Orbit and Gravity Field Solutions from Swarm GPS Observations

A. Jäggi[1], C. Dahle[2], D. Arnold[1], U. Meyer[1], J. van den IJssel[3]

[1] *Astronomical Institute, University of Bern, Switzerland*

[2] *German Research Centre for Geosciences, Potsdam, Germany*

[3] *Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands*

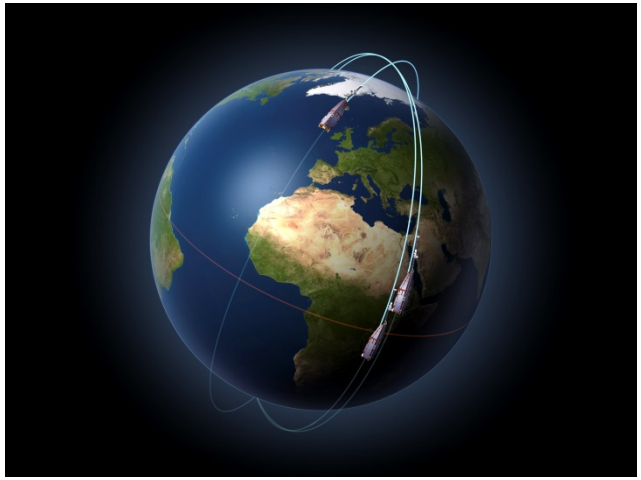
26th IUGG General Assembly

June 22–July 2, 2015

Prague, Czech Republic

The Swarm Mission

- **Orbit:**
  - Low Earth Orbiter; near-polar
  - Swarm-A/C: h=480-300 km, i=87.3°, 1.4° side-by-side sep.
  - Swarm-B: 530 km altitude, i=88°
  - 90° difference in orbital plane between lower pair and higher satellite after 3 years



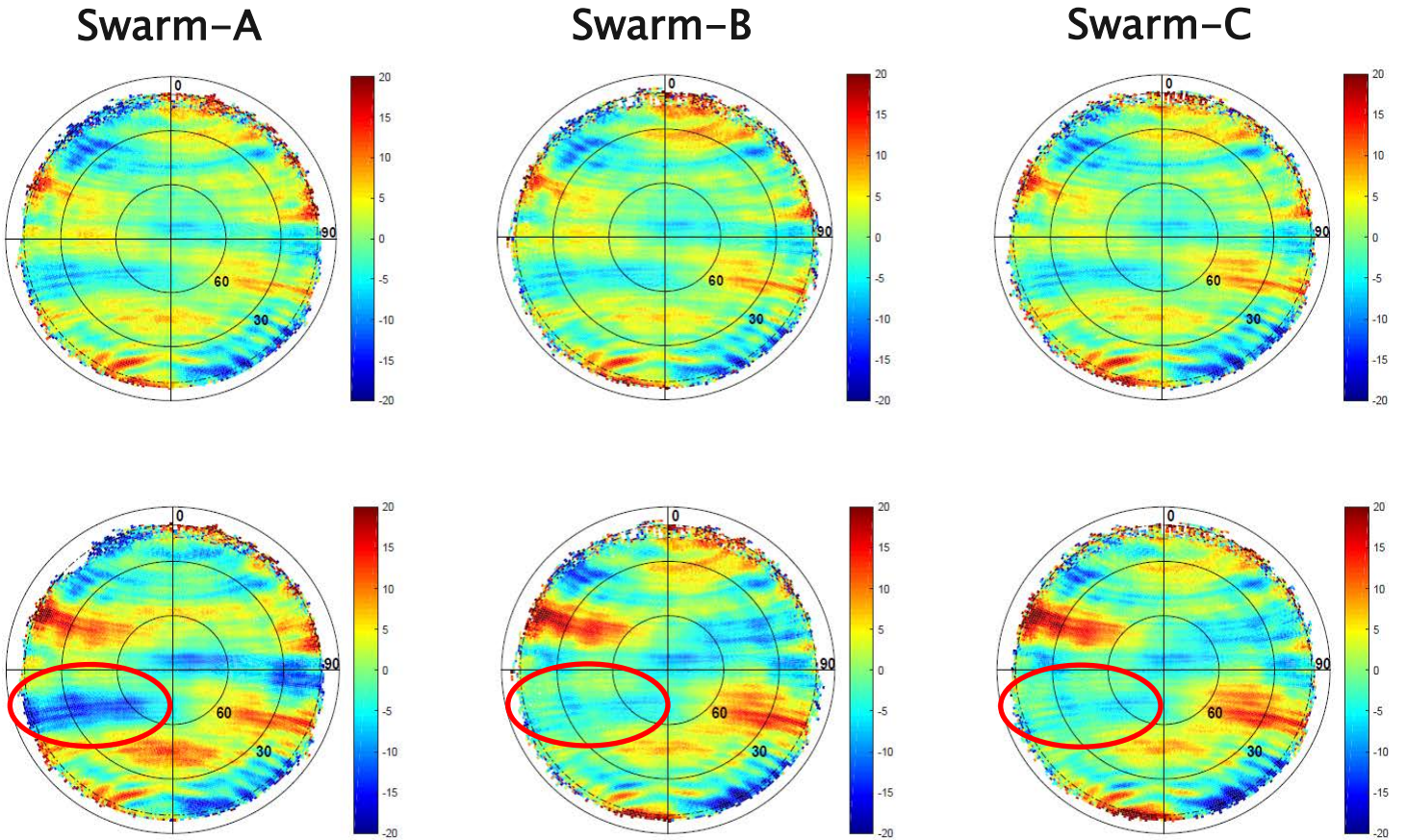
© ESA

- **Payload:**
  - Magnetometers, electric field instrument, GPS receiver, accelerometer, star-trackers, laser retro-reflector
- **Secondary mission objective:**
  - Measuring the Earth's gravity field (GPS hl-SST observing system)

Contents

- Swarm Kinematic Orbit Determination
  - In-flight antenna calibration
  - Ionosphere disturbances
- Static Gravity Field Recovery
  - Mitigation of systematic errors
  - Comparison with GRACE GPS hl-SST
- Time-Variable Gravity Field Recovery
  - Fit of annual signals
  - Analysis over the Amazon basin

Empirical Antenna Phase Center Variation Maps



"New" GPS data

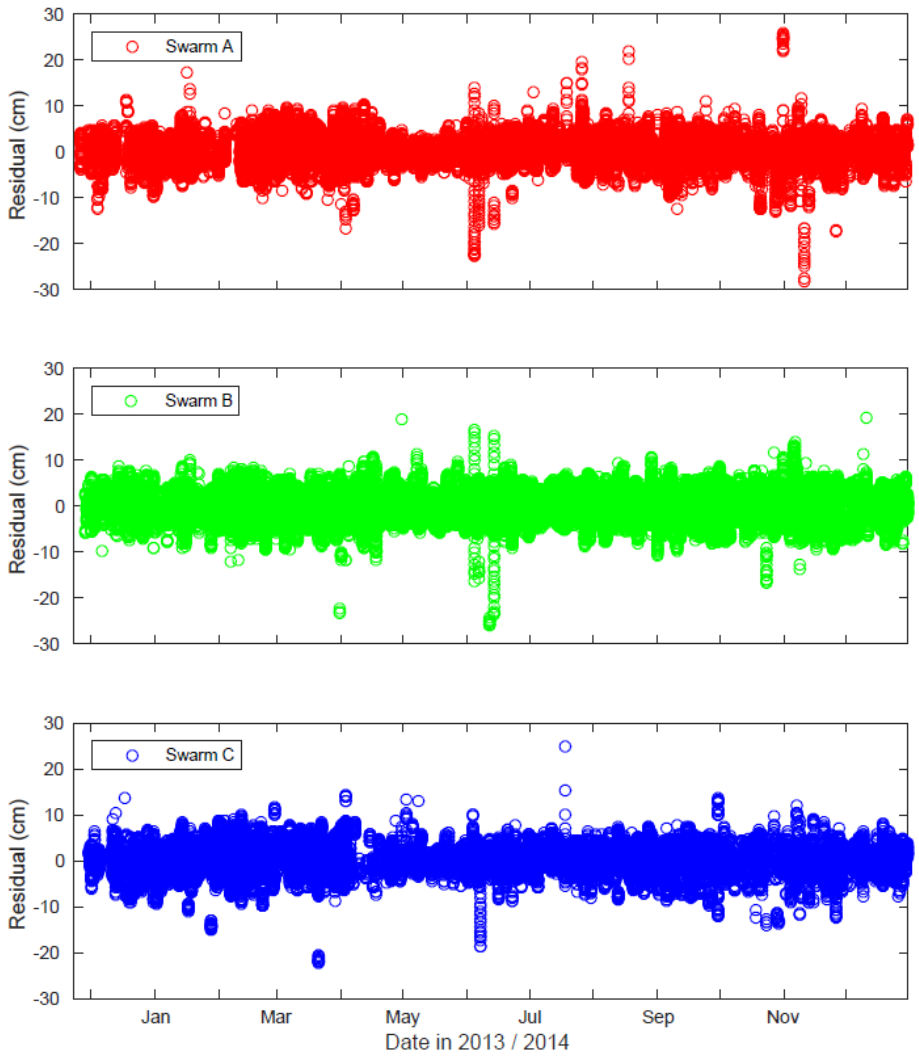
Similar maps

"Old" GPS data

Different maps

Differences in "old" GPS data may be compensated by a proper in-flight calibration and consequently do not affect the orbit and gravity results.

SLR Validation of Kinematic Swarm Orbits

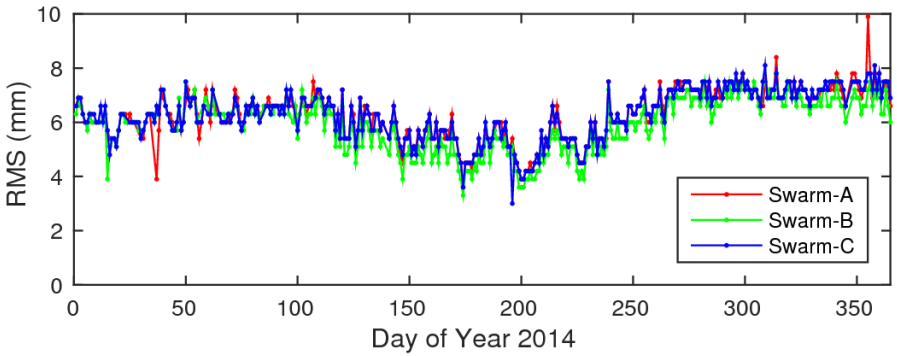


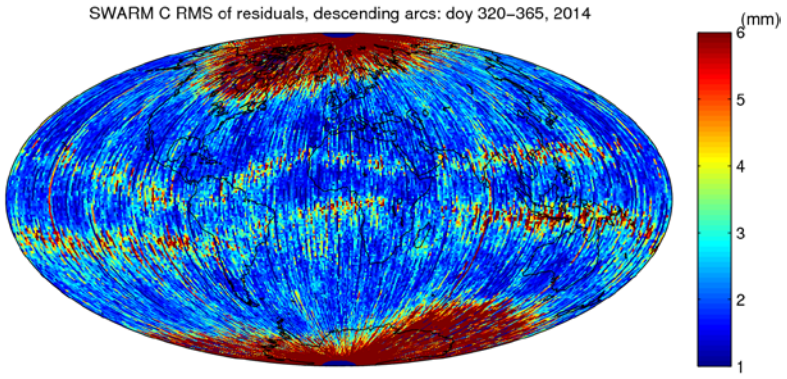
Mean = 2.7 mm
RMS = 32.5 mm

Mean = 1.0 mm
RMS = 27.4 mm

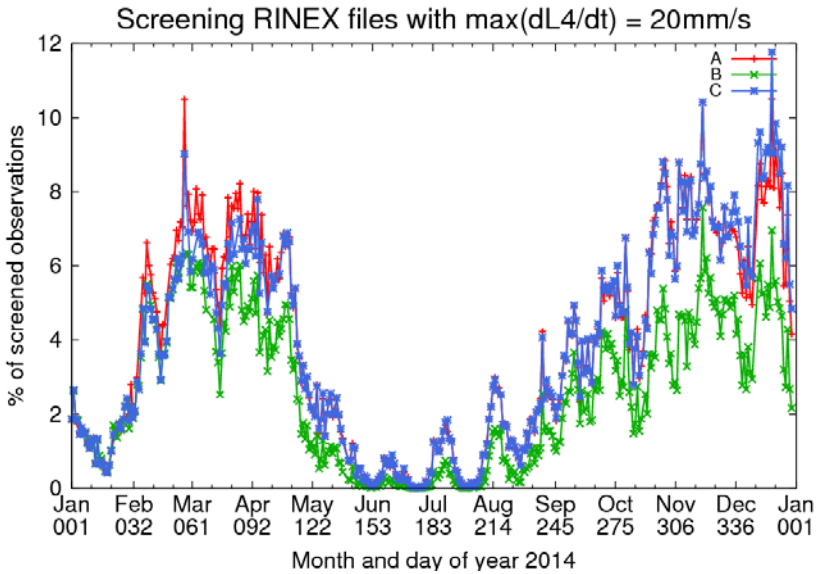
Mean = 0.6 mm
RMS = 31.1 mm

Ionosphere Disturbances



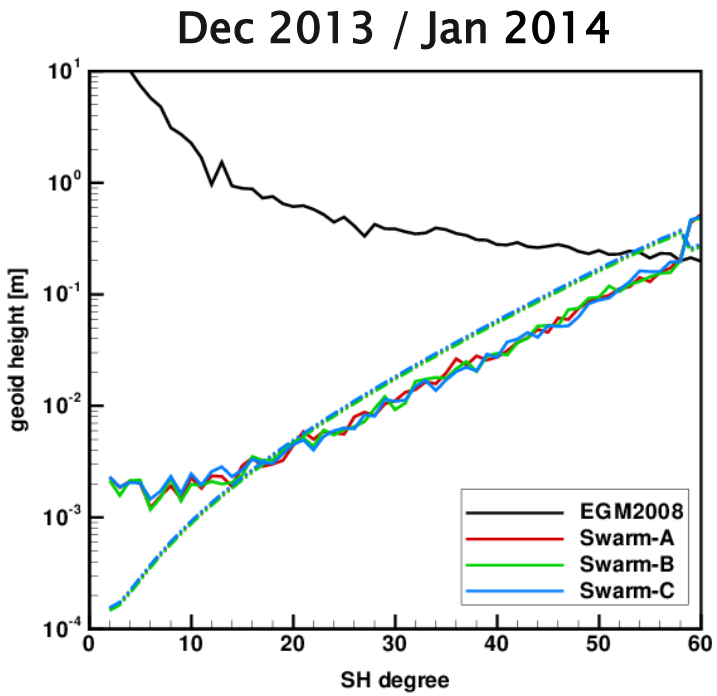


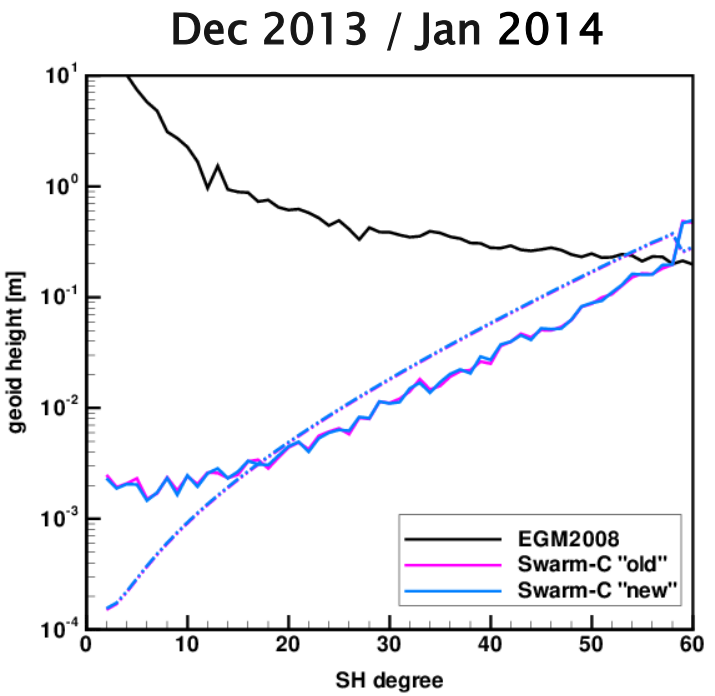
- **Random errors:**
  - Overall RMS is rather high
  - Dominated by polar areas
- **Systematic errors:**
  - Along geomagnetic equator
  - May be reduced by additional data screening (dL4/dt criterion)



Jäggi, A., C. Dahle, D. Arnold, U. Meyer, J. van den IJssel (2015): Orbit and Gravity Field Solutions from Swarm GPS Observations, 26th IUGG General Assembly, Prague, Czech Republic

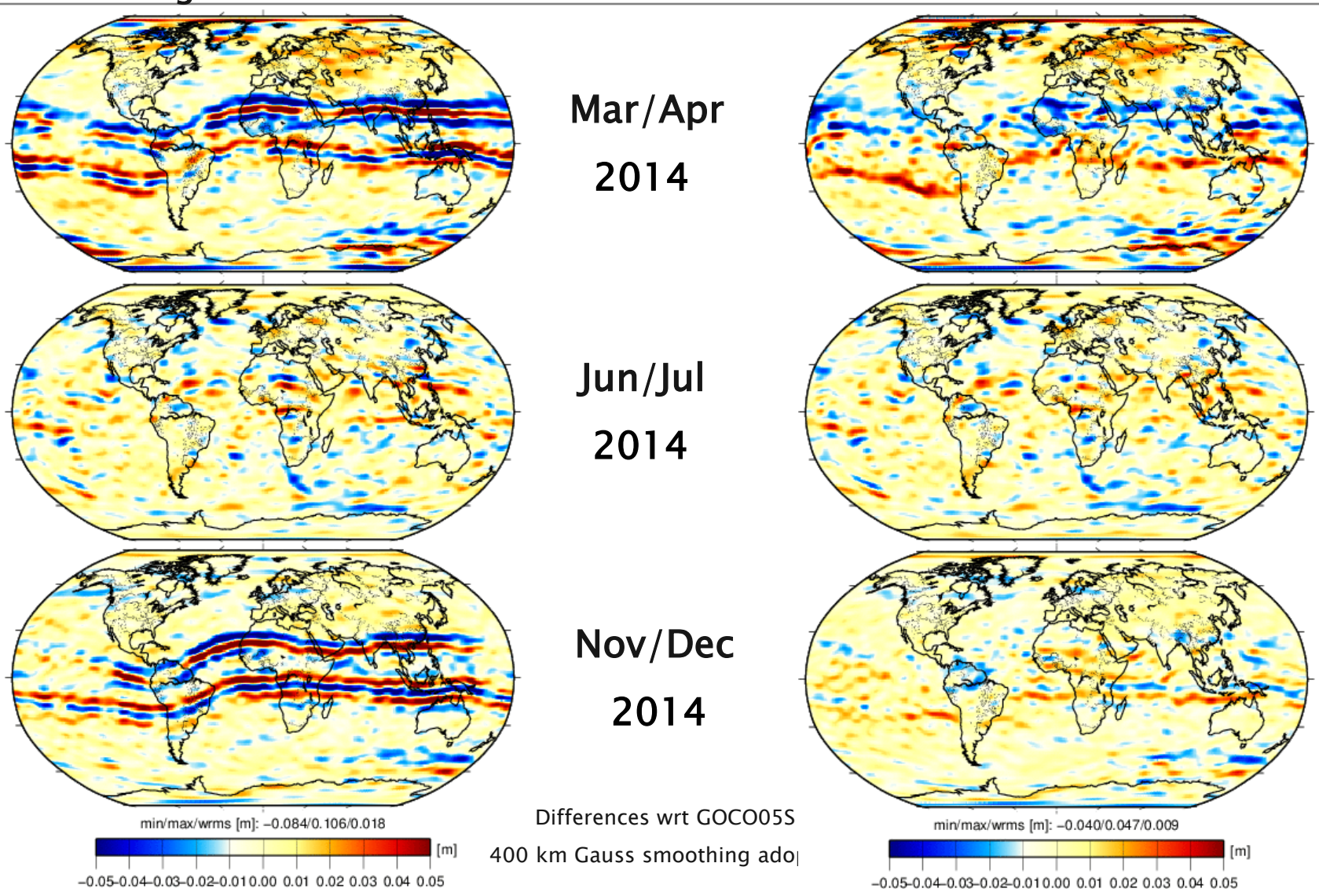
Gravity Field Solutions – two months of data



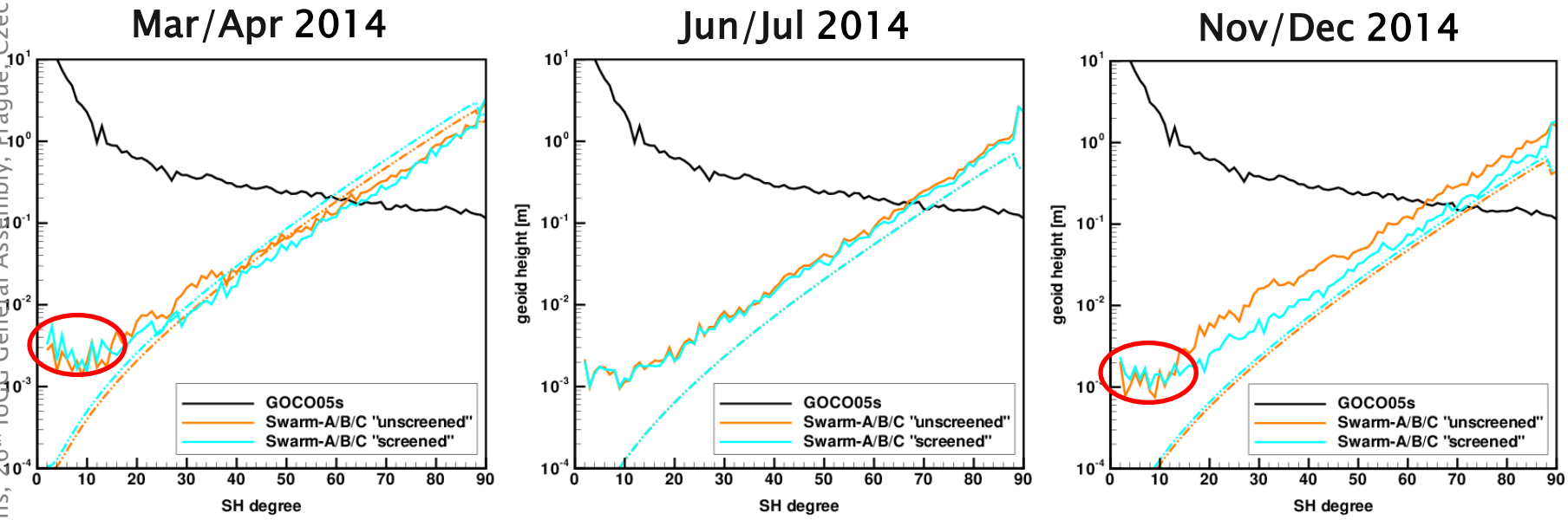


- Quality of gravity field recovery is very similar for all three Swarm satellites. This is only valid for the first 2 months with similar orbits.
- Virtually the same results when using “old” or “new” GPS data thanks to the in-flight calibration of the Swarm GPS antennas.

Bi-Monthly Gravity Field Solutions up to d/o 90



Bi-Monthly Gravity Field Solutions



Impact of screening the raw RINEX GPS data files (dL4/dt criterion):

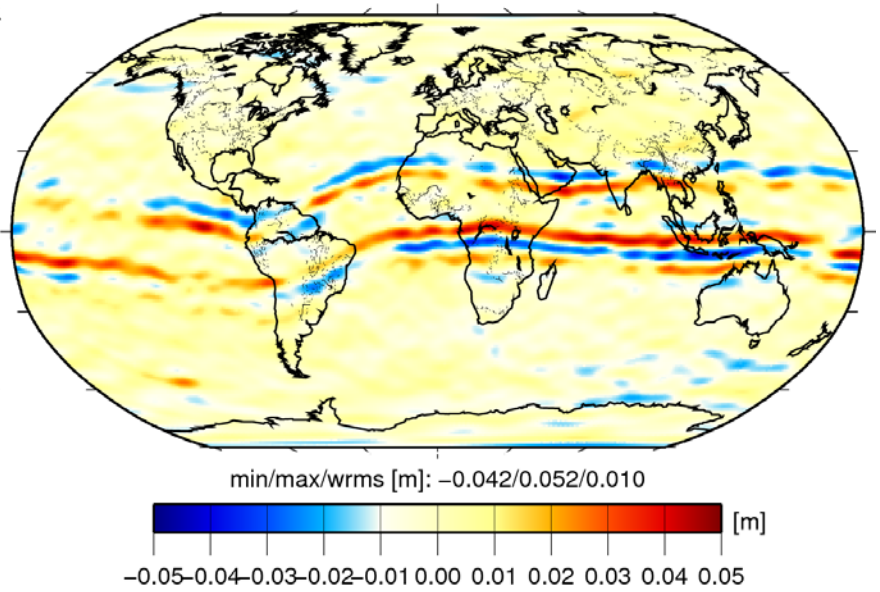
- Difference degree amplitudes are significantly improved, especially for periods with strong ionosphere conditions (spring, fall).
- Very low degrees ($n < 15$) tend to be weakened due to the very "crude" data screening.

Jäggi, A., C. Dahle, D. Arnold, U. Meyer, J. van den IJssel (2015): Orbit and Gravity Field Solutions from Swarm GPS Observations, 26th IUGG General Assembly, Prague, Czech Republic

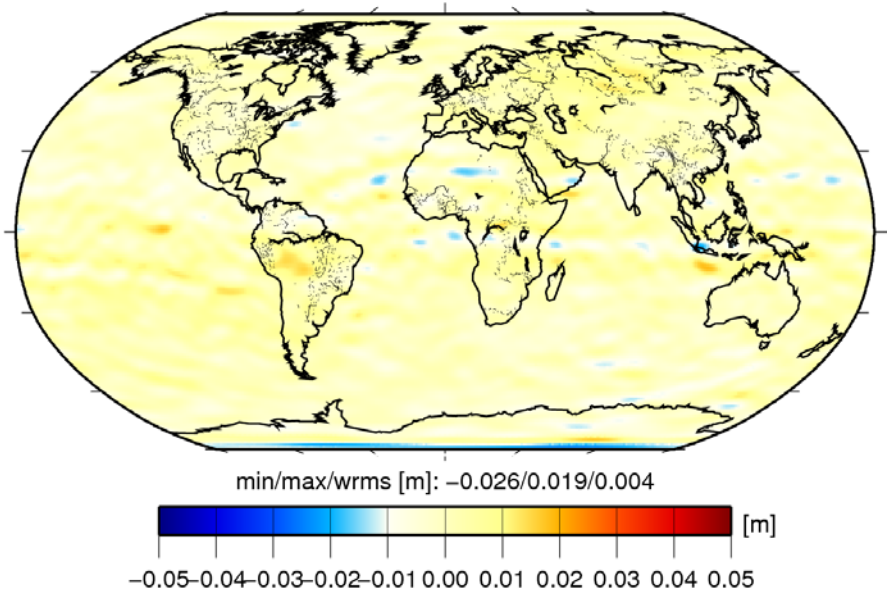
GFZ Helmholtz Centre Potsdam TU Delft

Static Gravity Field Solutions

Original GPS Data (13 months)



Screened GPS Data (18 months)

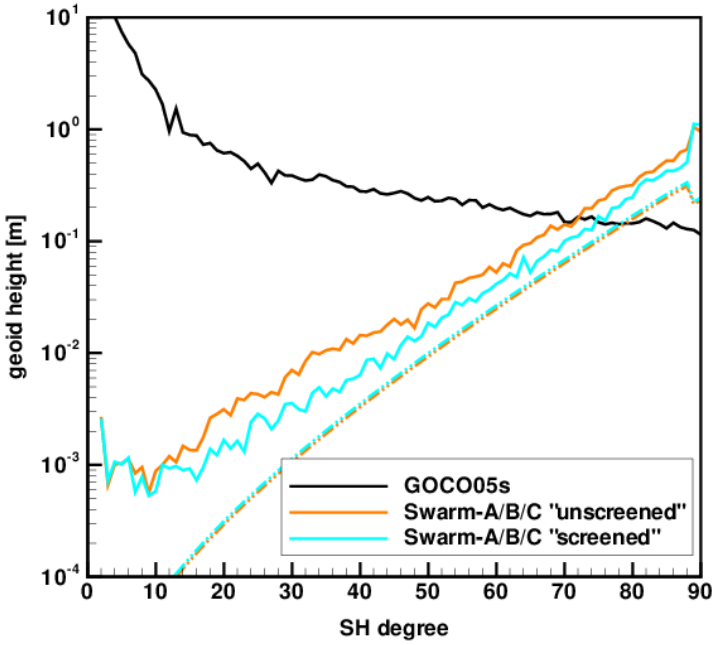


(Differences wrt GOCO05S, 400 km Gauss smoothing adopted)

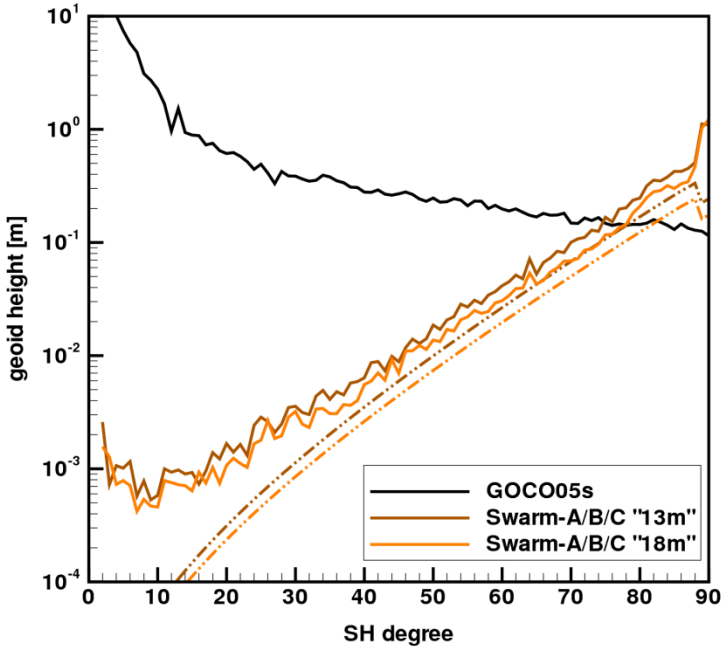
Systematic signatures along the geomagnetic equator may be efficiently reduced for static Swarm gravity field recovery when screening the raw RINEX GPS data files with the dL4/dt criterion.

Static Gravity Field solutions

13 months



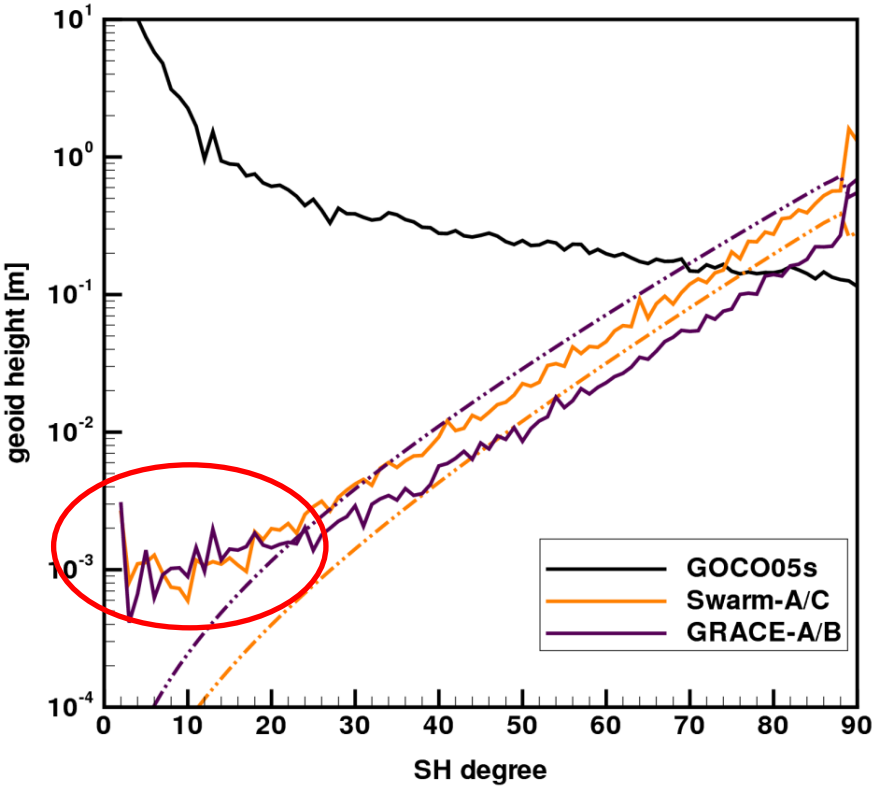
18 months



(Differences wrt GOCO05S)

Systematic signatures along the geomagnetic equator cause the artificial "bumps" and may be reduced for static Swarm gravity field recovery when screening the raw RINEX GPS data files with the dL4/dt criterion.

Comparison with GRACE hl-SST Solutions



Processed data:

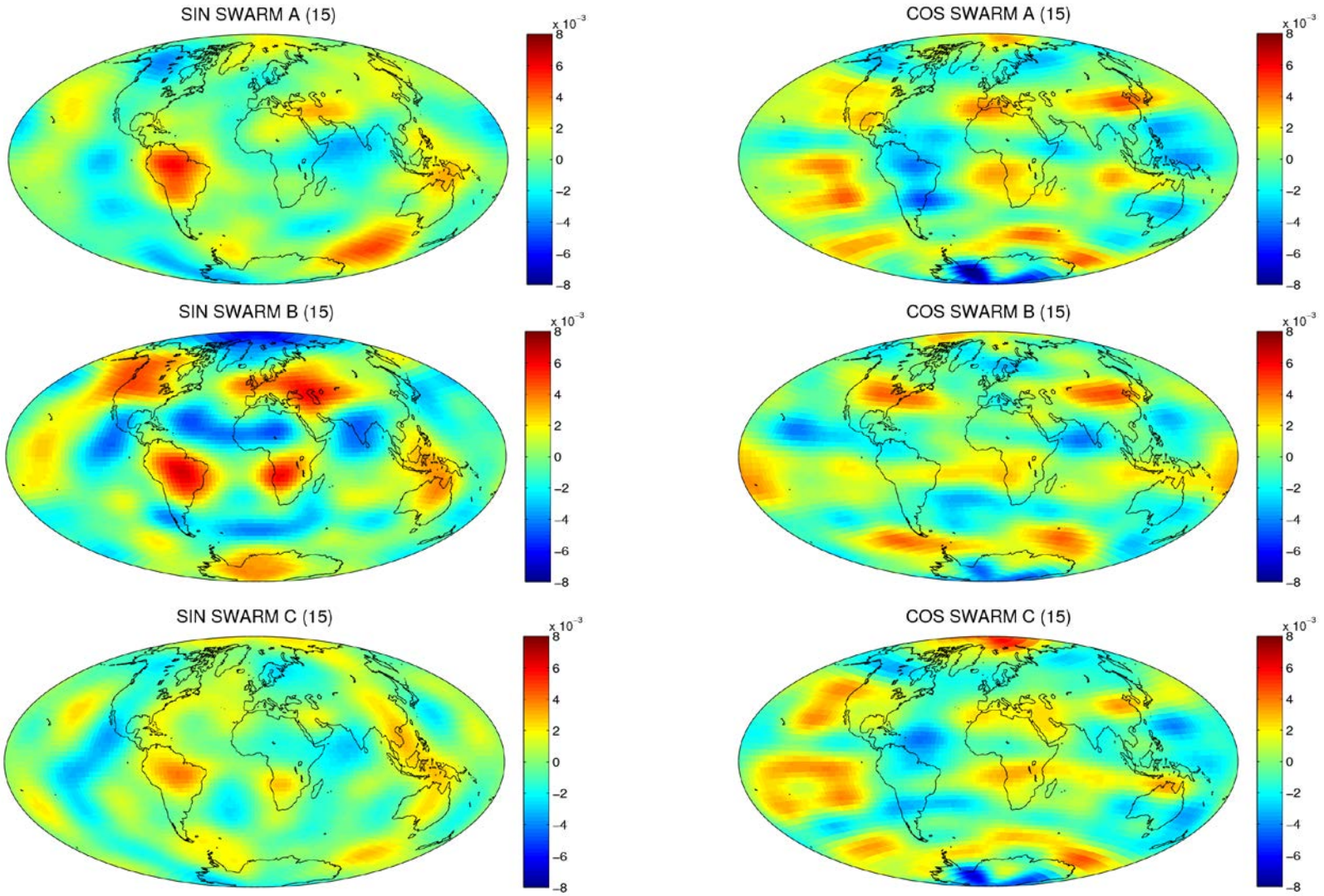
- Dec 2013 – Nov 2014
- Swarm-A/C
- GRACE-A/B (GPS-only)

Results:

- Similar performance for long wavelengths
- Worse performance for short wavelengths

Worse performance for higher degrees is to be expected due to the different orbital heights. The good agreement at the low degrees is very encouraging.

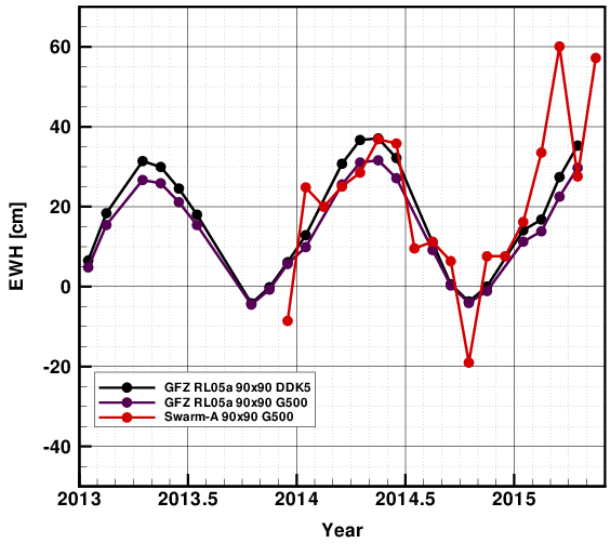
Time-Variable Gravity Field Solutions

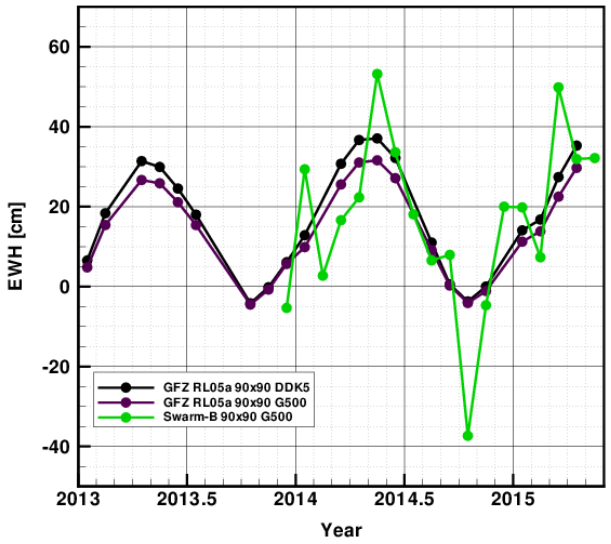


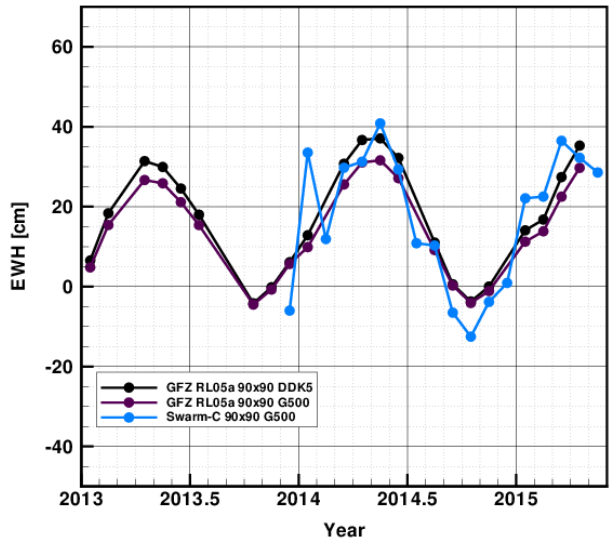
Jäggi, A., C. Dahle, D. Arnold, U. Meyer, J. van den IJssel (2015): Orbit and Gravity Field Solutions from Swarm GPS Observations, 26th IUGG General Assembly, Prague, Czech Republic

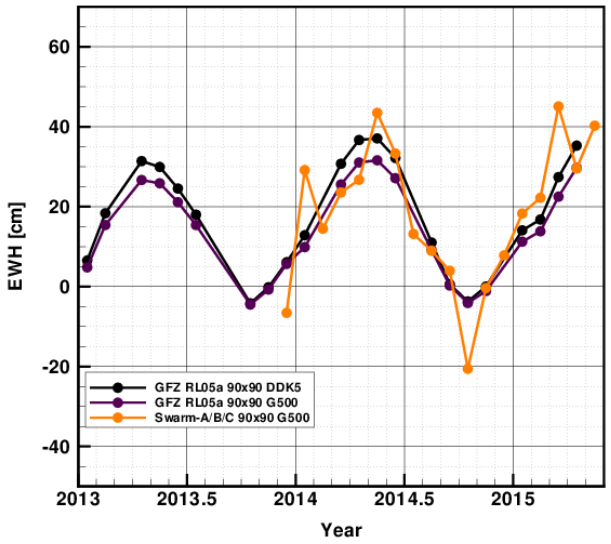
GFZ Helmholtz Centre Potsdam TU Delft

Time-Variable Gravity Field Solutions









"True" signal:

- GFZ-RL05a (DDK5-filtered)

"Comparison" signal:

- GFZ-RL05a (500km Gauss)

Swarm signal:

- 90x90 solutions (Gauss-filtered)

Result:

- Best agreement for Swarm-C

Summary and Conclusions

- SLR RMS of 3cm for Swarm kinematic orbits.
- Ionosphere disturbances affect orbit and gravity field solutions.
- GPS data screening for large ionosphere changes helps to reduce the geomagnetic signatures.
  - But also weakens low degrees.
- Very low degree coefficients are of similar quality as from GRACE GPS hl-SST.
- "Free-preview" on largest time-variable signals is encouraging despite the still very short time series.

Summary and Conclusions

Thanks a lot for your attention!