MASS CHANGE DETECTION FROM SWARM TIME-VARIABLE GRAVITY

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Introduction

We investigate the capability of ESA’s magnetometry mission SWARM (supposed to be launched in autumn 2013) for mass variation detection in the system Earth. Since the three SWARM satellites are equipped with high-quality GPS (Global Positioning System) receivers and accelerometers, orbit analysis from high-low Satellite-to-Satellite Tracking (hl–SST) can be applied for gravity field recovery. Within a series of closed-loop simulation studies we show that SWARM orbit data is supposed to have the quality to resolve long-wavelength features of the Earth’s gravity field, although the accuracy of a low–low SST mission like GRACE (Gravity Recovery And Climate Experiment) cannot be reached.

In a first step, models for mass variation in the hydrosphere, cryosphere and solid Earth are used to simulate the SWARM orbits. In a second step, we recover time-variable gravity by orbit analysis. Finally, we convert gravity changes to mass change and compare the results with the input models.

Simulation setup

Time-variable gravity: generated from a simulated data set according to Anselmi et al. (2011), including variations in atmosphere, ocean, hydrology (replaced by MERRA), ice and solid Earth in 6h–intervals. The overall simulation period is five years (2000–2004). The trend of the hydrology, ice and solid Earth contributions, as well as of their sum (HIS), are shown below.

Orbit design: according to ESA (2004), including orbit decay. Colored orbit noise was considered, which approximately reproduces the CHAMP (CHAllenging Minisatellite Payload) results when using only one SWARM satellite, denoted as ‘nominal noise’ here. Additional low–frequency noise models were investigated in order to account for both possible improvement (‘optimistic noise’ and possible degradation (‘pessimistic noise’) of the SWARM orbits compared to CHAMP.

Orbit analysis: the so-called point-wise acceleration approach (Reubelt 2009) was adopted to retrieve monthly gravity fields from the simulated SWARM orbits. This approach has been successfully applied to CHAMP and GOCE orbit analysis.

Mass variation patterns

Monthly-averaged HIS input fields as well as the recovered monthly gravity fields from orbit analysis were converted to mass change signals (Gaussian smoothing with a radius of 1000 km applied). Trends (in terms of equivalent water height) and annual variations have been determined on a 1° × 1° grid (see figure below; the delineated areas indicate the regions with dominating signal in the smoothed HIS pattern).

Orbit analysis (noise-free)

Orbit analysis (nominal noise)

Mass variation numbers

Estimated mass trends and annual amplitudes within specific regions of interest (Gaussian smoothing with a radius of 1000 km applied).

<table>
<thead>
<tr>
<th>Region</th>
<th>Trend amplitude</th>
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<tbody>
<tr>
<td>Greenland</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td></td>
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<tr>
<td>Amazon</td>
<td></td>
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<tr>
<td>Mekong</td>
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<td>Okavango</td>
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<td>Parana</td>
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Greenland mass balance

Spatial averaging in terms of Gaussian smoothing causes mass-variation signal to leak out the region of interest. In order to get change rates that are not affected by spatial averaging, we applied point mass modelling (Baur and Sneeuw 2011) to recover ‘real’ mass balance over Greenland.

Conclusions

SWARM and GRACE gravity field solutions overlap in the very long wavelength spectrum, which is an indicator for the sensitivity of hl–SST to time–variable signals. The estimation of mass trends and annual variations is only slightly affected by aliasing effects; orbit errors are the main driver for the quality of the spatial patterns, and spatially smoothness of the estimates. Importantly, some strong signals (such as the trends over Greenland and Antarctica) tend to be ‘robust’ against the adopted orbit noise. Most signals, however, wander spatially and/or change significantly in magnitude. The mass balance estimates over Greenland show a very good agreement between the simulated variations and the recovered signal; this holds for both the spatial patterns and the basin–wide change rates.

We conclude that SWARM is likely to be able to detect time-variable gravity. Therefore, we expect that the mission will provide valuable information to fill the potential gap between GRACE and GRACE follow-on.

Acknowledgements & References

We thank C. Lorenz (Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology) for providing time-variable gravity fields generated by the MERRA model. We used this data to substitute the hydrological gravity fields (PCR-GLOBEM2) of the ADHS data set (Anselmi et al. 2011), which is due to the large and unrealistic trends produced by the AHOIS data set.


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