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Processing LEO Data and Gravity Field Determination at AIUB: A Status Report

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INTRODUCTION

The GPS orbit and clock products of the Center for Orbit Determination in Europe (CODE) are used at the Astronomical Institute of the University of Bern (AIUB) for kinematic and reduced-dynamic orbit determination of Low Earth Orbiting (LEO) satellites. While the reduced-dynamic orbits depend on force models and aim at the highest possible precision, the kinematic orbits are independent from any force model and are therefore well suited for subsequent gravity field determination.

The spherical harmonic coefficients of the gravity field are set up as additional parameters in a generalized orbit determination problem using kinematic positions as pseudo-observations. Depending on the orbit height coefficients up to degree and order 120 (corresponding to a spatial resolution of 167 km) may be solved from the kinematic LEO orbits. In case of GRACE additional inter-satellite K-band measurements with micrometer accuracy allow for the determination of the static field up to degree 160 (125 km) and monthly gravity field solutions with a limited resolution of about degree 60. Finally the short scales of the gravity field are measured by the GOCE gradiometer and combined with the static part of the GRACE gravity model.

LEO ORBIT DETERMINATION

So-called pseudo-stochastic orbit modeling techniques are used at AIUB. They allow for a very flexible orbit determination by estimating empirical parameters, e.g., piecewise constant accelerations, at a frequency of typically 6 to 15 minutes (depending on the orbit characteristics).

AIUB was responsible for the precise science orbit determination of the GOCE mission. Fig. 1 shows SLR residuals (kindly provided by Markus Heinze, IAPG) to assess the high quality of the reduced-dynamic GOCE orbits for the entire mission. Temporary increases in the differences between kinematic and reduced-dynamic orbits (Fig. 2) are clearly correlated with solar activity, as recorded by the mean Total Electron Content (TEC , Fig. 3). Figures 1-3 are taken from Bock et al. (2014).

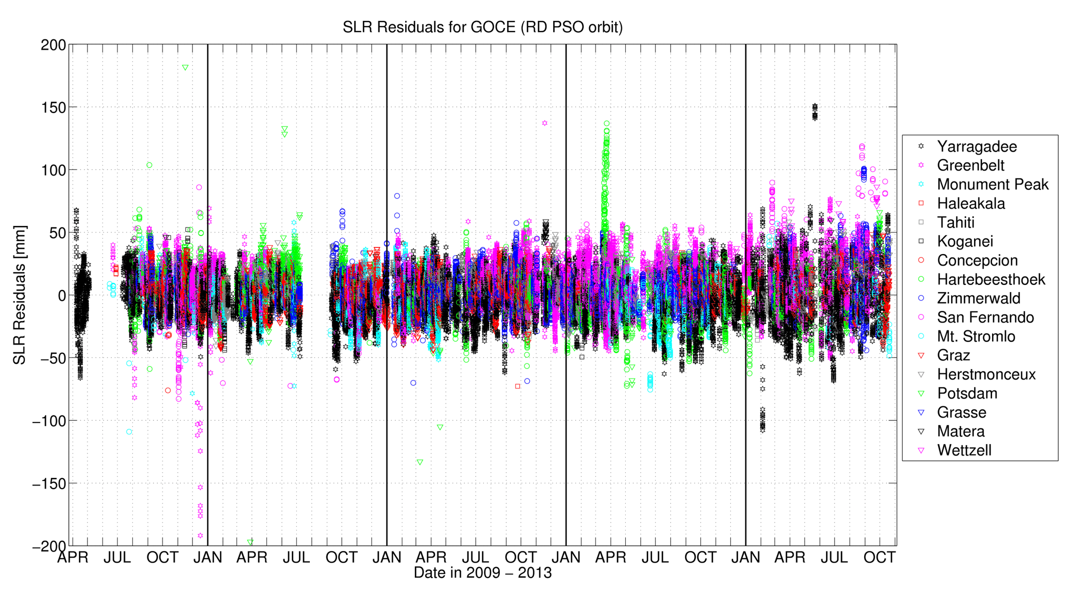

Fig. 1: SLR residuals (RMS = 1.84 cm) to reduced-dynamic GOCE orbits. A decrease in quality due to increased solar activity is slightly visible.

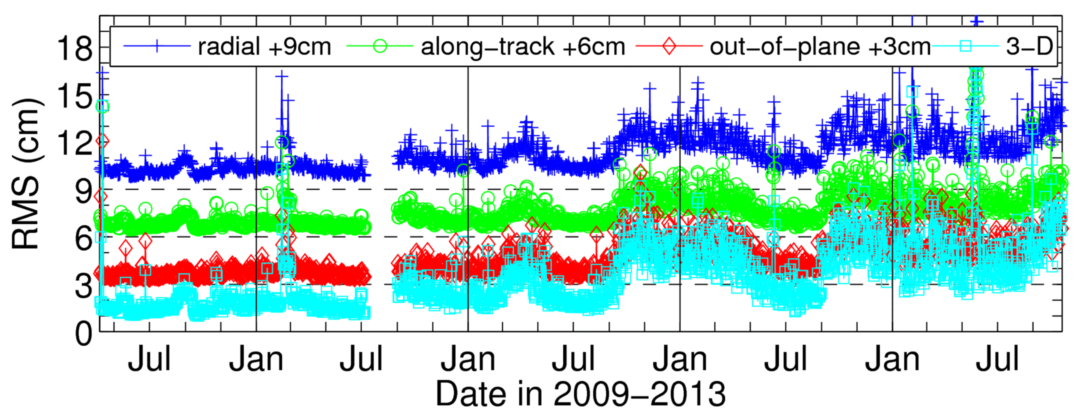

Fig. 2: Daily RMS of differences between kinematic and reduced-dynamic GOCE orbits. An increase in the RMS generally points to a decrease in the quality of the kinematic orbit.

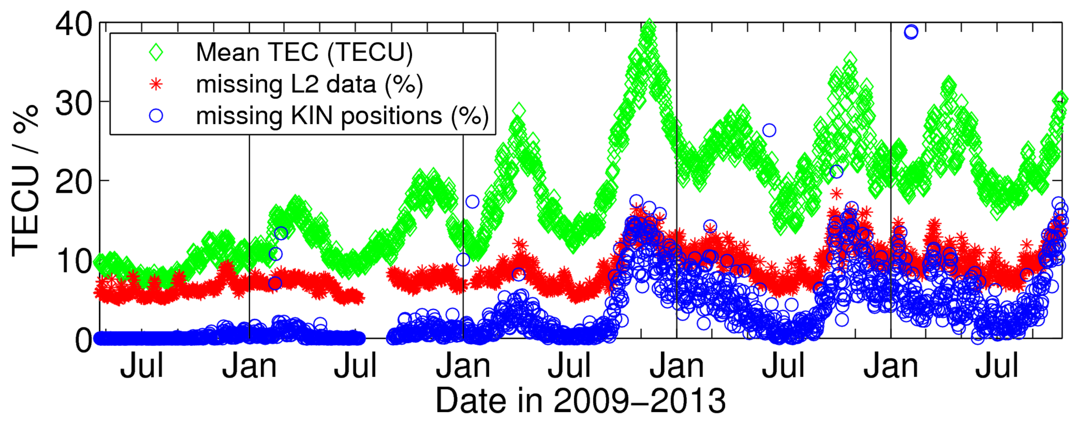

Fig. 3: Mean TEC as a measure for solar activity. Correlations with missing L2 data and missing kinematic positions are clearly visible.

STATIC GRAVITY FIELD

The kinematic orbit positions are taken as pseudo-observations for gravity field determination. They are used together with GRACE K-band data and/or GOCE gradiometer observations to derive combined or mission specific static gravity field models. To minimize the impact of external information EGM96 is used as a priori model.

The characteristics of the solvable spectrum of gravity field coefficients depend on the satellite orbits (near polar in case of GRACE, sun-synchronous in case of GOCE) and on the type of observations. A careful combination preserves the strength of each type of data and each satellite mission (Figs. 4 and 5).

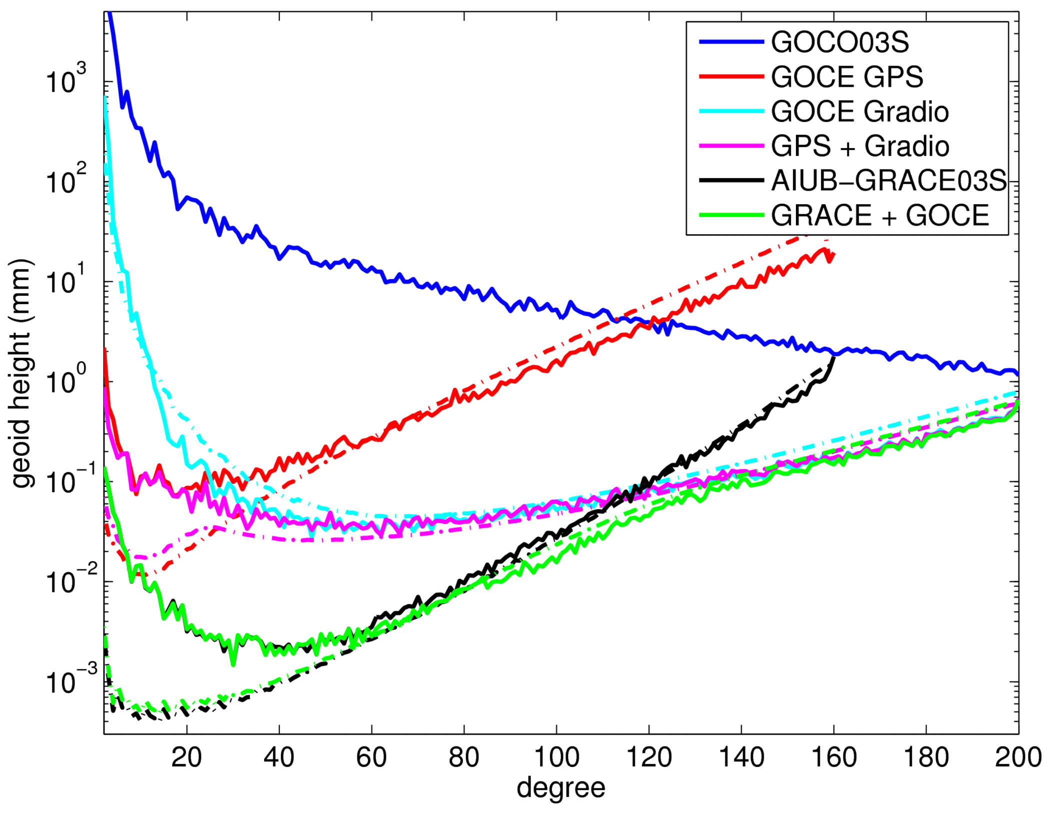

Fig. 4: Difference degree medians to superior gravity field model GOCO03S (solid lines) and corresponding formal errors (dash-dot). The contributions from different observation techniques from GRACE and GOCE are clearly visible.

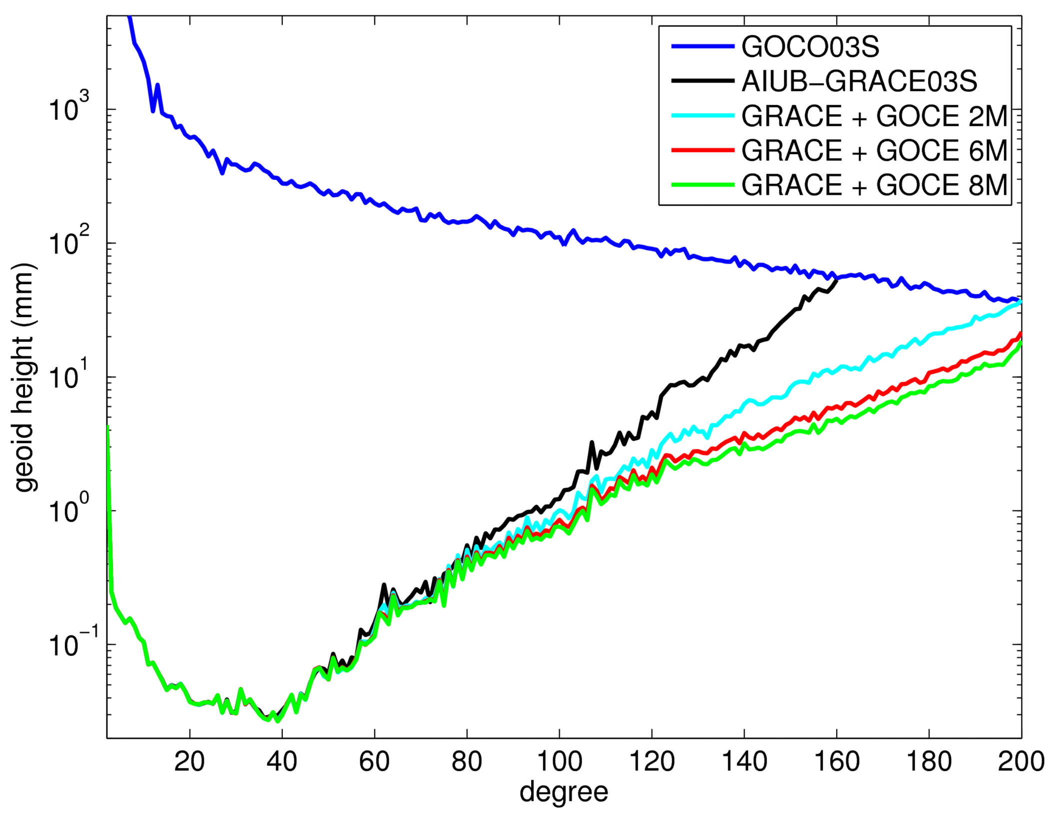

Fig. 5: Improvement of combined GRACE/GOCE gravity model with increasing amount of GOCE data (difference degree amplitudes).

Gravity anomalies computed from the combined AIUB gravity model including 7 years of GRACE and 8 months of GOCE data (Fig. 6) show significantly less artifacts (stripes) than the corresponding GRACE only model (not shown). A comparison with EGM2008 reveals discrepancies in continental areas, where EGM2008 is know to be based on sparse or poor terrestrial gravity data (Fig. 7). Note that EGM2008 was truncated at degree 190 for the comparison. At degree 190 cutoff errors in the GRACE/GOCE field start to play a role (visible as noisy patches over the oceans).

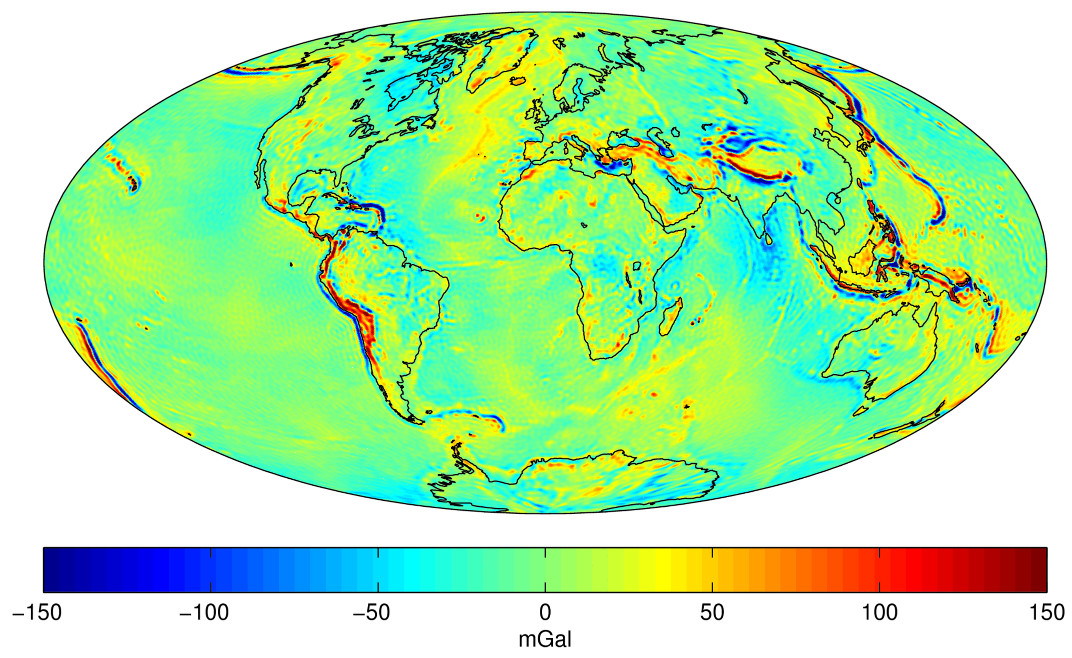

Fig. 6: Gravity anomalies from 7 years of GRACE data combined with 8 months of GOCE data (the max. degree is 200).

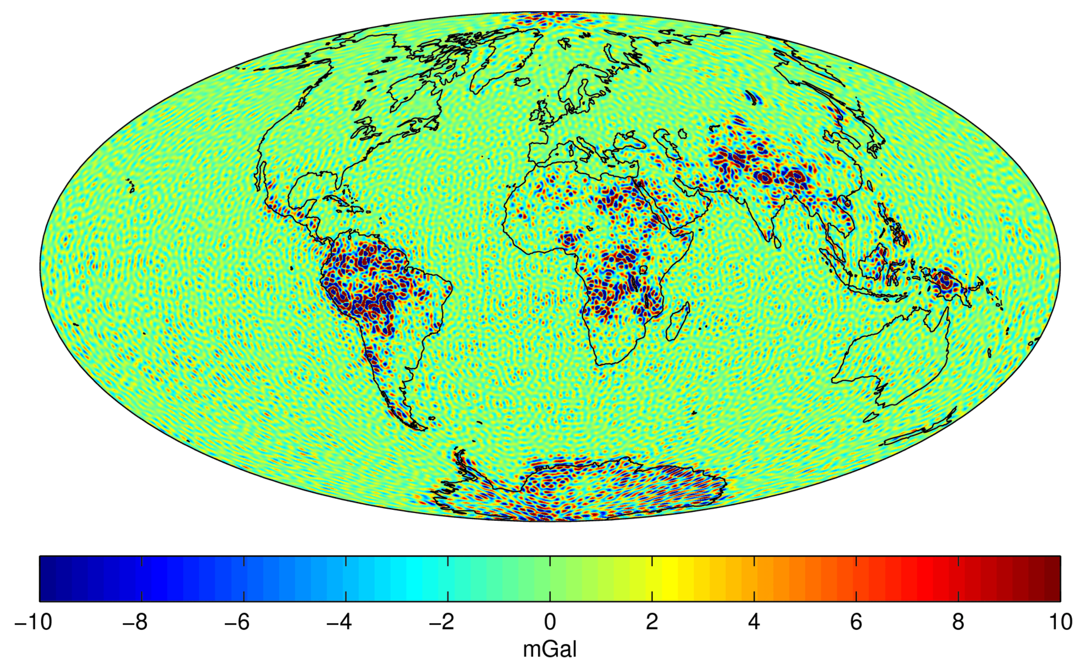

Fig. 7: Differences between EGM2008 (truncated at degree 190) and combined GRACE/GOCE gravity model. Visible are errors in EGM2008 due to terrestrial data of poor quality.

TIME-VARIABLE GRAVITY FIELD

The GRACE mission was designed to track temporal variations of the gravity field. The ground track of the orbit densely covers the Earth's surface within one month (with sub-cycles of 4 to 7 days) and allows for monthly solutions of a reduced resolution (up to degree 90). A reprocessed series AIUB-RL02 of monthly gravity fields based on updated background models and adjusted parametrization is currently computed. Comparisons of preliminary fields to degree and order 60 with other time series confirm their remarkable quality (Fig. 8). Evaluation of the monthly models in selected regions (Fig. 9) reveals a wealth of information about the hydrological cycle, climate change and post-seismic deformation.

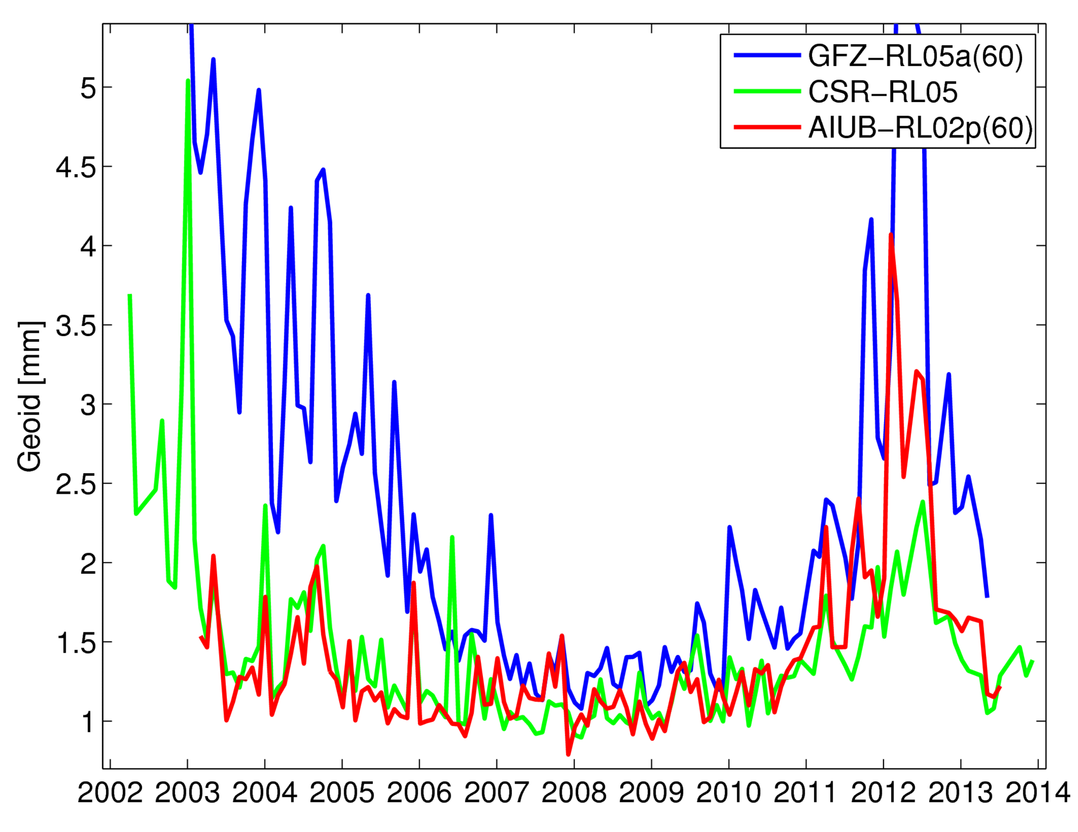

Fig. 8: Quality of monthly solutions in terms of weighted standard deviations over the oceans. Periods with higher noise at the beginning and the end of the timespan correspond to times of high solar acctivity.

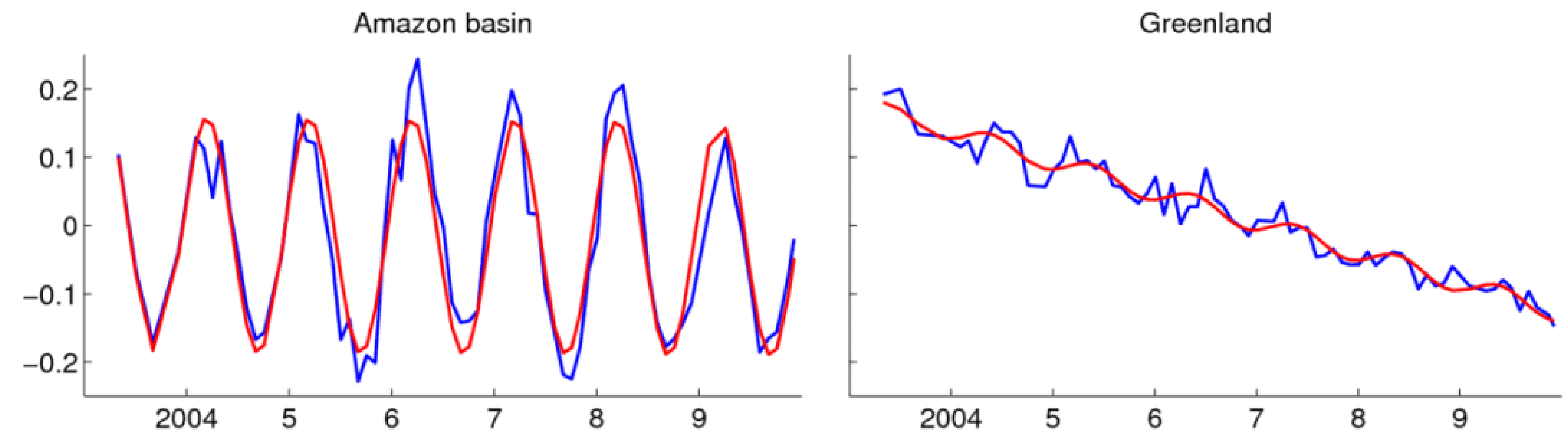

Fig. 9: Temporal gravity variations (in meter of corresponding water height) observed by GRACE in two selected regions (blue: point values, smoothed with a 500 km Gauss filter, red: model fit including a trend and seasonal variations).

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http://www.bernese.unibe.ch/publist

References:

Bock H, Jäggi A, Meyer U, Beutler G (2014). GOCE - precise orbit determination for the entire mission. Accepted for Journal of Geodesy.