On the capability to derive mass estimates from high-low satellite-to-satellite tracking data

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Introduction

Recently, Weigelt et al. (2013) demonstrated that it is possible to derive time variable gravity (TVG) from position observations of the CHAMP satellite mission in the high-low satellite-to-satellite tracking mode (hl-SST). Here we present results which (1) have been derived by combining the hl-SST observations of CHAMP, GRACE A/B and GOCE (combined solution) and (2) have been filtered by the Kalman filter method proposed by Kurtenbach et al. (2009). Kinematic position information for CHAMP are provided by AIUB, Bern; for GRACE A/B by ITSG, Graz. For GOCE, AIUB provided monthly solutions.

Processing strategy

The Kalman filter is based on the algorithm of Kurtenbach et al. (2009). It is applied to the time series of each coefficient separately, i.e. spatial correlations are neglected. Instead of using stochastic a priori information, the prediction model is designed according to the desired frequency behaviour allowing for variations around the annual frequency.

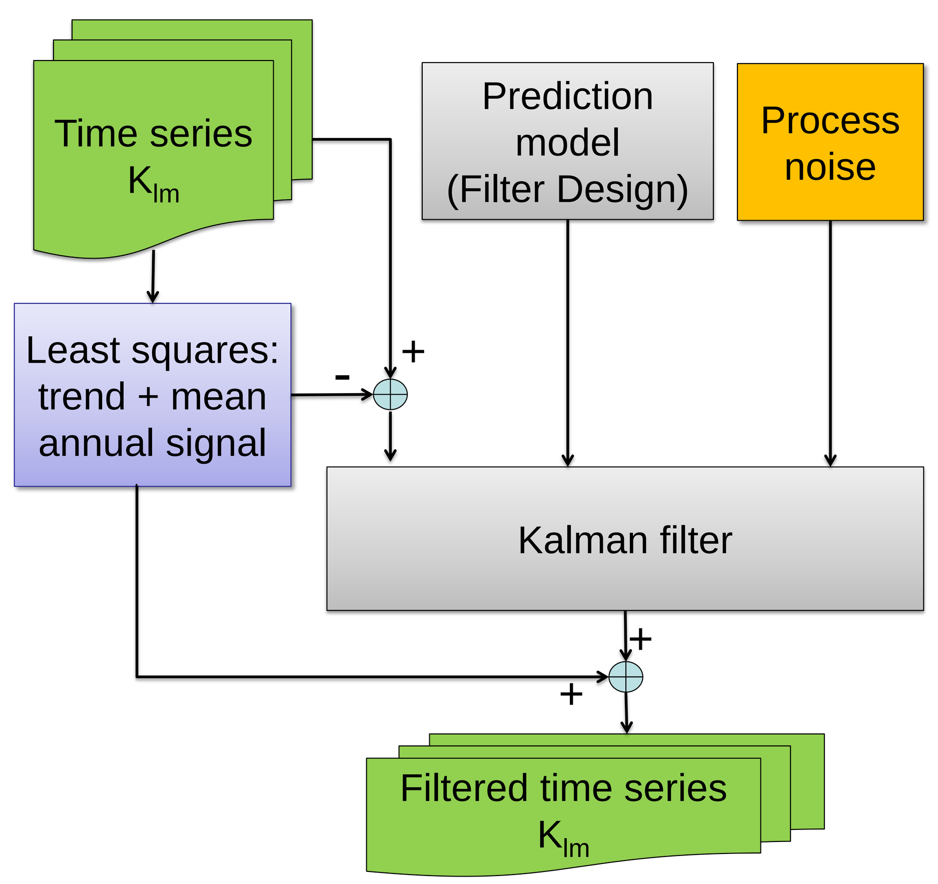

Figure 1: Scheme of the Kalman-Filtering

Sensitivity of GOCE to time-variable gravity

AIUB tested the sensitivity of GOCE to temporal gravity field variations by (1) derivation of monthly solutions and (2) by estimation of mean annual amplitudes from residuals over the entire data range (2009-2013). Both show that GOCE is sensitive to the TVG and thus is suitable for the combination with other hl-SST mission data.

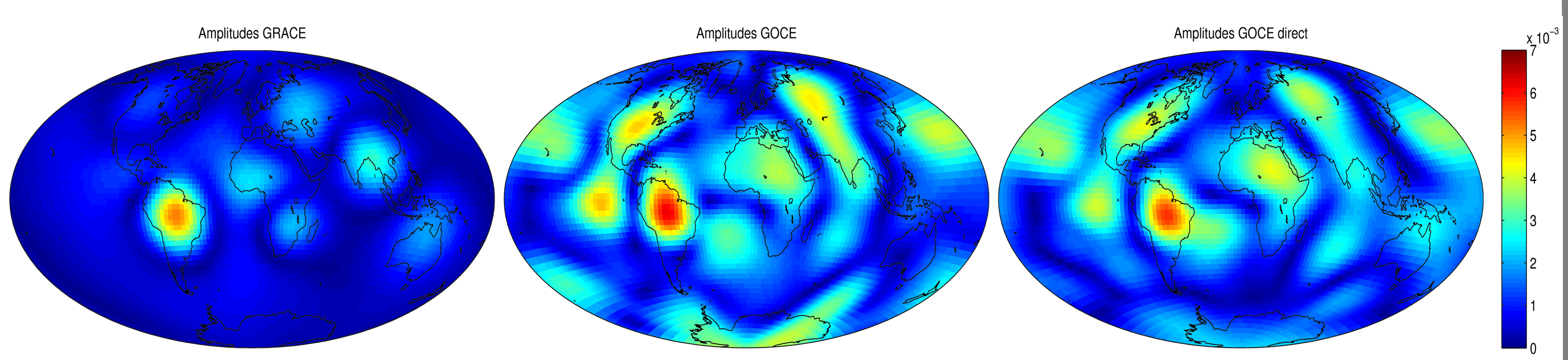

Figure 2: Amplitude in [mm] geoid height of the annual signal of GRACE (left), GOCE via monthly solution (middle) and GOCE via estimation (right); Gaussian smoothing with 1500km radius has been applied. Results available by contacting AIUB.

Mass estimates

From monthly solutions, the trend and the amplitude of the annual signal is determined. The comparison between the CHAMP-only hl-SST solution, the combined solution and GRACE shows vast improvements for the combined solution.

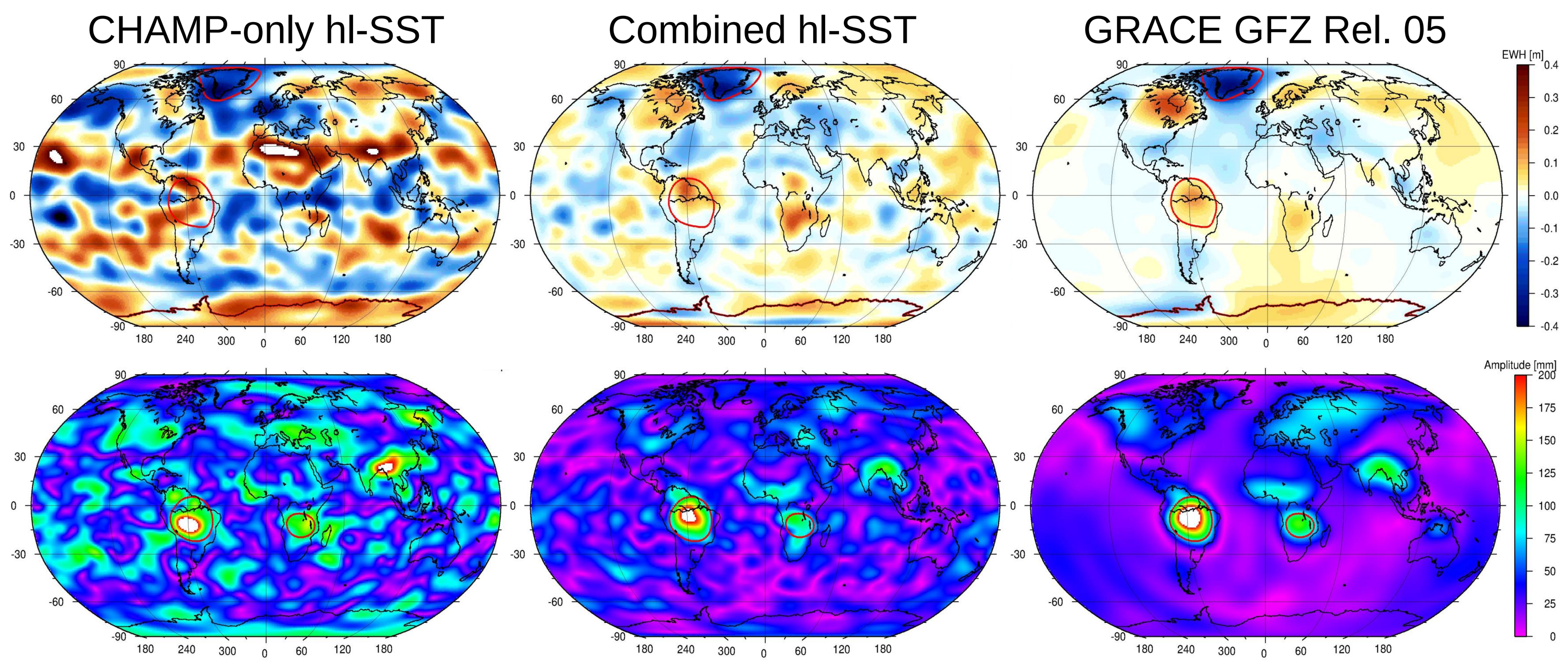

Figure 3: Trend (top) and annual amplitudes (bottom) of mass estimates derived from CHAMP-only (left), combined (middle) and the GRACE GFZ Rel. 05 (right) solution; Leakage out correction according to Baur et al. (2009) has been applied; Solutions have been filtered with a Gaussian 750km radius filter.

Area	Filter radius	GRACE GT/yr	CHAMP-only GT/yr	Difference to GRACE in %	Combined GT/yr	Difference to GRACE in %
Greenland	1000 km	-239 ± 9	-261 ± 8	7	-208 ± 8	13
	750 km	-238 ± 7	-255 ± 7	9	-218 ± 7	8
Amazon	1000 km	90 ± 18	120 ± 9	33	95 ± 11	6
	750 km	92 ± 17	128 ± 9	39	96 ± 10	4
Antarctica	1000 km	52 ± 16	250 ± 21	481	42 ± 20	19
	750 km	50 ± 14	247 ± 20	494	39 ± 19	22

Hydro-meteorological comparison

Storage mass changes derived from the combined solution and GRACE are compared to the difference of vertical integrated moisture flux divergences (ERA-INTERIM) and river discharge (GPCC). High correlations for the combined solution are achievable by hl-SST.

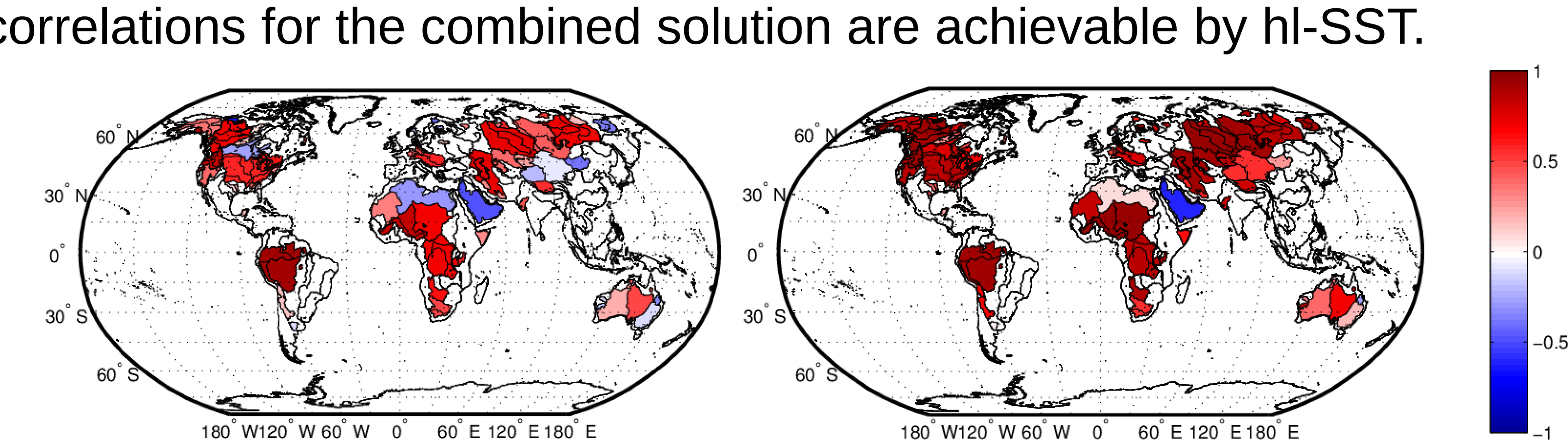

Figure 4: Correlation between storage mass changes derived from hydro-meteorological data and the combined solution (left) and GRACE GFZ Rel.05 (right)

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Glacial Isostatic Adjustment

The quality of the combined solution allows to test the applicability to GIA investigations. For this, gravity values are computed on a 1°×1° grid for each monthly solution in Scandinavia and North America using a 1000-km Gaussian filter. The linear trend is estimated together with a constant, the annual and a 2.5-yr periodicity and compared to estimates from the GRACE GFZ Rel. 05 solution. For the latter, a 161-d and 3.7-yr periodicity (S2 and K2 tides, Ray et al., 2003) is also co-estimated.

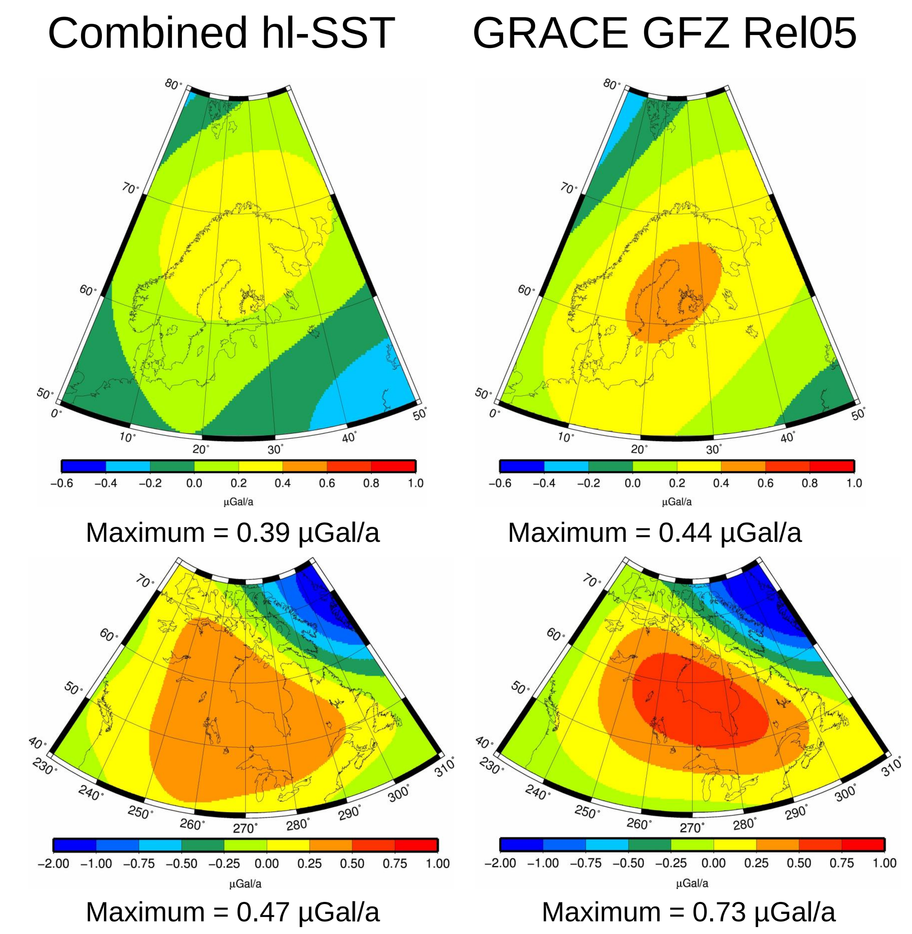

Figure 5: GIA pattern for the combined hl-SST solution (left) and for GRACE (GFZ, Rel. 05, right) for Scandinavia (top) and North America (bottom)

The combined hl-SST solution shows similar pattern but amplitudes are generally too small which indicates over-smoothing. The maximum in Scandinavia is further northeast compared to GRACE which does not agree with current knowledge. In North America the maximum is in James Bay whereas the GRACE solution is in south-western Hudson Bay. Thus, the combined solution is not yet giving acceptable results but the achieved solution is better than anything before derived from hl-SST observations.

Summary

- Combining hl-SST observations of several satellites improves estimates of the time-variable gravity field compared to a single satellite solution.
- Results converge to GRACE estimates but at a reduced spatial scale. Typically Gaussian filtering of 750 km is necessary.
- Mass estimates show a difference of (only) up to 22% for Greenland, the Amazon basin and Antarctica. Correlations increase compared to a CHAMP-only solution. GIA investigations remain difficult.

References

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