

First monthly gravity field solutions derived from GPS orbits of Swarm

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Context and objectives

Context :

- ▶ GRACE is at end-of-life
- ▶ GRACE Follow-On to be launched in August 2017
- ▶ Continued monitoring is fundamental

Objectives :

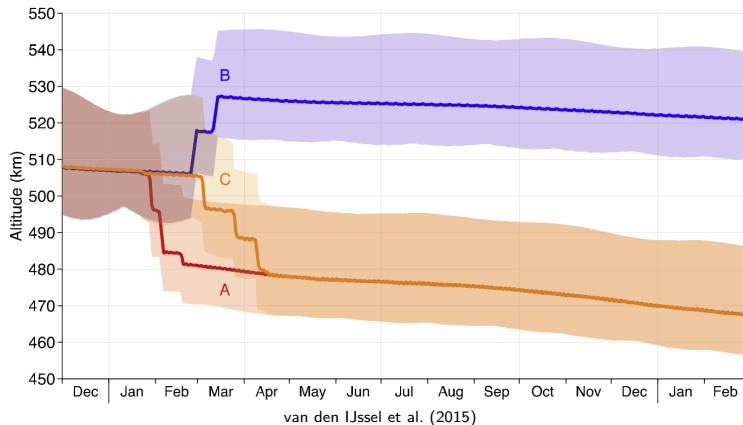
- ▶ Compare the signal content of
 - ▶ GRACE II-SST gravity field solutions with
 - ▶ Swarm II-SST solutions
- ▶ Estimate the practical spatial resolution of Swarm solutions
- ▶ Illustrate the regions where the signal is well recovered

N.B. :

- ▶ Only individual monthly solutions considered (i.e. no time series analysis)
- ▶ Swarm solutions combine data from all three satellites

Swarm mission

- ▶ aim: study of the dynamics of the Earth's magnetic field and its interaction with the Earth system
- ▶ 8-channel, dual-frequency GPS receiver
- ▶ launched on 22 November 2013
- ▶ three identical satellites
- ▶ near-polar orbit
- ▶ Swarm-A and Swarm-C side-by-side @ 480 km altitude
- ▶ Swarm-B @ 530 km altitude



Swarm kinematic orbits

| Institute | Location | Software | Reference |
|-----------|-----------------------|----------------------------------|--|
| AIUB | Bern, Switzerland | Bernese (Dach et al., 2007) | Jäggi et al. (2016) ^a |
| IfG | Graz, Austria | GROOPS (in-house development) | Zehentner and Mayer-Gürr (2015) ^b |
| TUD | Delft, Netherlands | GHOST (Wermuth et al., 2010) | van den IJssel et al. (2015) ^c |

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^b<ftp://ftp.tugraz.at/outgoing/ITSG/tvgogo/orbits/Swarm>

^c<http://earth.esa.int/web/guest/swarm/data-access>

Gravity field models

| Institute | Location | Approach | Orbits | Reference |
|-----------|-----------------------|--|--------|--|
| AIUB | Bern, Switzerland | Celestial Mechanics Approach (Beutler et al., 2010) | AIUB | Jäggi et al. (2016) ^a |
| ASU | Prague, Czech Rep. | Acceleration approach (Bezděk et al., 2014) | IfG | Bezděk et al. (2014) ^b |
| IfG | Graz, Austria | Short-arc approach (Mayer-Gürr, 2006) | IfG | Zehentner and Mayer-Gürr (2015) ^c |

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^b<http://www.asu.cas.cz/~bezdek/vyzkum/geopotencial>

^c<ftp://ftp.tugraz.at/outgoing/ITSG/tvgogo/gravityFieldModels/SwarmMonthly>

Combination of Swarm solutions

Arithmetic averaging:

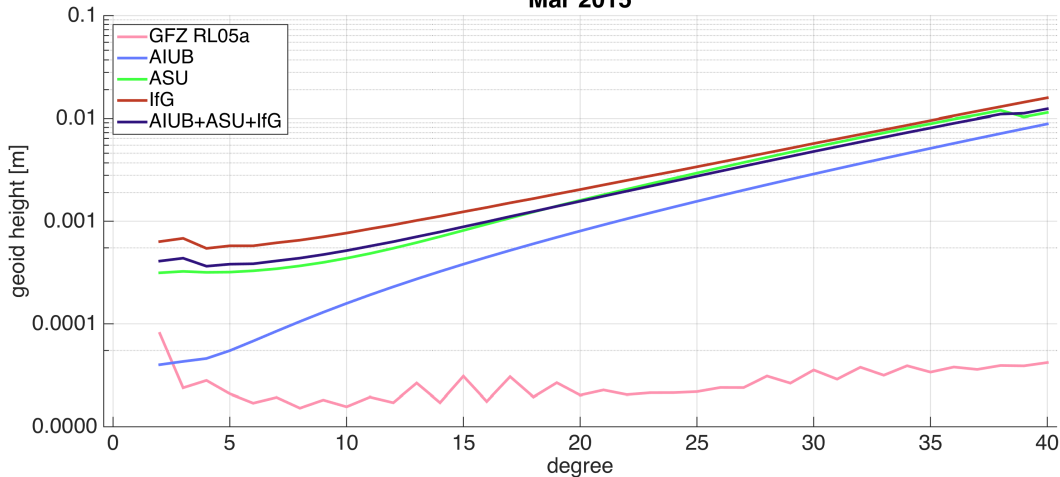
$$\bar{c}_{\ell m}^{(\text{AIUB+ASU+IfG})} = \frac{1}{3} \sum_i \bar{c}_{\ell m}^{(i)}, \quad i = \text{AIUB, ASU, IfG}$$

$$\sigma_{\ell m}^{(\text{AIUB+ASU+IfG})} = \frac{1}{3} \sqrt{\sum_i \left(\sigma_{\ell m}^{(i)}\right)^2}, \quad i = \text{AIUB, ASU, IfG}$$

The values of $\sigma_{\ell m}^{(i)}$ are those provided with in the data files.

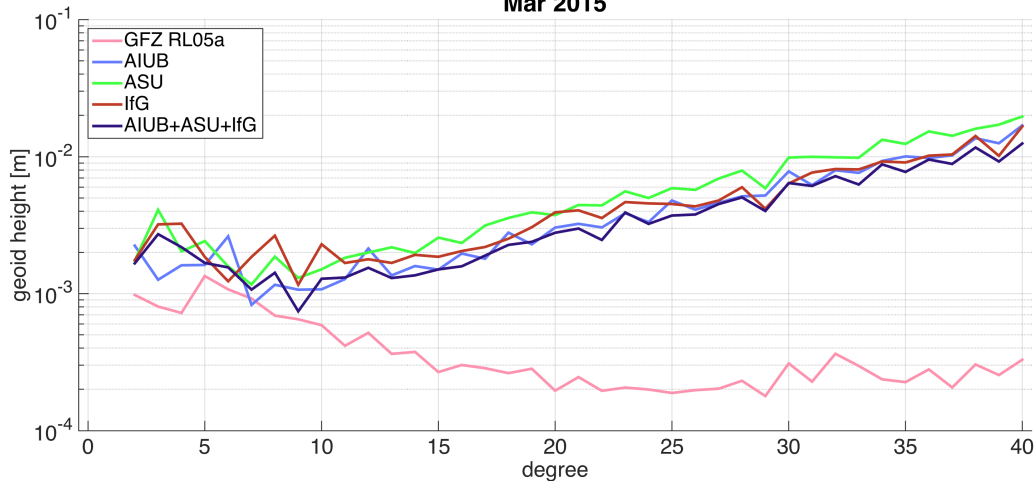
Formal errors

Mar 2015



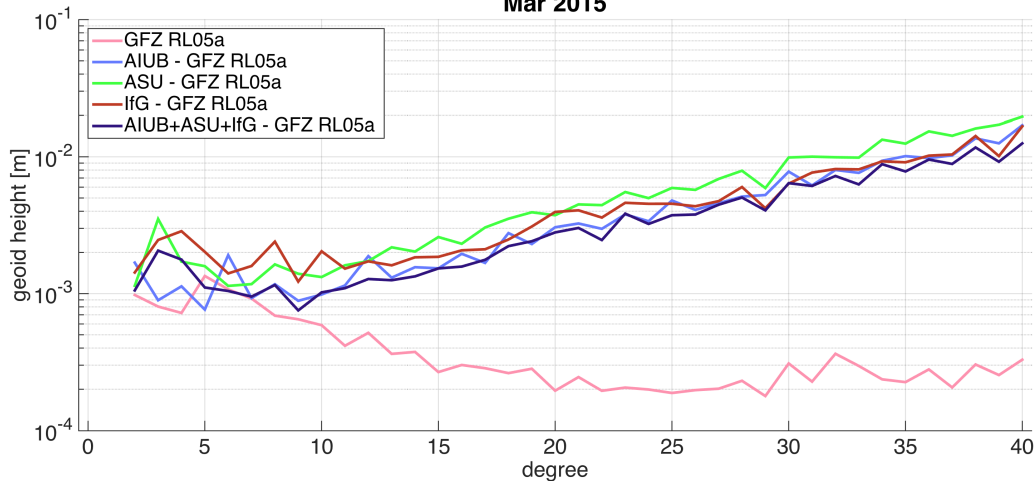
Time-variable signal (residuals vs. GGM05G)

Mar 2015

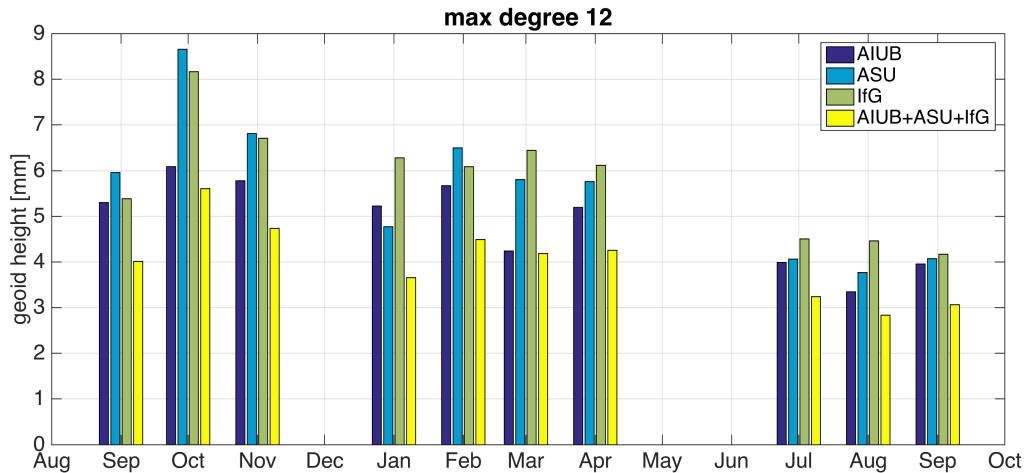


Error estimate (residual vs. GRACE)

Mar 2015



Relative solution quality



Degree correlation coefficient

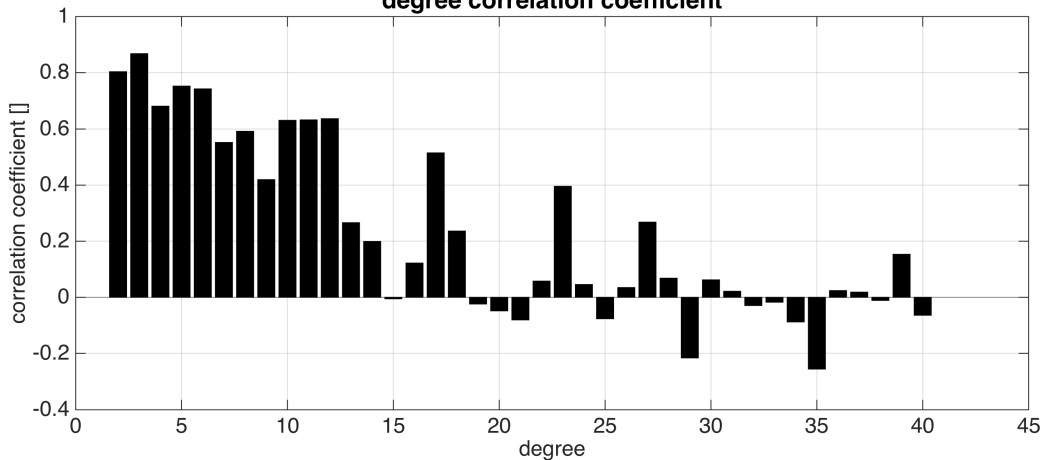
For every degree, compute the correlation coefficient between GRACE and Swarm solutions:

$$r_\ell = \frac{\sum_{m=0}^{\ell} \bar{c}_{\ell m}^{(\text{Swarm})} \bar{c}_{\ell m}^{(\text{GRACE})}}{\sqrt{\sum_{m=0}^{\ell} \left(\bar{c}_{\ell m}^{(\text{Swarm})}\right)^2} \sqrt{\sum_{m=0}^{\ell} \left(\bar{c}_{\ell m}^{(\text{GRACE})}\right)^2}}$$

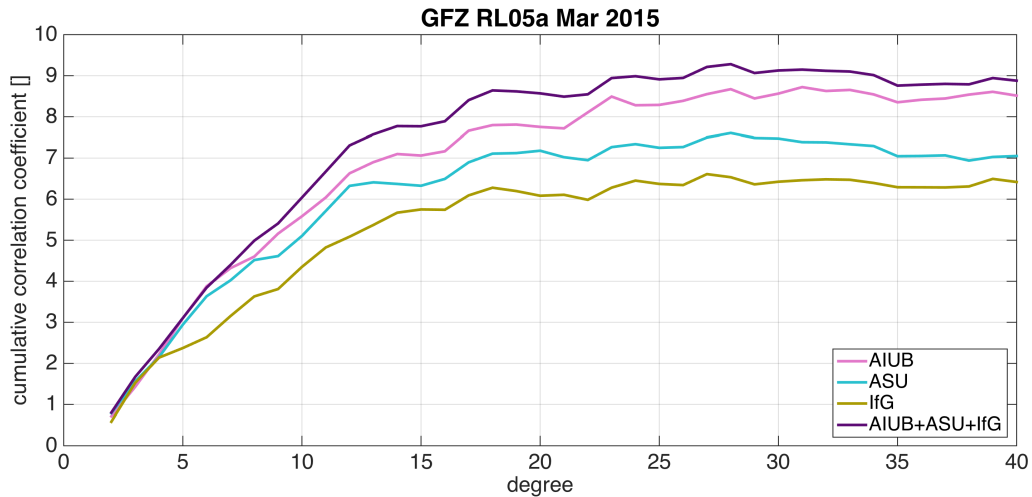
Models $\bar{c}_{\ell m}^{(\text{Swarm})}$ and $\bar{c}_{\ell m}^{(\text{GRACE})}$ represent time-variable signal (i.e. reference model GGM05G is subtracted).

Degree correlation coefficient

AIUB+ASU+IfGxGFZ RL05a Mar 2015
degree correlation coefficient



Cumulative degree correlation



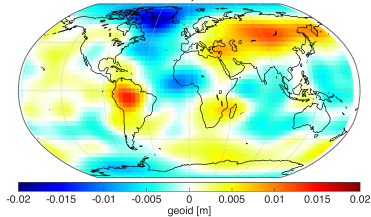
Cumulative degree correlation

- ▶ Strong correlation up to degree 12
- ▶ Marginal cumulative correlation increase from degree 12 to 20
- ▶ No correlation above degree 21
- ▶ \Rightarrow Gaussian smoothing at 833 , 625 and 500 km (\approx degrees 12, 16 and 20)

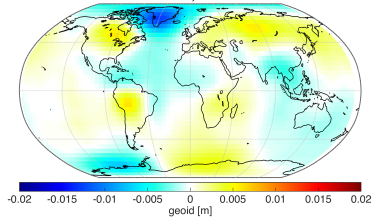
Further analysis considers the combined AIUB+ASU+IfG model.

Spatial correlation with GRACE (833 km smoothing)

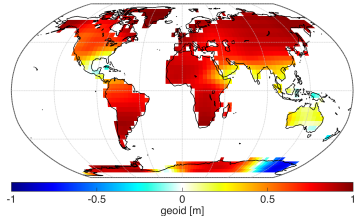
AIUB+ASU+IfG smooth 12 Mar 2015
RMS=0.0047114; max=0.018311



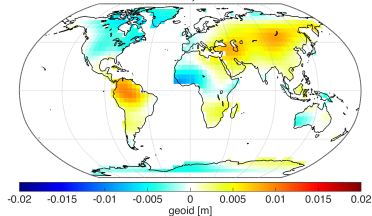
GFZ RL05a smooth 12 Mar 2015
RMS=0.0026291; max=0.012883



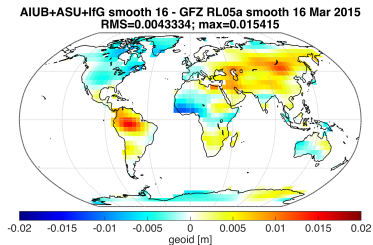
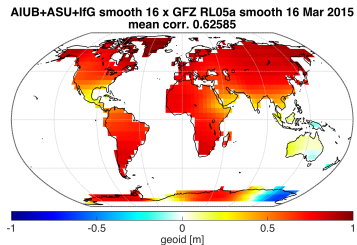
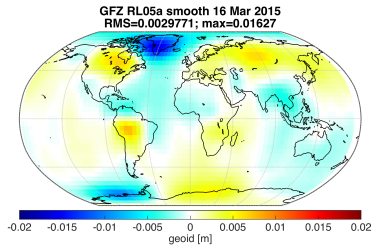
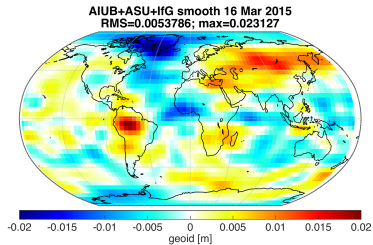
AIUB+ASU+IfG smooth 12 x GFZ RL05a smooth 12 Mar 2015
mean corr. 0.65951



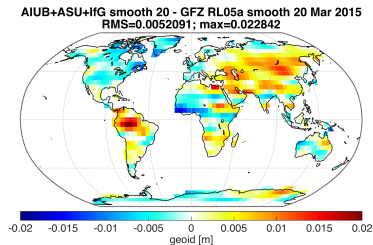
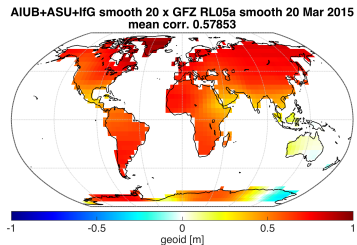
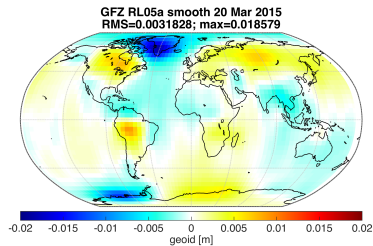
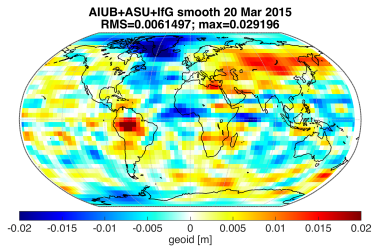
AIUB+ASU+IfG smooth 12 - GFZ RL05a smooth 12 Mar 2015
RMS=0.0037945; max=0.010149



Spatial correlation with GRACE (625 km smoothing)



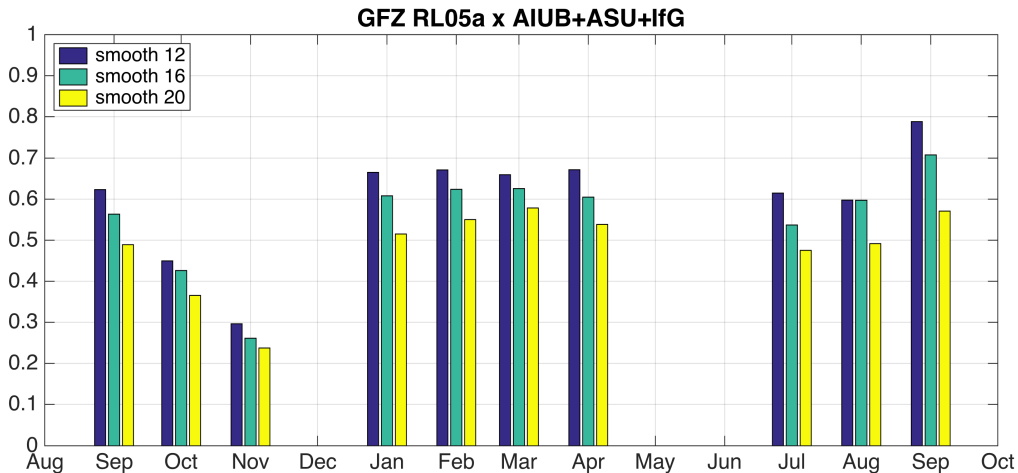
Spatial correlation with GRACE (500 km smoothing)



Summary (2015-03)

| Smoothing radius [km] | Smoothing degree [] | Mean spatial correlation land [] | GRACE residual RMS land [mm] |
|-----------------------|---------------------|----------------------------------|------------------------------|
| 833 | 12 | 0.70 | 2.1 |
| 625 | 16 | 0.65 | 2.3 |
| 500 | 20 | 0.59 | 2.8 |

Solution consistency (Sep 2014 to Sep 2015)



References

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