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

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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)

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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

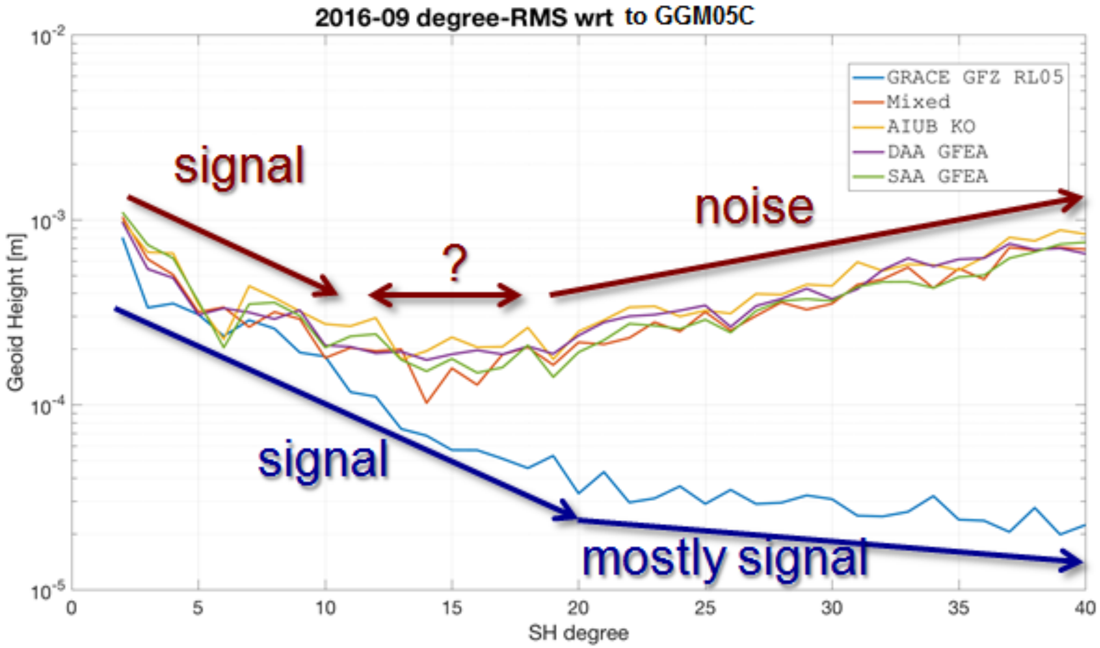
Gravity field model pre-processing

- 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



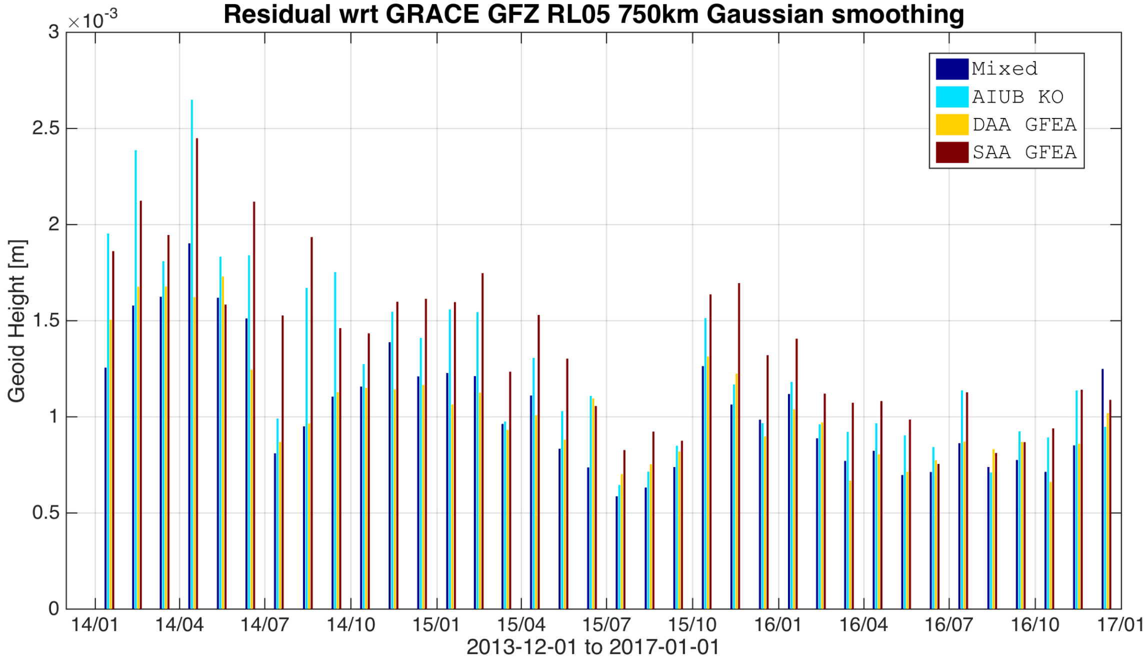
Spatial agreement with GRACE

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

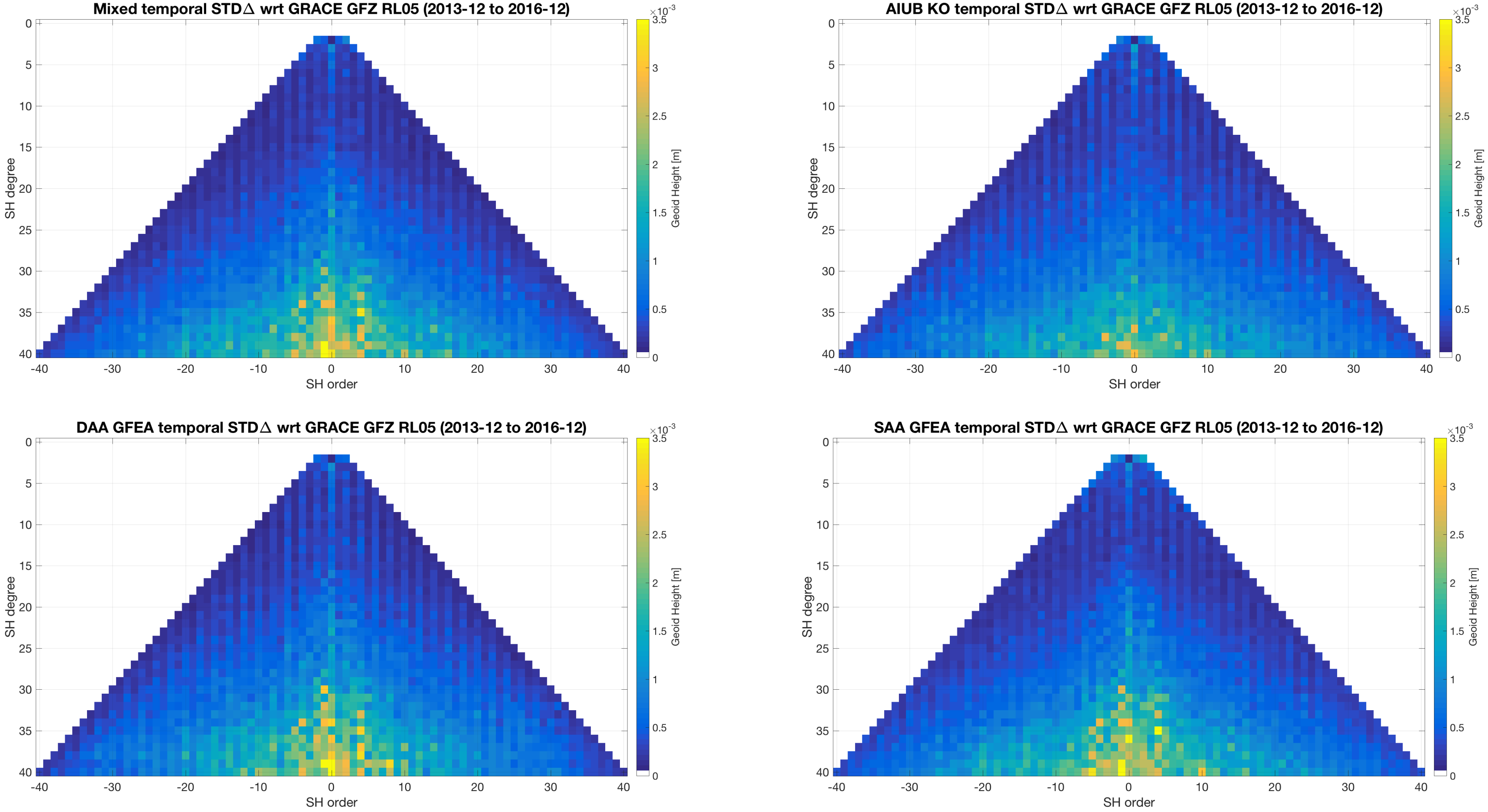
- same as RMS of the spatial maps of the difference between GRACE and Swarm GFMs

- <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)

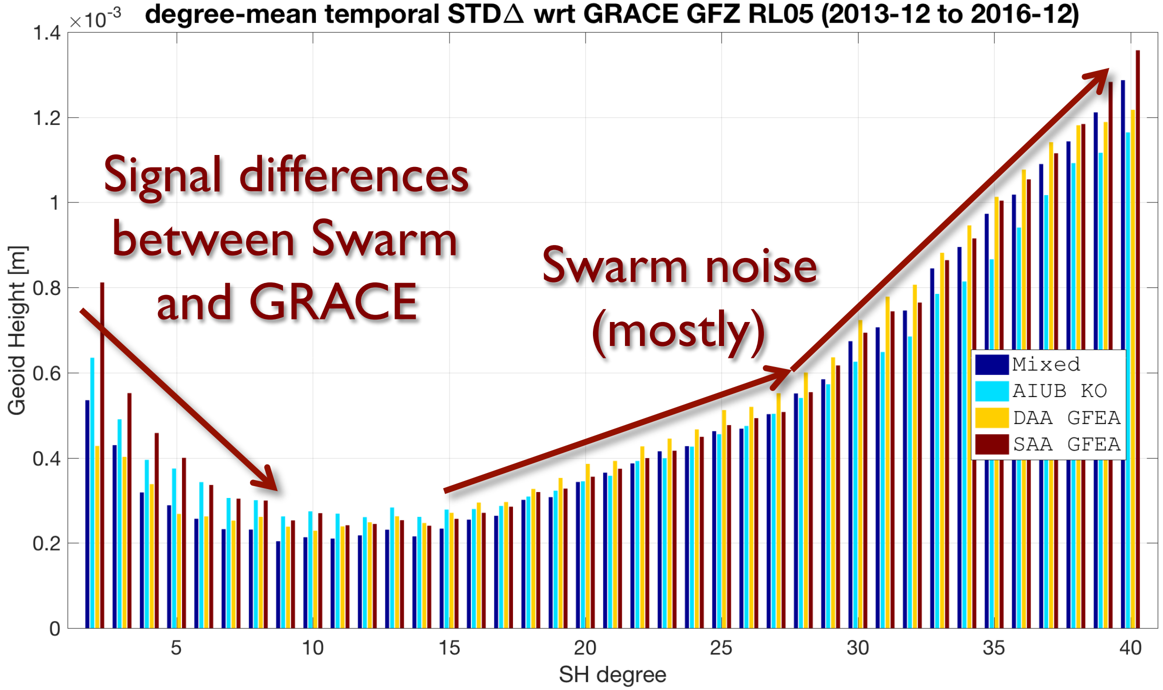


Temporal agreement with GRACE
(no smoothing)

- average of each row in the previous plots

- results for 3 years of data

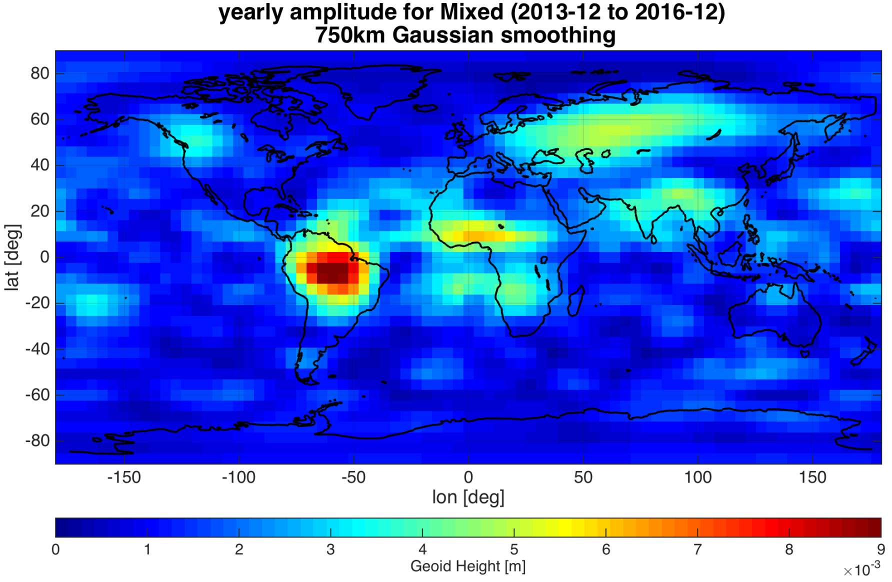
- Gaussian smoothing is advisable:
- consider choice of smoothing radius: e.g. 500/660/750 km

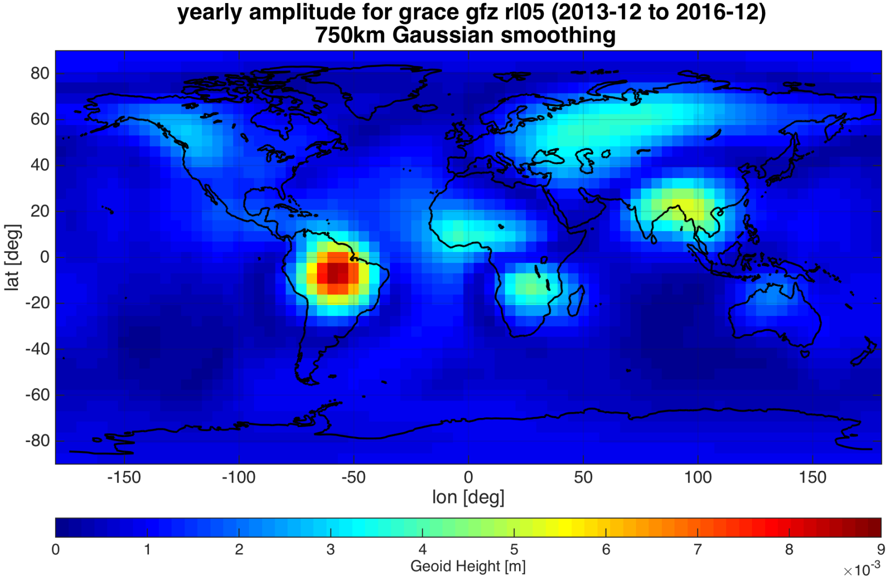


Parametric decomposition of time-variable Gravity signal in Swarm models

- 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





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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