Signal contents of combined monthly gravity field models derived from Swarm GPS data

EGU2018-10773 - Session G4.3 - 13 April 2018

João de Teixeira da Encarnação[1,2], Pieter Visser[2], Eelco Doornbos[2], Jose van den IJssel[2], Xinyuan Mao[2], Elisabetta Iorfida[2], Daniel Arnold[3], Adrian Jäggi[3], Ulrich Meyer[3], **Aleš Bezděk**[4], Josef Sebera[4], Jaroslav Klokočník[4], Matthias Ellmer[5], Torsten Mayer-Gürr[5], Norbert Zehentner[5], Junyi Guo[6], Peter Luk[6], C.K. Shum[6], and Yu Zhang[6]

(1) Center for Space Research, University of Texas at Austin, Austin, United States, (2) Faculty of Aerospace Engineering of the Delft University of Technology, Delft, The Netherlands, (3) Astronomical Institute of the University of Bern, Bern, Switzerland, (4) Astronomical Institute of the Czech Academy of Sciences, Ondrejov, Czech Republic, (5) Institute of Geodesy of the Graz University of Technology, Graz, Austria, (6) School of Earth Science of the Ohio State University, Columbus, Ohio, USA

Multi-approach gravity field models from Swarm GPS data

- ESA/DISC funded project (9/2017 to 9/2018)
- Provide highest-quality monthly Swarm gravity field models (GFM)
- Combine individual gravity solutions, computed with:
  - different kinematic orbit solutions
  - different inversion approaches
- Monthly combined Swarm gravity field models:
  - from Dec. 2013 to Jun. 2018
  - publicly available by end of September 2018 (usual ESA channels)

TUDelft

Multi-approach gravity field models from Swarm GPS data

- Other EGU 2018 contributions related to this project:

  - Adrian Jäggi et al.: Assessment of individual and combined gravity field solutions from Swarm GPS data and mitigation of systematic errors.
    EGU2018-8944 - 9 April 2018

  - Norbert Zehentner et al.: Investigations of GNSS-derived baselines for gravity field recovery.
    EGU2018-11920 - 12 April 2018

Kinematic orbit solutions

- TU Delft: **GPS High precision Orbit determination Software Tool** (GHOST) Helleputte (2004); Wermuth et al. 2010
- AIUB: **Bernese** v5.3 Dach et al., (2015); Jäggi et al. (2007)
- IfG: **Gravity Recovery Object Oriented Programming System** (GROOPS) Zehentner et al. (2016)

Gravity field estimation approaches

- AIUB: **Celestial Mechanics Approach** (CMA), Beutler et al. (2010)
- ASU: **Decorrelated Acceleration Approach** (DAA), Bezdek et al. (2014); Bezdek et al. (2016)
- IfG: **Short-Arc Approach** (SAA), Mayer-Gürr (2006)
- OSU: **Improved Energy Balance Approach** (IEBA), Shang et al. (2015) (not considered in this presentation)

Combination of individual gravity field solutions

- Variance Component Estimation (VCE)
- More information presented by Adrian Jäggi on Monday (EGU2018-8944)
- Intermediate step in the project: combination at the level of normal equations (NEQ) is the goal

Combination Scenarios

- **Mixed**: different Gravity Field Estimation Approaches (GFEAs) using different kinematic orbits (KOs)
- **AIUB KO**: different GFEAs using AIUB kinematic orbits
- **DAA GFEA**: Decorrelated Acceleration Approach with different KOs
- **SAA GFEA**: Short Arc Approach with different KOs

"Mixed" combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.	0.37		
Decorr. Acceleration App.		0.23	
Short Arc A.			0.40

“AIUB KO” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.	0.28		
Decorr. Acceleration App.	0.21		
Short Arc A.	0.51		

“DAA GFEA” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.			
Decorr. Acceleration App.	0.40	0.25	0.35
Short Arc A.			

“SAA GFEA” combination scenario

- time-averaged VCE-derived weights

Gravity Field Est. App.	Kinematic orbit solution		
	AIUB	TU Delft	IfG
Celestial Mech. App.			
Decorr. Acceleration App.			
Short Arc A.	0.41	0.28	0.31

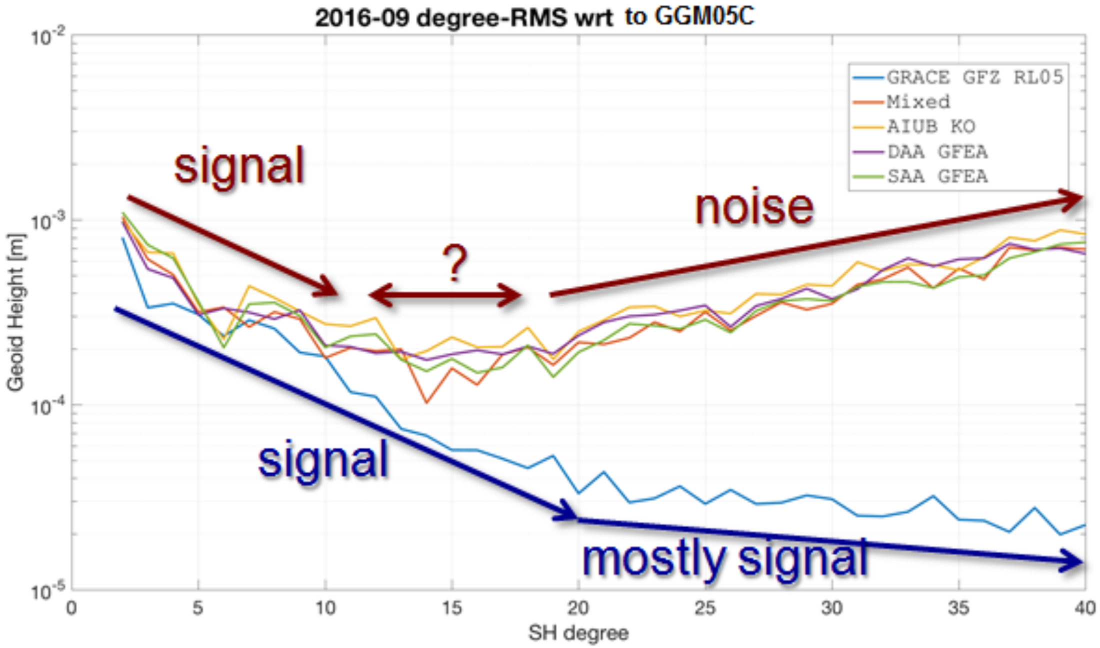
Gravity field model pre-processing

- Truncation to degree 40
- C_{20} replaced with value from *GRACE Technical Note 07*
- Temporal variations relative to static GGM05G (GRACE and GOCE)
- Gaussian smoothing with 750-km radius (unless noted)
- GRACE GFZ RL05 used as reference (with same pre-processing)
- GRACE solutions interpolated to the mid-month epochs of the Swarm solutions (identical for all scenarios)

Typical degree RMS
(no smoothing)

Swarm gravity monthly
- agreement with GRACE up to degrees 10–13
- flattening over degrees 15–20
- noise prevails afterwards
- reason for applying Gaussian smoothing (e.g. 750 km)

GRACE gravity monthly
- keeps decreasing in amplitude with higher degrees
- "mostly signal" after degree 15, because mascons start to deviate from SH solutions



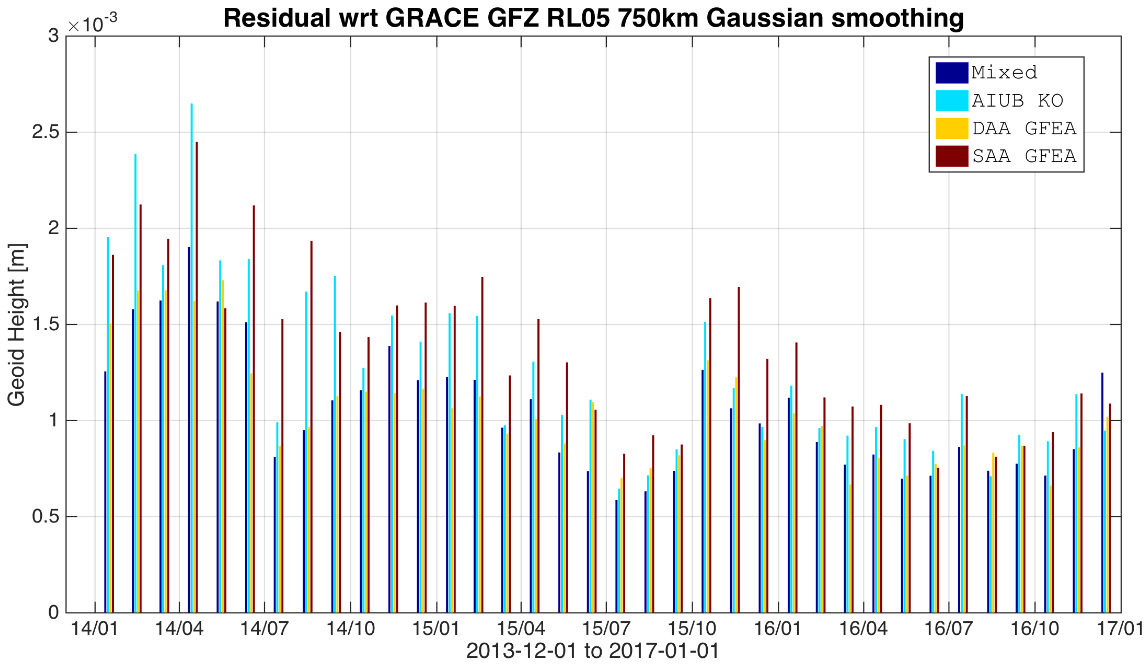
Spatial agreement with GRACE

- per-solution cumulative degree-RMS of difference between Swarm and GRACE

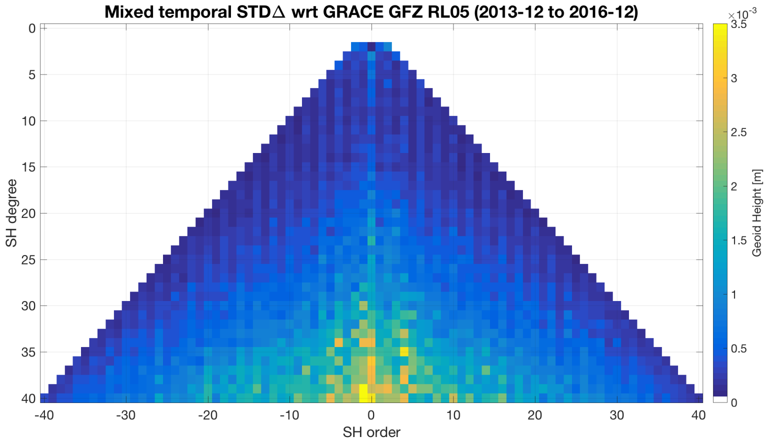
- same as RMS of the spatial maps of the difference between GRACE and Swarm GFMs

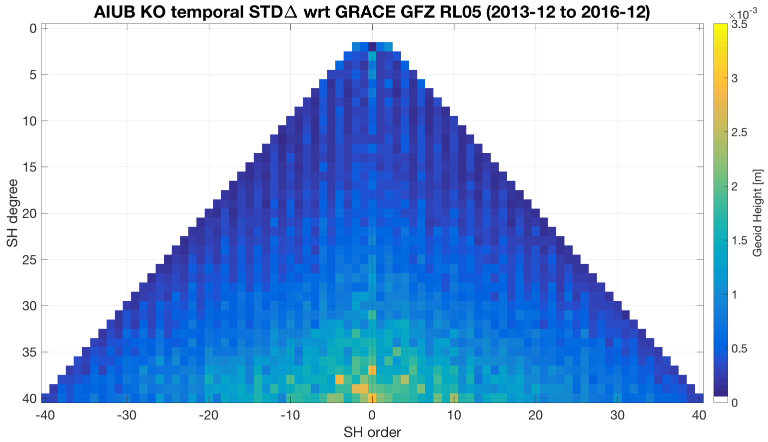
- <u>correlation with intensity of ionospheric disturbances</u>
(cf. presentation of A. Jäggi)

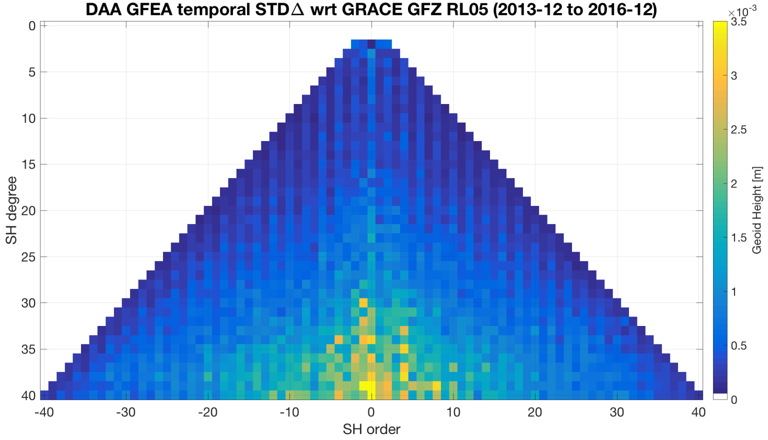
- agreement on 1 mm RMS
(Gaussian smoothing of 750 km)

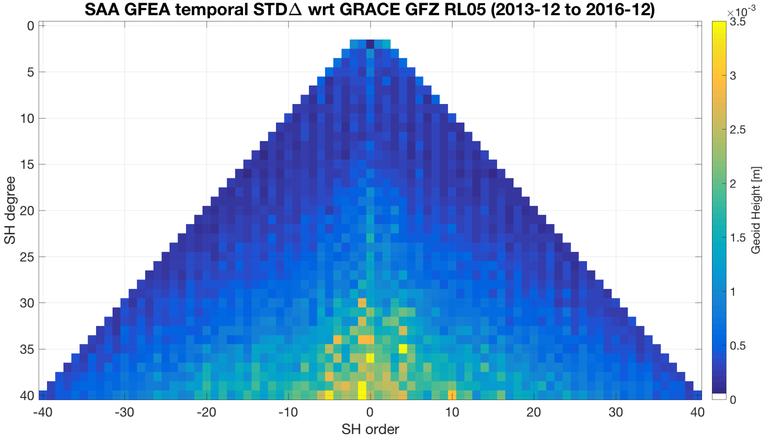


Temporal agreement with GRACE (no smoothing)







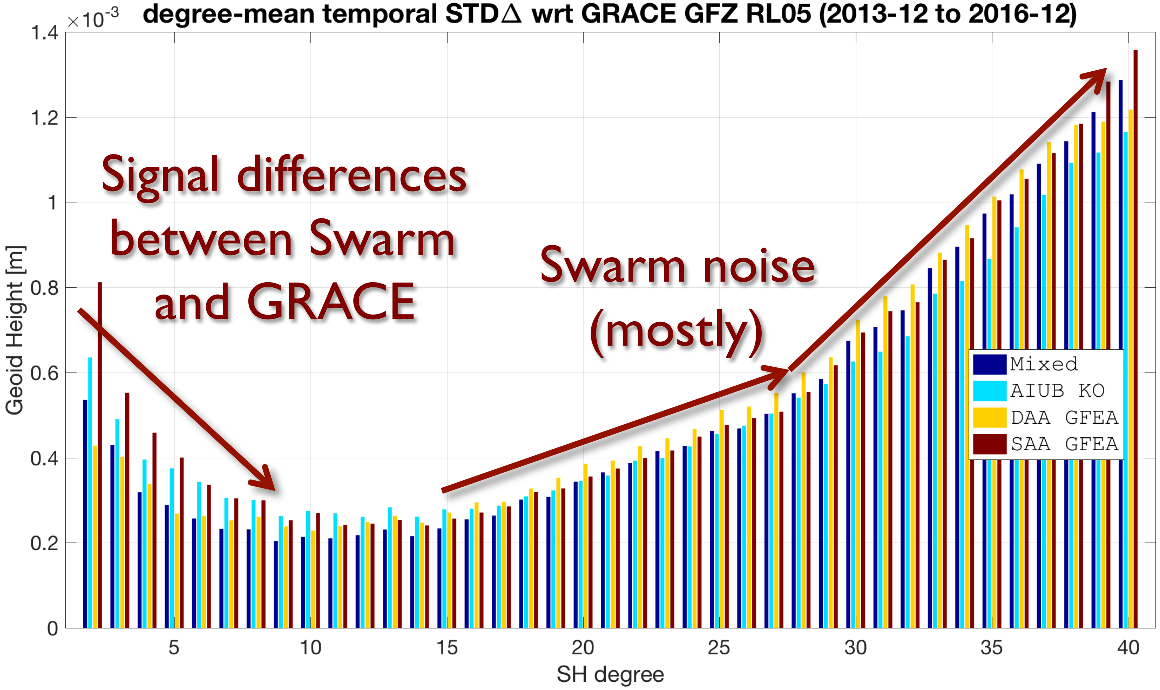


Temporal agreement with GRACE (no smoothing)

- average of each row in the previous plots

- results for 3 years of data

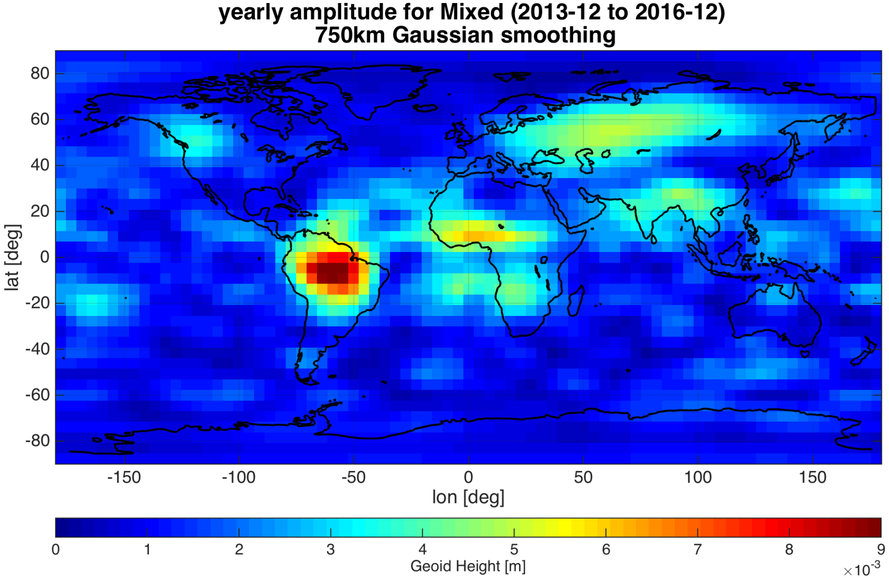
- Gaussian smoothing is advisable:
- consider choice of smoothing radius: e.g. 500/660/750 km

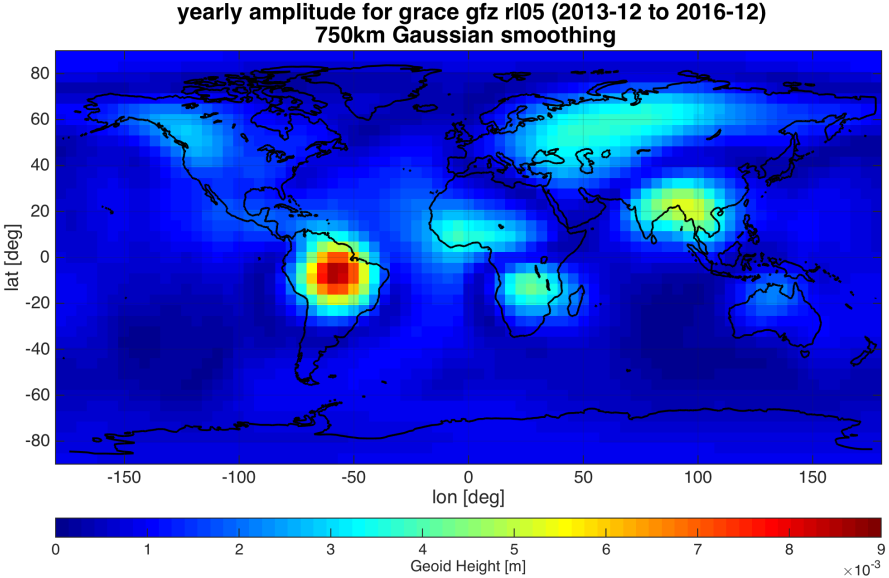


Parametric decomposition of time-variable Gravity signal in Swarm models

- The Swarm and GRACE time variable signal is represented as:
  - constant
  - trend
  - yearly sinusoidal
- Yearly amplitude maps are the norm of the sine and cosine terms
- GRACE is on right-hand side, the “best” Swarm scenario is on the left

Yearly amplitude term: “Mixed” scenario





TU Delft | UNIVERSITÄT BERN | Astronomical Institute of the Czech Academy of Sciences | TU Graz | The Ohio State University | TEXAS The University of Texas at Austin | EGSIEM European Gravity Service for Improved Emergency Management | swarm | SWARM DISC

Summary and conclusions

- Swarm signal useful below **degree 15**
- Global spatial agreement with GRACE at **1 mm RMS**
    - over periods of low solar activity
    - Gaussian smoothing radius of 750 km
- **Seasonal yearly signal** clearly resolvable by Swarm
    - larger signals over the oceans (consider masking)
- **“Mixed” scenario** in better agreement with GRACE:

  → superior combination is obtained on using **different approaches** to estimating **both KOs and Gravity Field models**

Stay tuned!

Monthly NEQ-combined Swarm models:

- from Dec. 2013 to Jun. 2018
- publicly available by **end of September 2018**

Research Gate project webpage

- https://www.researchgate.net/project/Multi-approach-gravity-field-models-from-Swarm-GPS-data