On the capability of non-dedocated GPS-tracked satellite constellations for estimating mass variations: case study SWARM


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GRACE and GRACE Follow-On

low-low-SST

- K-Band (Laser)
- GPS
- Accelerometer

~ 4-5 year data gap (?)

IAD Scientific Assembly 2013, Potsdam, Germany, Sept 1-6, 2013
Other gravity field missions

high-low SST

GOCE

SWARM

(COSMIC I/II)

SWARM

GOCE

GFO

GRACE

IAD Scientific Assembly 2013, Potsdam, Germany, Sept 1-6, 2013
CHAMP reprocessing

GPS positions
- 10 s sampling
- empirical absolute antenna phase center model

Approach
- acceleration approach
- no regularization and no a priori information

Kalman filter:
- prediction model:
  - trend
  - mean annual signal

(source: Weigelt et al. 2012)
CHAMP results – time series

KOUR, Brazil

CUSV, Thailand

(source: Weigelt et al. 2012)
CHAMP results – time series

Equivalent water height [mm]

Sermilik, Greenland

HYDE, India

(source: Weigelt et al. 2012)

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Change rates [Gt/yr] from point mass approach (no GIA correction applied)

(source: Baur (2012))

<table>
<thead>
<tr>
<th>Spectral resolution</th>
<th>GRACE</th>
<th>CHAMP</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>-223</td>
<td>-267</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>-222</td>
<td>-252</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>-218</td>
<td>-242</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>-203</td>
<td>-211</td>
</tr>
</tbody>
</table>
SWARM orbit parameters

satellite A: \( h \approx 455 - 330 \text{ km} \)
\[ I = 87.3^\circ; \ M_0 = 0^\circ; \ \Omega_0 = 0^\circ \]

satellite B: \( h \approx 455 - 330 \text{ km} \)
\[ I = 87.3^\circ; \ M_0 = 0.5^\circ; \ \Omega_0 = 1.4^\circ \]

satellite C: \( h \approx 530 - 515 \text{ km} \)
\[ I = 88^\circ; \ M_0 = 0^\circ; \ \Omega_0 = 0^\circ \]
Trends of input mass fields

hydrology (H) trend

solid Earth (S) trend

ice (I) trend

combined (HIS) trend

time-period J2000 - J2004; $L_{\text{max}} = 60$; AOHIS fields from Gruber et al. 2011, H from MERRA
maximum degree: $L = 60$
sampling-time: $\Delta t = 5$ s
background errors: 30% of AOHIS
tidal error: EOT08a – GOT4.7
orbit noise: $\sigma_X = 4$ cm, coloured
Gaussian smoothing (spatial averaging) with a radius of 1000km applied
SWARM basin mass trends

Mass trends of selected basins

Greenland (GRE)
Canada (CAN)
Amazon (AMA)
Antarctica (ANT)
West-Antarctica (WAN)
Mekong (MEK)
Okawango (OKA)
Congo (CON)
Parana (PAR)
SWARM basin mass trend errors

Mass trend errors of selected basins

- Greenland (GRE)
- Canada (CAN)
- Amazon (AMA)
- Antarctica (ANT)
- West-Antarctica (WAN)
- Mekong (MEK)
- Okawango (OKA)
- Congo (CON)
- Parana (PAR)

Trend relative to mean fields (%)
Annual amplitudes of selected basins

- Amazon (AMA)
- Mekong (MEK)
- Eurasia (EUR)
- Australia (AUS)
- Okawango (OKA)
Amplitude errors of selected basins

Amazon (AMA)
Mekong (MEK)
Eurasia (EUR)
Australia (AUS)
Okawango (OKA)
• SWARM (CHAMP) and GRACE solutions overlap for low degrees
  → sensitivity of hl-SST to long wavelength time-variability

• CHAMP results demonstrate that mass trend estimation is possible from hl-SST

• basins with strong signals (e.g. GRE, CAN, ANT) show in our SWARM simulations little affected spatial patterns and normal signal strength
  → estimation within 10% - 30% (Greenland: 10%).

• Kalman-filtering is able to reduce errors of solutions with larger error source (e.g. CHAMP, SWARM ‘basis + low freq. noise’), but might also reduce signals, especially for scenarios of lower noise.

• We conclude that SWARM is likely able to see time variable gravity field patterns, especially where the signals are strong.
  → valuable source of information for GRACE/GFO gap filling.


We thank C. Lorenz (Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology) for providing time-variable hydrology gravity fields generated by the MERRA model.