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Combined GRACE / SLR monthly gravity field solutions

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Introduction

GRACE K-Band is highly sensitive to gravity field variations at low to medium spherical harmonic degrees. But for very low degrees the results are affected by aliasing from slowly varying geophysical signals or tides (Seo et al, 2008). Especially C_{20} shows a spurious signal at a 160 day period. These aliasing effects can be mitigated by the combination of GRACE data with other satellite data sensitive to the gravity field variations, e.g., from Satellite Laser Ranging (SLR).

GRACE + SLR

It has been common practice to replace C_{20} in GRACE gravity fields by SLR-derived values (Cheng and Ries, 2007). Combined GRACE / SLR solutions including SLR observations to LAGEOS were generated by GRGS (Bruinsma et al, 2010). Lately Sośnica (2014) and Sośnica et al. (2015a, b) showed that a gravity field solution from up to nine dedicated SLR satellites (LAGEOS 1 and 2, Starlette, Stella, AJISAI, LARES, Larets, BLITS and Beacon-C) shows sensitivity to temporal gravity field variations at least up to degree 6. At AIUB these SLR solutions were combined with GRACE GPS and K-Band at the level of normal equations with a relative weight of 1e-10.

GRACE GPS + SLR

Since 2011 data gaps are occuring in the GRACE K-Band data due to the aging of the batteries and consequently a shutdown of the onboard accelerometers and K-Band instrument during phases of extended shadow passes (occurring every 160 days). During these times only GPS and attitude observations are available. Lately the sensitivity of monthly gravity fields derived from LEO GPS observations to temporal variations has been studied widely (e.g., Weigelt et al, 2014). GPS-derived gravity fields may also be used to bridge the short K-Band gaps of GRACE. We therefore also derived monthly GRACE GPS-solutions and GPS / SLR combinations to show, if the GPS solutions may benefit from the combination with SLR data. The relative weight of SLR in this combination is 1e-2.

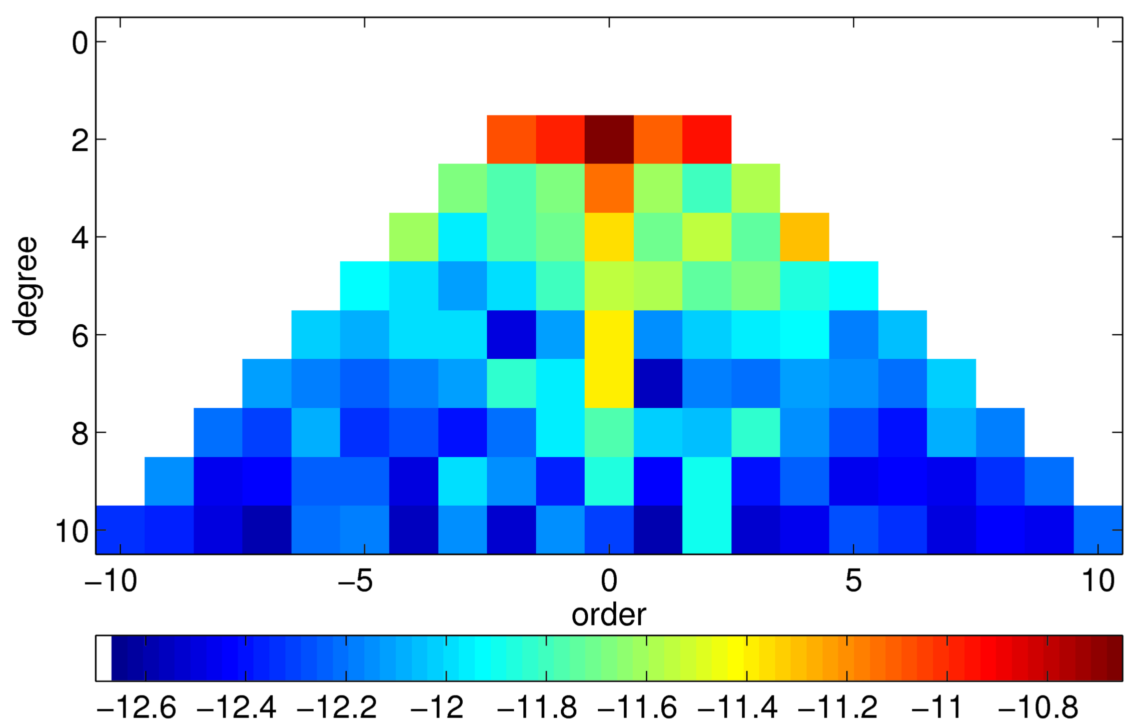

Fig 1: Impact of SLR on monthly GRACE GPS / K-Band solutions 2003-2013 (in terms of the RMS of the differences GRACE only - SLR only per coefficient).

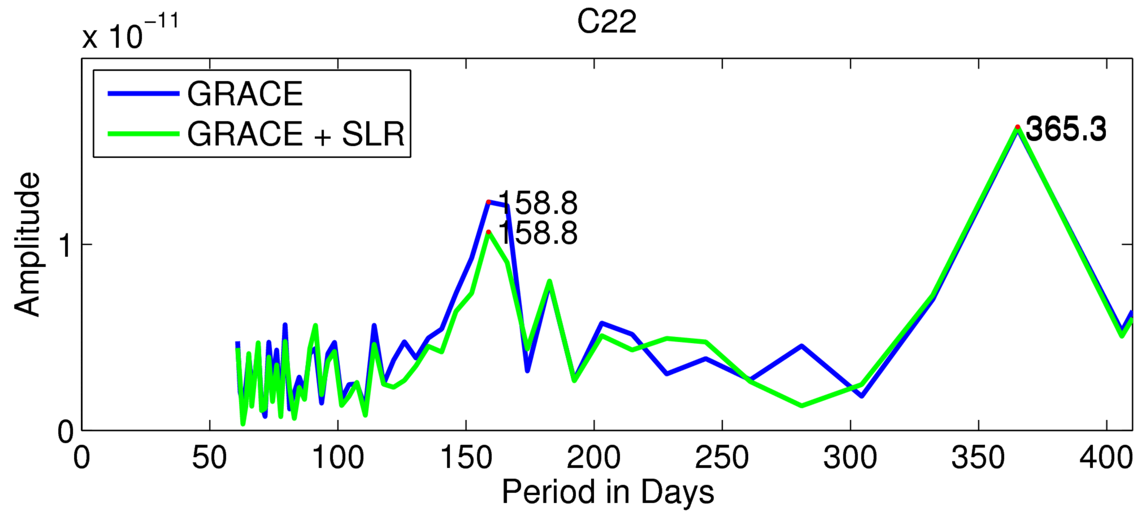

Fig 2: Spectra of monthly C_{22}-values from 2004-2013. The spurious peak around 160 day period is slightly reduced by the combination.

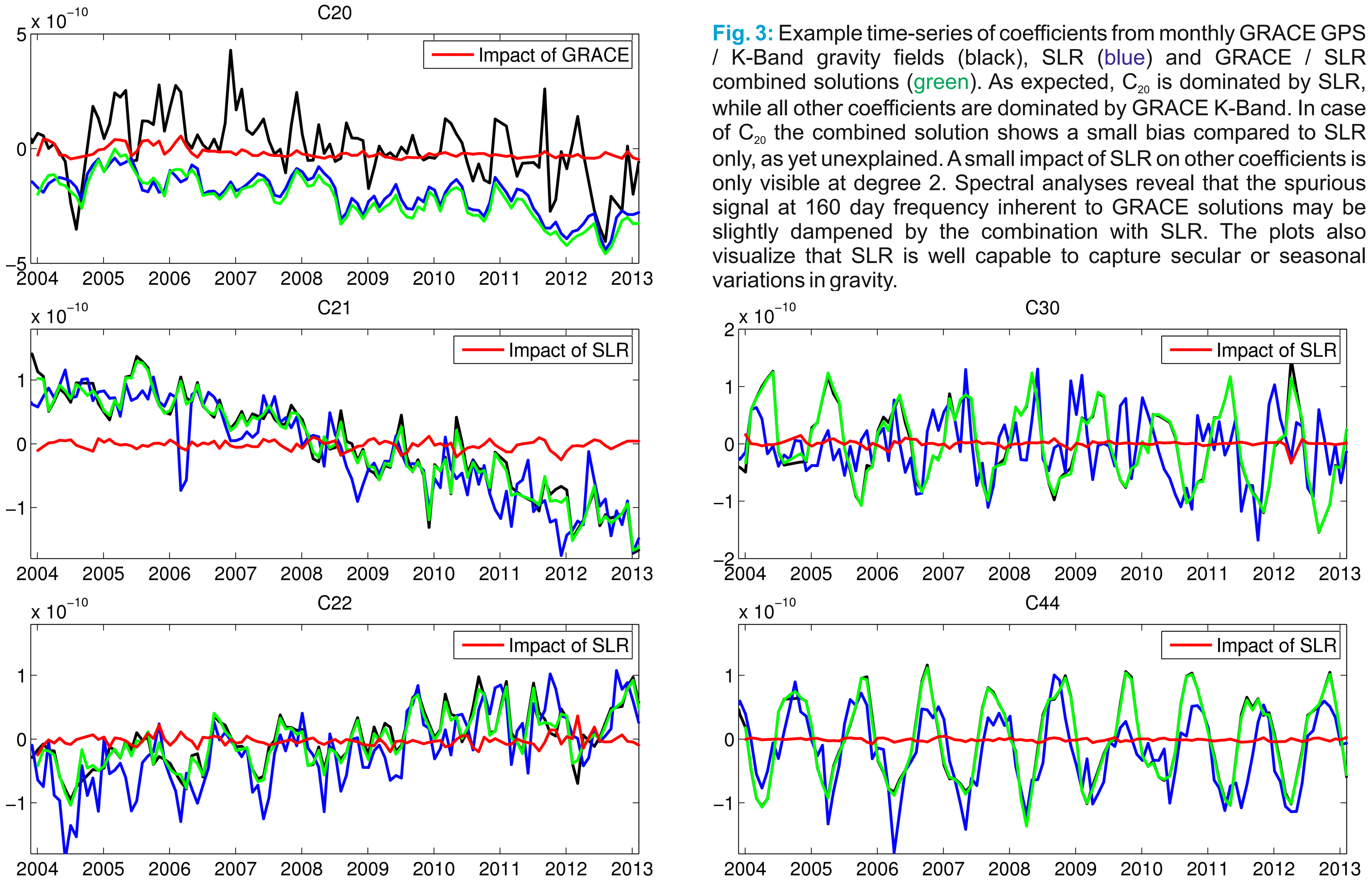

Fig. 3: Example time-series of coefficients from monthly GRACE GPS / K-Band gravity fields (black), SLR (blue) and GRACE / SLR combined solutions (green). As expected, C_{20} is dominated by SLR, while all other coefficients are dominated by GRACE K-Band. In case of C_{20} the combined solution shows a small bias compared to SLR only, as yet unexplained. A small impact of SLR on other coefficients is only visible at degree 2. Spectral analyses reveal that the spurious signal at 160 day frequency inherent to GRACE solutions may be slightly dampened by the combination with SLR. The plots also visualize that SLR is well capable to capture secular or seasonal variations in gravity.

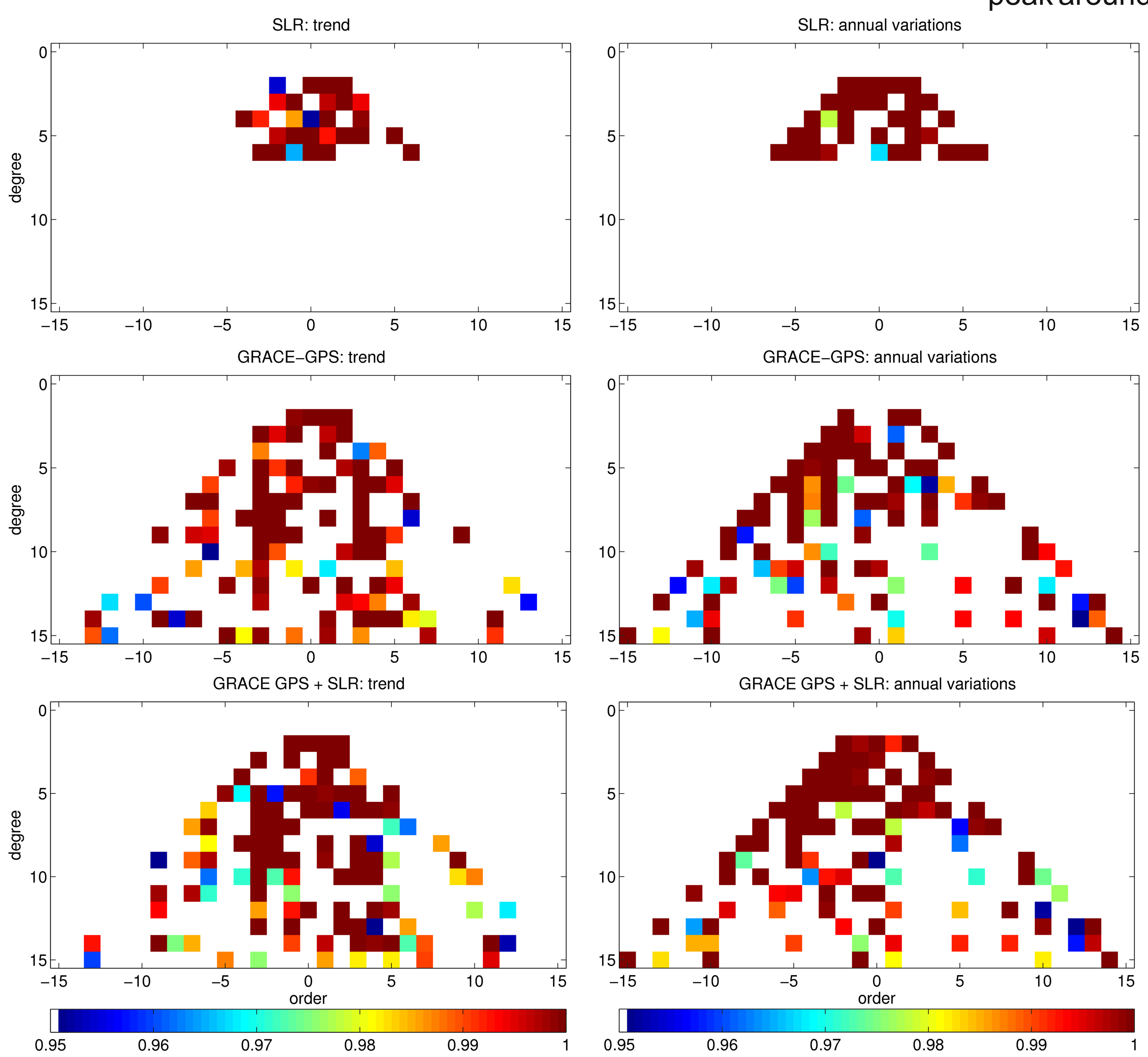

Fig. 4: Significance of secular and annual variations per coefficient. GPS is sensitive mainly at low order and sectorial coefficients. SLR does not only contribute to the low degree coefficients, but also increases sensitivity beyond degree 6 due to the different inclination of the SLR satellite orbits that help to de-correlate the coefficients.

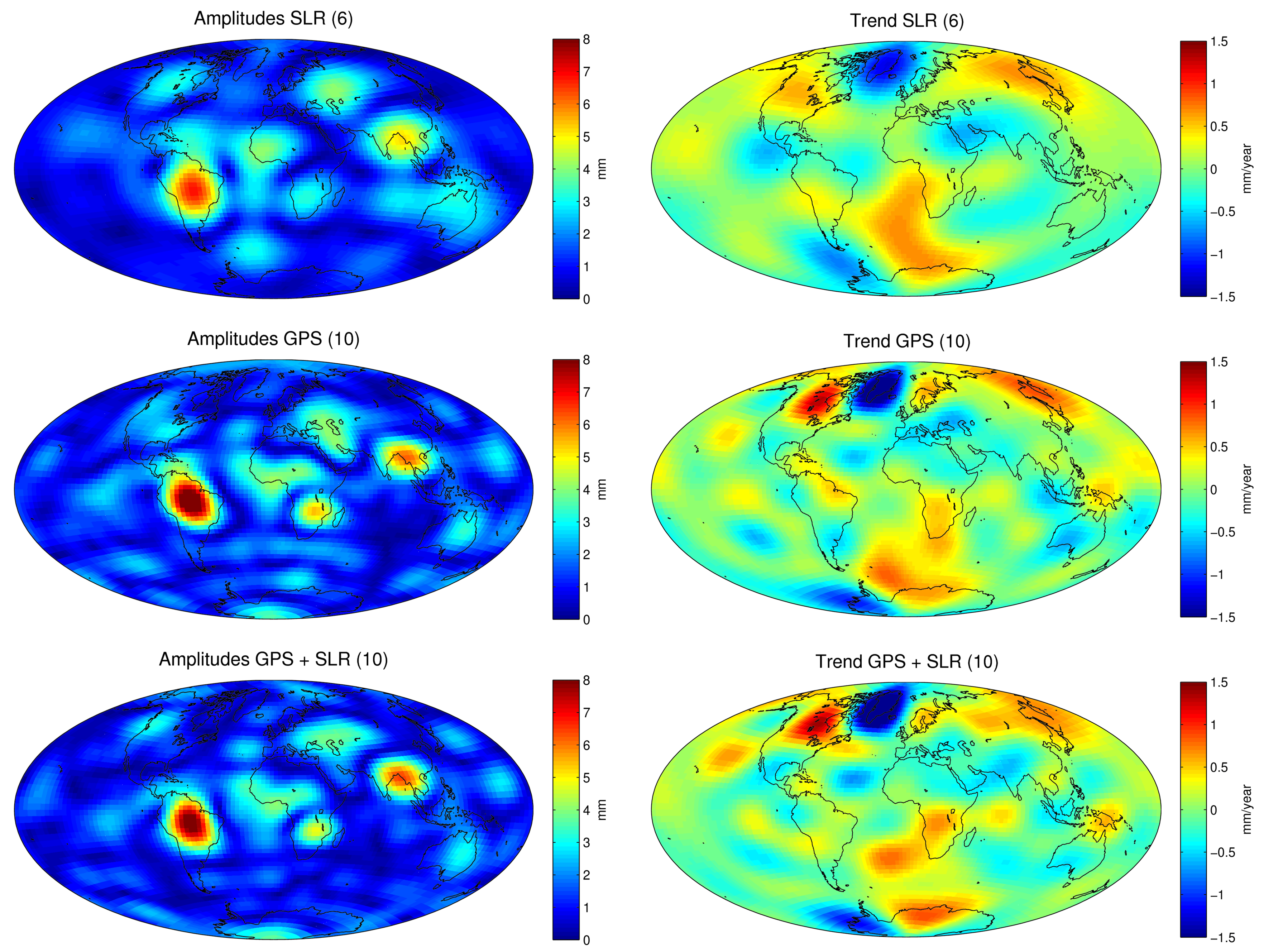

Fig. 5: Amplitude of annual variations that were fitted to the time series of monthly gravity fields (left) and trends derived from the period 2004 to 2013 (right), both in geoid heights. The combination of GPS and SLR leads to a slight damping of the observed signals, but also to an improved localization and a reduction of noise.

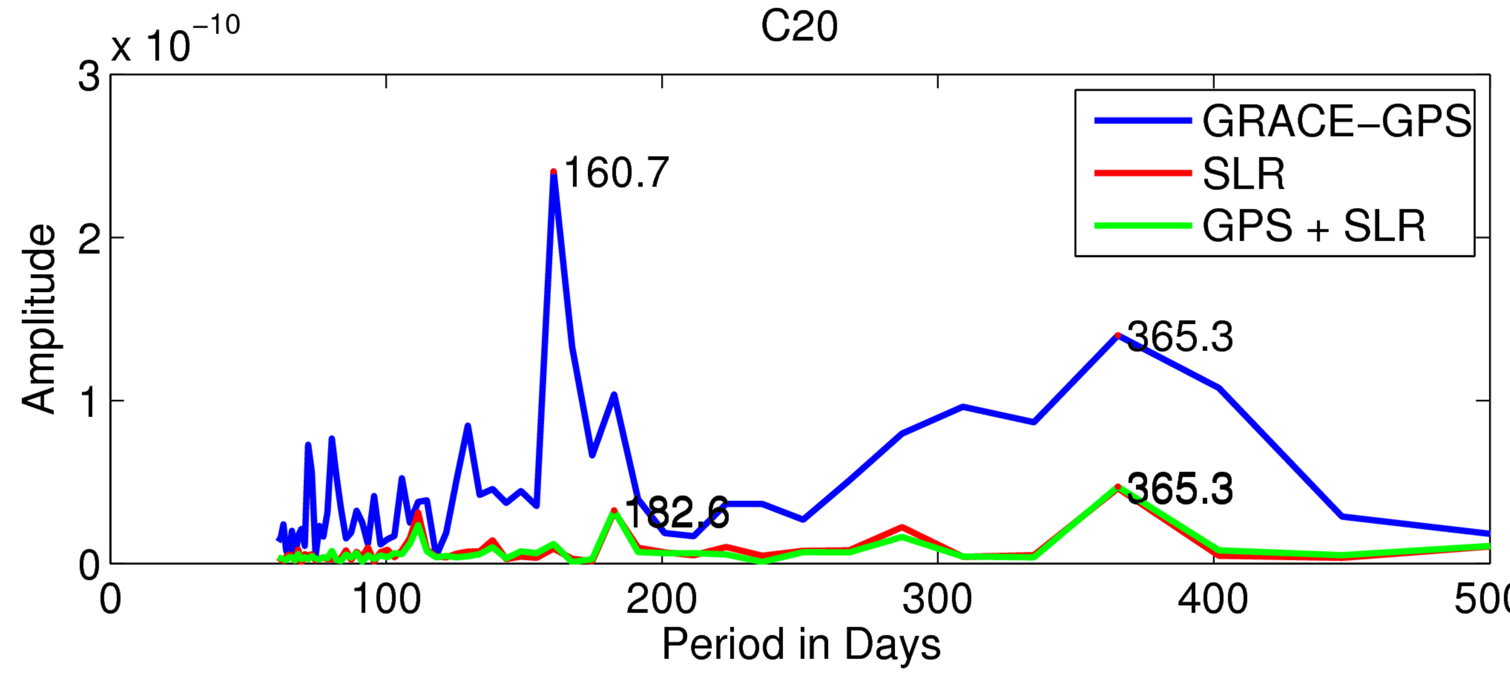

Fig 6: Spectra of monthly C_{20}-values from 2003-2013. GRACE solutions, in this case from the GPS data only, are affected by spurious signal at 160d-period that is cured by the combination with SLR.

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