Observing Earth's mass transport processes with the Swarm satellites

GGHS-2018 – September 2018

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SWARM DISC

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 Sep. 2018
  - publicly available early 2019 (usual ESA channels)

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)

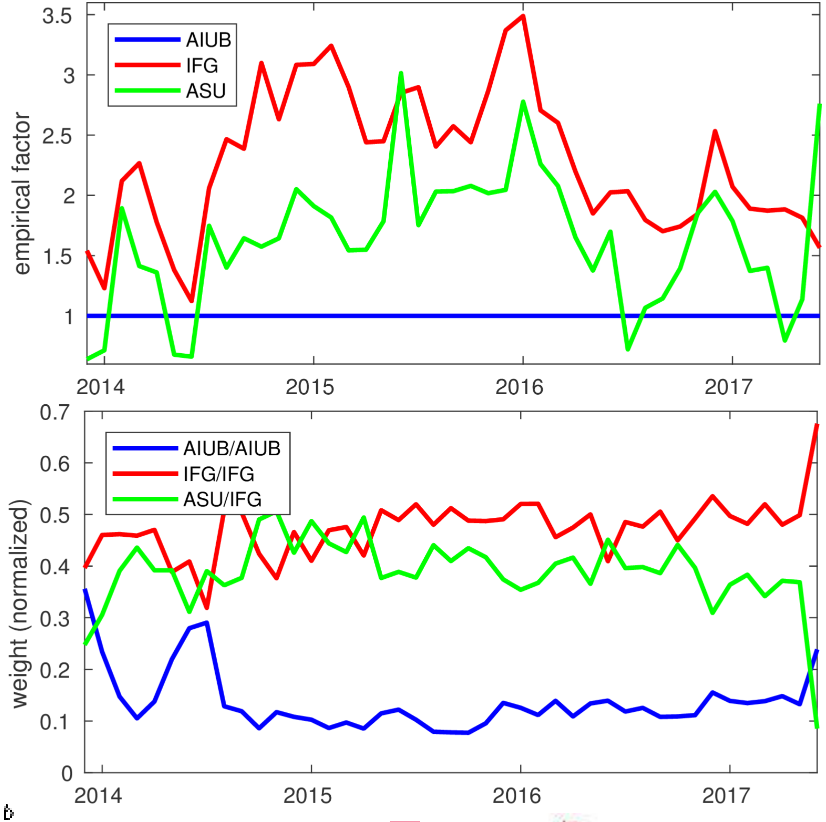
Gravity field estimation approaches

- 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)

Combination of individual gravity field solutions

- Quality control prior to combination (OSU excluded)
- Three types of combination were tested:
  - Arithmetic mean at solution level
  - Weighted mean (VCE) at solution level
  - Combination at NEQ-level
- Combination complicated due to different noise models, biases introduced by kinematic orbits and artefacts due to ionosphere activity (magnetic equator).

Relative weighting / scaling of NEQs



A mean scaling factor per time-series is applied prior to combination to balance the general level of impact on the monthly combinations

Weights derived by variance component estimation are biased due to the kinematic orbits used (2*IfG, 1*AIUB).

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Validation: gravity field 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

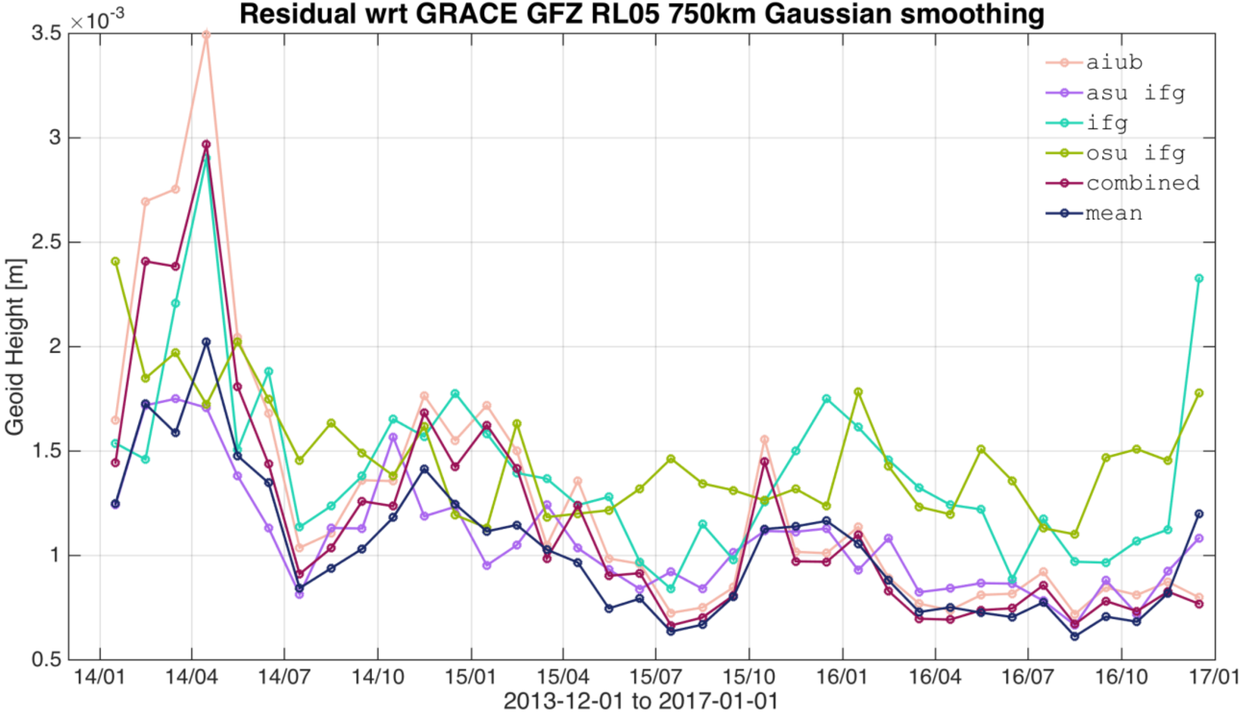
Global agreement with GRACE

- 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

- degree-RMS correlate well with the intensity of ionospheric disturbances

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



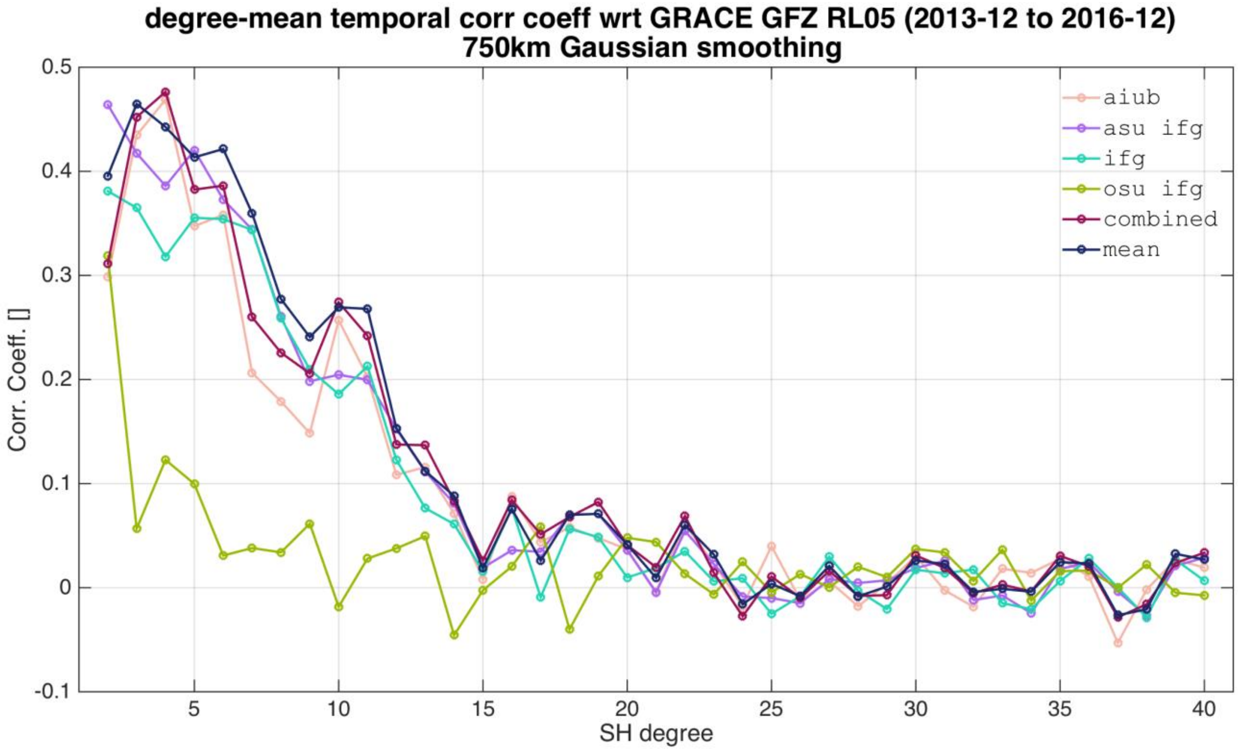
Spectral agreement with GRACE

- per-solution correlation coefficient between Swarm and GRACE (computed coefficient-wise, averaged over all orders)

- high correlation (considering it's an average) for degrees below 12

- OSU solution lacks temporal signature of GRACE

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

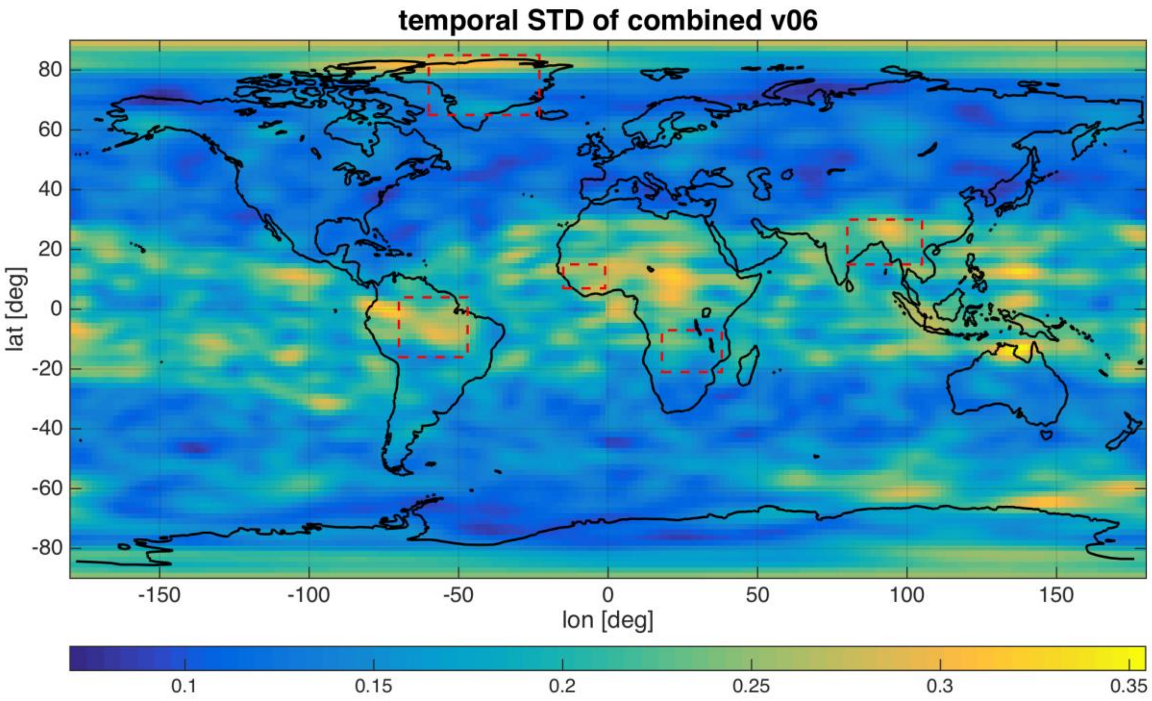


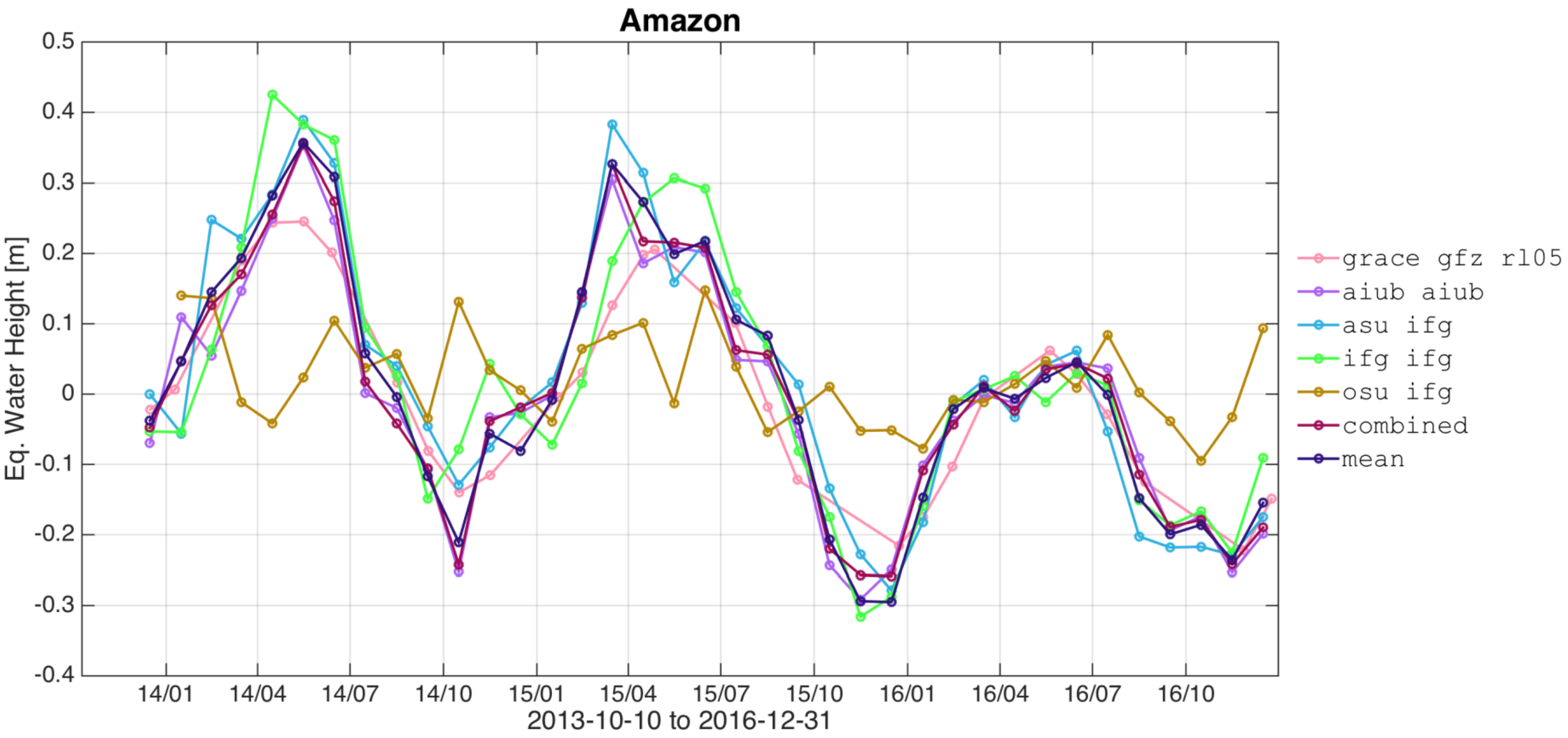
Basin time series

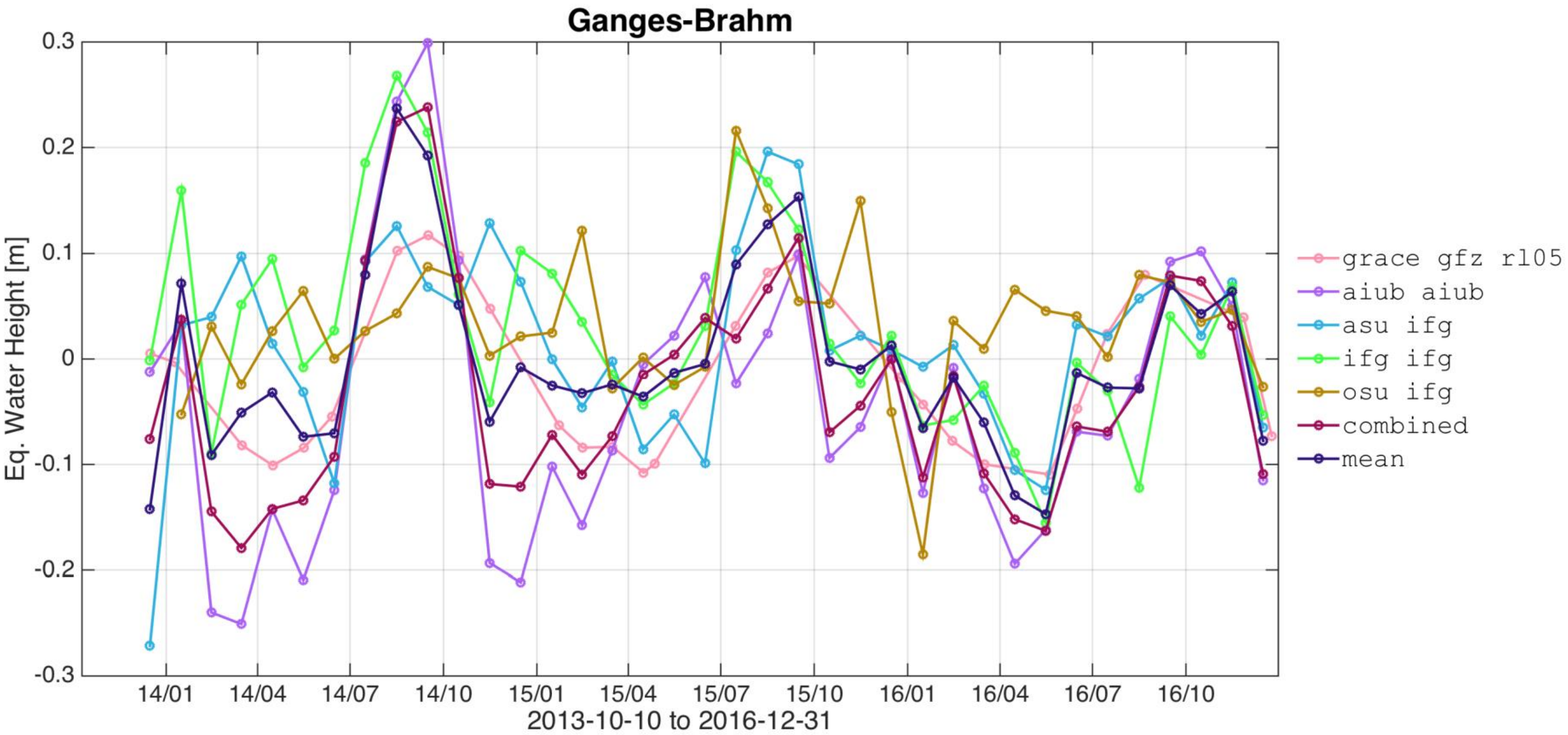
- Spatial variability (combined model):
- in Eq. Water Height [m]
- For 12/2013 – 12/2016

- Signature of geomagnetic equator is of similar amplitude as geophysical signal

- Basins analysed (red squares)
- Amazon
- Ganges Brahmaputra
- Greenland
- Western Sub-Sahara
- Zambezi




Amazon
Eq. Water Height [m]
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
14/01
14/04
14/07
14/10
15/01
15/04
15/07
15/10
16/01
16/04
16/07
16/10
2013-10-10 to 2016-12-31
grace gfz rl05
aiub aiub
asu ifg
ifg ifg
osu ifg
combined
mean



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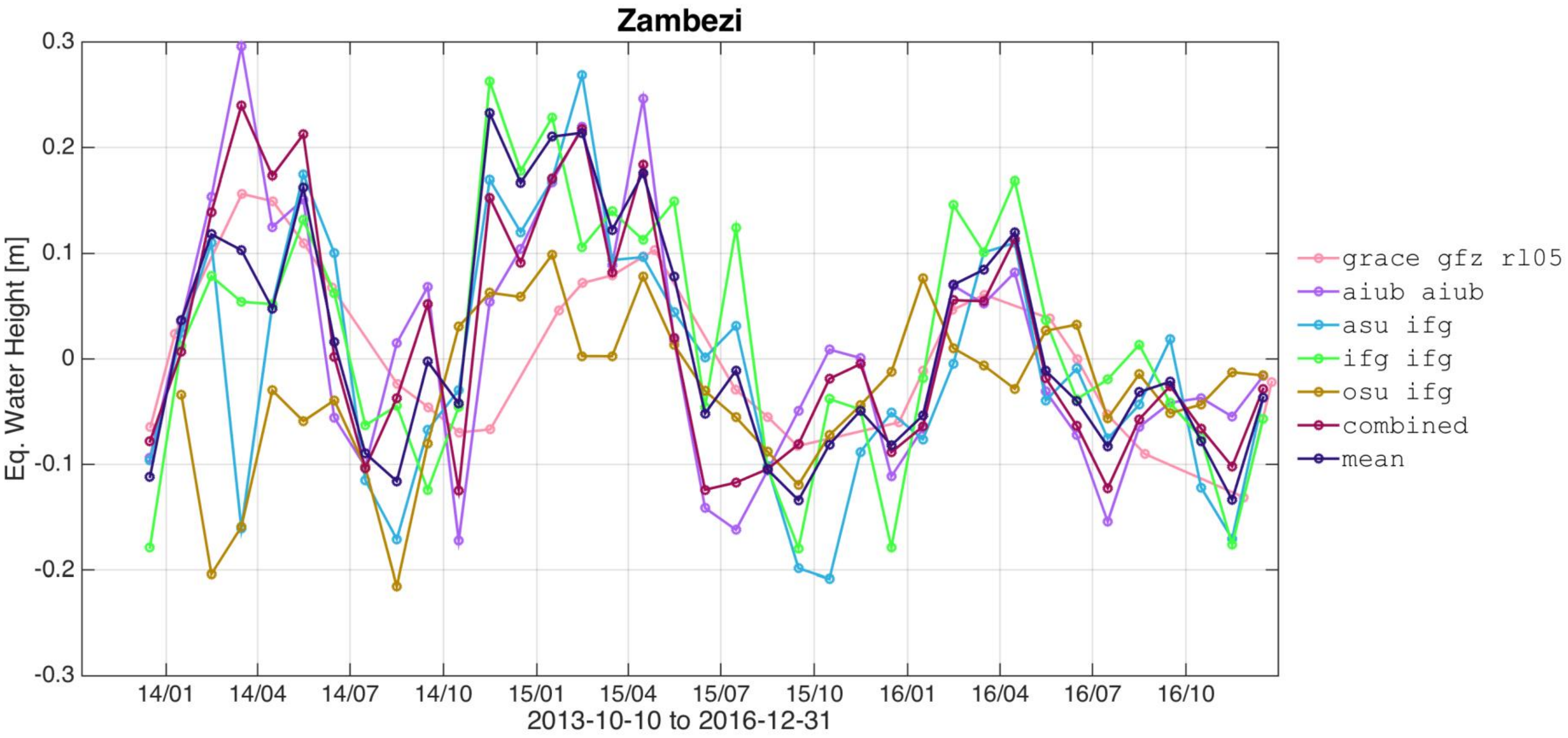
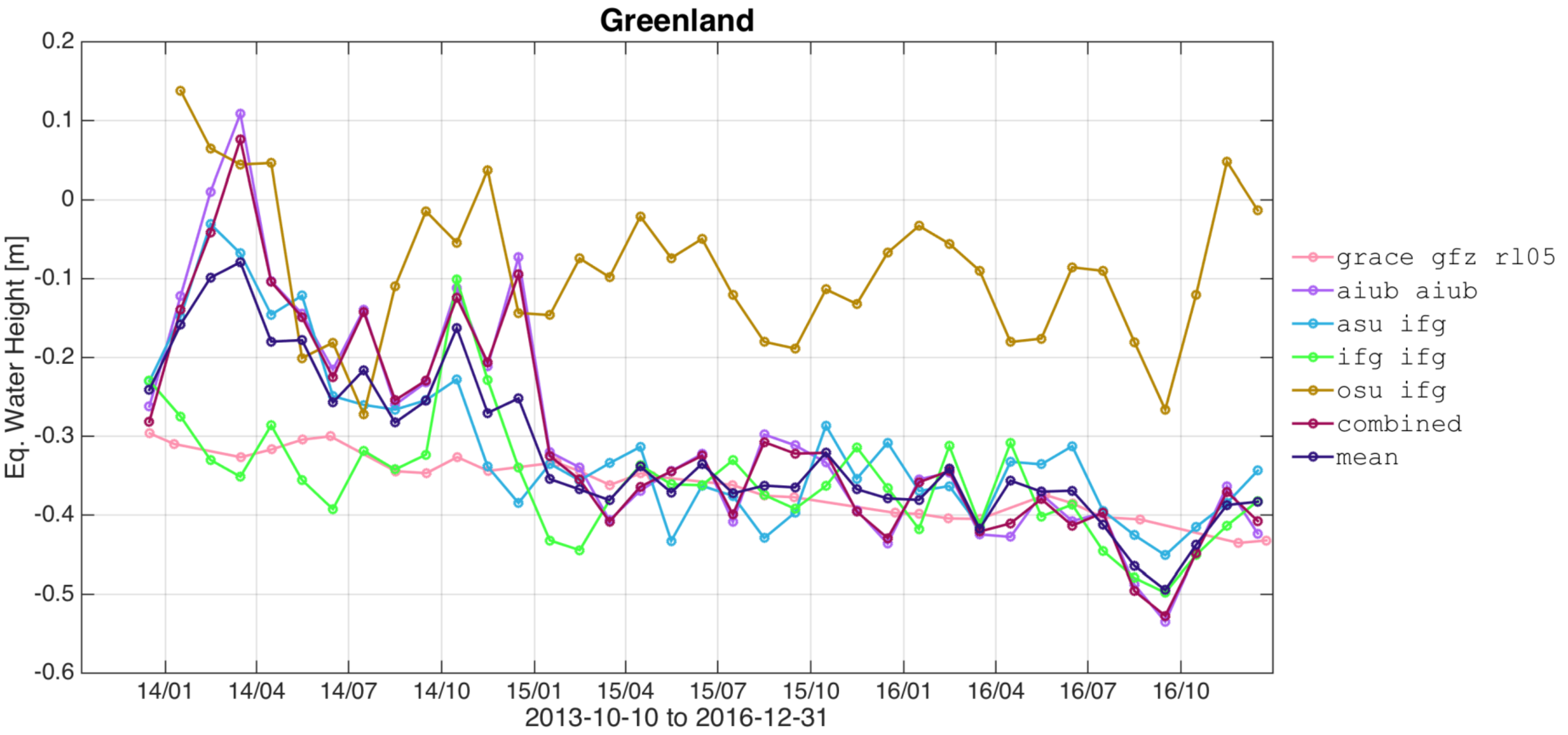


Zambezi
Eq. Water Height [m]
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
14/01
14/04
14/07
14/10
15/01
15/04
15/07
15/10
16/01
16/04
16/07
16/10
2013-10-10 to 2016-12-31
grace gfz rl05
aiub aiub
asu ifg
ifg ifg
osu ifg
combined
mean



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Summary and conclusions

- Global agreement with GRACE at **1 mm RMS**
  - with Gaussian smoothing radius of 750 km
  - over periods of low solar activity
- **Basin time series** well resolvable by Swarm
  - larger amplitudes than GRACE (reason unknown)
- **Arithmetic mean** is always superior to any individual solutions
- **Weighted combination** suffers from biases
- Combination at **Normal Equation** level needs empirical scaling to account for different formal error characteristics

Stay tuned!

Monthly NEQ-combined Swarm models:

- from Dec. 2013 to Set. 2018 (and onwards)
- publicly available **early 2019**

Research Gate project webpage

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