Hydrological mass changes inferred from high-low satellite-to-satellite tracking data

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GRACE und GRACE Follow-On (GFO)

- K-Band (Laser)
- GPS
- Accelerometer

~ 4-5 year data gap (?)
Other gravity field missions

High-low

GPS - satellites

SST - bl

mass anomaly

Earth

GOCE

SWARM

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year


SWARM

GOCE

GFO

GRACE
CHAMP
GPS positions:
• 10 s sampling
• empirical absolute antenna phase
center model

Approach:
• acceleration approach
• no accelerometer data used
• no regularization and no *a priori* model / information

Postprocessing with a Kalman filter:

1. Time series $K_{lm}$
2. Kalman filtering (Davis et al. 2012)
3. Trend + mean annual signal
4. Prediction model
5. Process noise
6. Filtered time series
Filtered monthly gravity field solution
CHAMP vs. GRACE

CHAMP:
- Trend
- Amplitude
- Phase

GRACE:
- Trend
- Amplitude
- Phase

750km
EVALUATION WITH HYDROMETEOROLOGY
Mass change as a hydrological observable

\[ P - ET_a - R = \frac{\partial S_H}{\partial t} \]

\[ \nabla \cdot \bar{Q} = \text{divergence of vertically integrated moisture flux} \]

\[ \frac{\partial S_A}{\partial t} = -\nabla \cdot \bar{Q} - R \]

\[ \frac{\partial M}{\partial t} \]

\[ \text{hydrology} \]

\[ \text{geochemistry} \]

\[ \text{hydro-meteorology} \]

\[ \text{CHAMP} \]

\[ \text{GRACE} \]

\[ P = \text{precipitation} \]

\[ ET_a = \text{evapotranspiration} \]

\[ R = \text{runoff} \]
Mass estimate & correlation – 750km

RMS(dM/dt) / RMS(dS/dt), dM/dt from CHAMP (filtered with G750)

Correlation of dM/dt from CHAMP (filtered with G750) and dS/dt

RMS(dM/dt) / RMS(dS/dt), dM/dt from GRACE (filtered with G750)

Correlation of dM/dt from GRACE (filtered with G750) and dS/dt
Filter size for Amazon basin

Correlation of dM/dt from CHAMP and dS/dt from Hydro-meteorological data

Filter radius [km]

RMS (dM/dt)

RMS (dS/dt)

Amazon water storage changes from CHAMP and hydrometeorological data

[m/month]

2003 2004 2005 2006 2007 2008 2009 2010
“Optimal” filter radius is catchment and signal dependent (see Tourian 2013)
EVALUATION WITH GPS
Loading analysis - Amazon

Surface displacement - 450 km

- GPS
- CHAMP
- GRACE
- BRAZ
- KOUR

[Graph showing surface displacement over years from 2000 to 2012]
Loading analysis – South Africa

Surface displacement - 450 km

[Graph showing surface displacement over time]
Loading analysis – East Asia

Surface displacement - 450 km

GPS  CHAMP  LHAS

GRACE  YAKT

Year
Summary

• Time variable gravity field from high-low SST
• Long wavelength features
• Refinement in the processing possible/necessary
  – Spatial error pattern needs to be understood
• Filter dependency on catchment and application
  – Processing might include a beneficial smoothing!
• Remarkable agreement with hydro-meteorology and GPS

• Expectations for SWARM:
  – better GPS receiver
  – three satellites