satellite data types and the impact on a preliminary combined solution. The next step will be to update the environment by using the new ITG-GRACE2010S model. Additionally, also normal equation systems based on SLR observations, altimetry, and terrestrial gravity data will be set up and included into the combination procedure. For instance, using SLR observations the very low degrees of the spherical harmonics will be significantly improved (cf. Fig. 3). Additional issues will be the definition of common standards and reference frames and the implementation and study of optimum weighting techniques.

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