On computation of atmospheric de-aliasing products and its impact on GRACE-derived mass estimations

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Abstract

Temporal aliasing caused by incomplete reduction of background models is still a factor that affects the quality of the gravity field solutions derived from GRACE products. Our study addresses: (i) the computational aspect of the atmospheric de-aliasing (AD) products (**de-aliasing aspect**), and (ii) the biases caused by existing jumps in the atmospheric part of GRACE-AOD1B on GRACE-derived mass estimations (**signal separation aspect**). Regarding to (i), we introduce an improved 3-dimensional (3D) integration approach (ITG-3D) to compute the AD products (Forootan et al., 2013). Geometrical, physical and numerical aspects of the improvements (in ITG-3D) are assessed on de-aliasing of the GRACE products, by computing monthly solutions using different assumptions within the 3D integration.

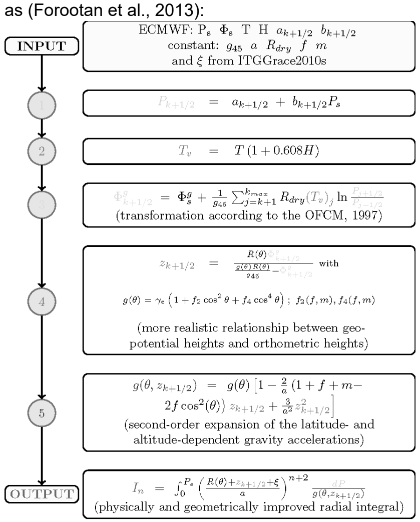
Regarding to (ii), in fact, two spurious jumps exist in the atmospheric part of the GRACE-AOD1B (January-February of 2006 and 2010), as a result of the vertical level and horizontal resolution changes in the ECMWF operational model. These jumps cause a bias in the estimation of mass changes from GRACE time-variable level-2 products. Thus, an improved and more long-term consistent AD product (ITG3D-ERA-Interim), is computed covering January 2003 to July 2011 (http://www.igg.uni-bonn.de/apmg/index.php?id=itg3d_erainterim). The differences of ITG3D-ERA-Interim and GRACE-AOD1B are processed similar to the GRACE level-2 post-processing. The possible biases are evaluated over the 33 world largest river basins, along with Greenland and Antarctica ice sheets (Forootan et al., 2014).

Method: 1. ITG-3D Integral Approach for Computing Atmospheric De-aliasing Products

Atmospheric De-aliasing products consist of a set of 6-hourly series of spherical harmonic coefficients ($\Delta C_{nm}(t)$ and $\Delta S_{nm}(t)$, t: time) corresponding to total atmospheric mass changes:

$$\left.\begin{matrix}\Delta C_{nm}(t)\\ \Delta S_{nm}(t)\end{matrix}\right\} = \frac{\left(1+k'_n\right)a^2}{(2n+1)M}\iint_\sigma \Delta I_n(\theta,\lambda,t)P_{nm}(\cos(\theta))\left\{\begin{matrix}\cos(m\lambda)\\ \sin(m\lambda)\end{matrix}\right\}d\sigma$$

k'_n: degree dependent load Love number, a: the semi major axis of the reference ellipsoid, M: mass of the Earth, θ and λ: colatitude and longitude, P_{nm}: the fully normalized associated Legendre polynomials, and σ: surface element. $\Delta I_n(\theta,\lambda,t) = I_n(\theta,\lambda,t)$ - $\bar{I}(\theta,\lambda)$: represents a vertical integration of atmospheric mass (density), where $\bar{I}$ represents a mean field. An improved vertical integration (ITG-3D) is formulated as (Forootan et al., 2013):



2. Impact of Using ITG-3D Derived Atmospheric De-aliasing Products on a Monthly GRACE Solution

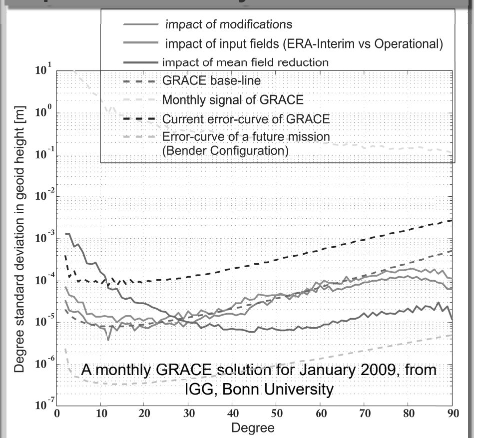
Geometrical and Physical improvements within the integral:

$$\text{IT-G3D: } I_n(\theta,\lambda,t) = \int_0^{P_s}\left(\frac{R(\theta)+z_{k+1/2}+\xi(\theta,\lambda)}{a}\right)^{n+2}\frac{dP(\theta,\lambda)}{g(\theta,z_{k+1/2})}$$

$R(\theta)$: ellipsoidal radius, $\xi(\theta,\lambda)$: geoid heights from ITG-GRACE2010s, $g(\theta,z_{k+1/2})$: latitude- and altitude-dependent gravity accelerations, P_s: surface pressure, and k: pressure levels.

Numerical improvements:
Adding sub-intervals for computing $\Delta I_n(\theta,\lambda,t)$
Using the Gauss-Legendre Quadrature approach for estimating spherical harmonics (Forootan et al., 2013).

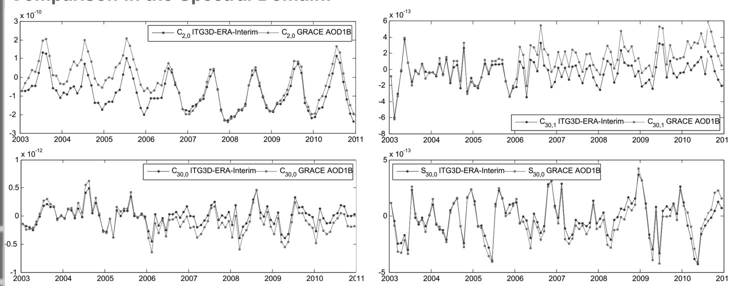
Results – De-aliasing Aspect Impact on a Monthly GRACE Solution



➢ The impact of ITG-3D improvements can be seen in GRACE monthly products up to degree and order ~ 40.

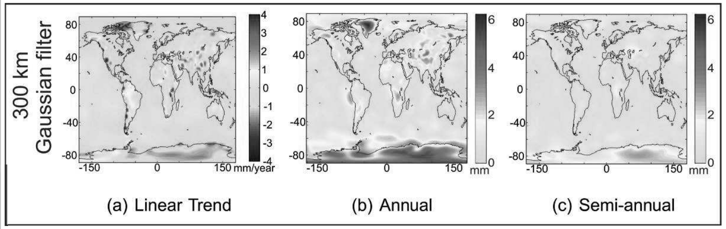
Results – Signal Separation Aspect

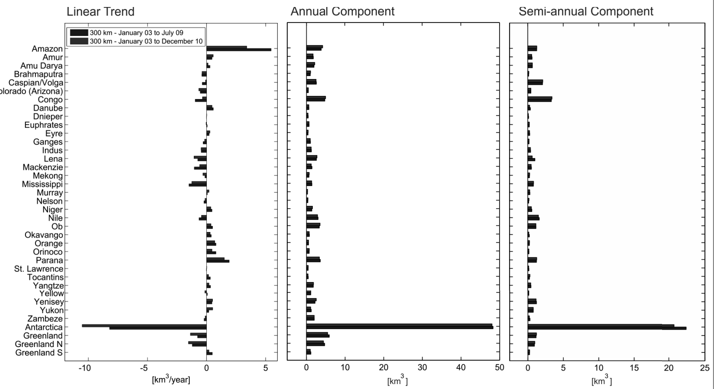
Comparison in the Spectral Domain:



➢ Existing jumps in the GRACE-AOD1B product affects all spectra of the GRACE-derived mass estimations, making the separation of the bias difficult.

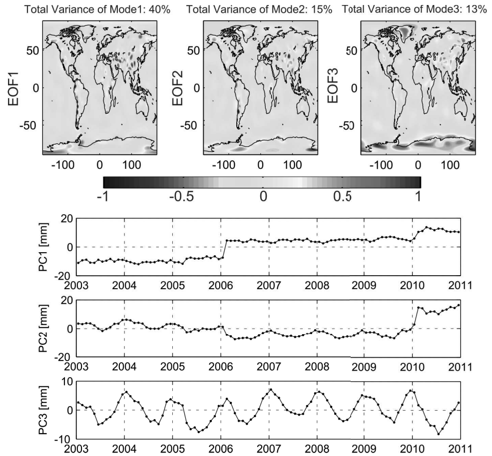
The Linear Rate, Annual and Semi-annual Components of Mass Biases Caused by Two Spurious Jumps in GRACE-AOD1B Products:





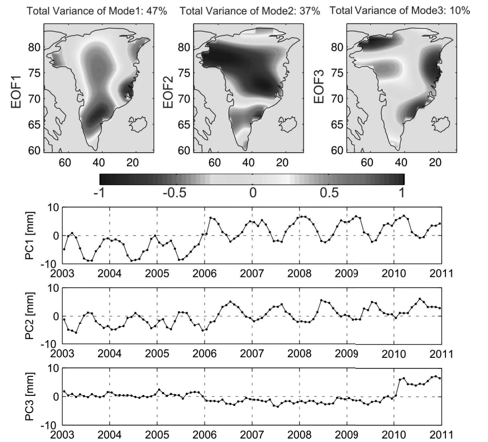
➢ Considerable trend and seasonal amplitude biases are found over the Central Asia, the west coast of South America, as well as parts of Greenland and Antarctica ice sheets.

Local Scale Impact of the Jumps on GRACE-derived Mass Estimations:



➢ Local impact reaches up to 2 cm total water storage over the Central Asia and Antarctica, see Jan. 2006 of PC1 and PC2.

Local Scale Impact of the Jumps on GRACE-derived Mass Estimations over Greenland



➢ Over Greenland, the bias is mainly distributed over the sub-basins.

Conclusions and Outlooks

De-aliasing investigations indicate that the suggested ITG-3D approach, which involves a more realistic parameterization of the Earth within a numerically and physically improved 3D integration approach, performs better than previous methods for computing atmospheric de-aliasing products suited to future missions (Forootan et al., 2013). **Signal separation investigations** indicate a considerable difference in total atmospheric mass derived from the two ITG3D-ERA-Interim and GRACE-AOD1B products over some of the mentioned regions. We suggest that future GRACE studies consider these through updating uncertainty budgets or by applying corrections to estimated trends and amplitudes/phases (Forootan et al., 2014). **Outlook:** the local impacts of using regionally downscaled/assimilated atmospheric models such as the COSMO-EU and the CORDEX-Reanalysis on the de-aliasing of satellite gravimetry observations will be subjected to further research.

References

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