On the capability of non-dedocated GPS-tracked satellite constellations for estimating mass variations: *case study SWARM*

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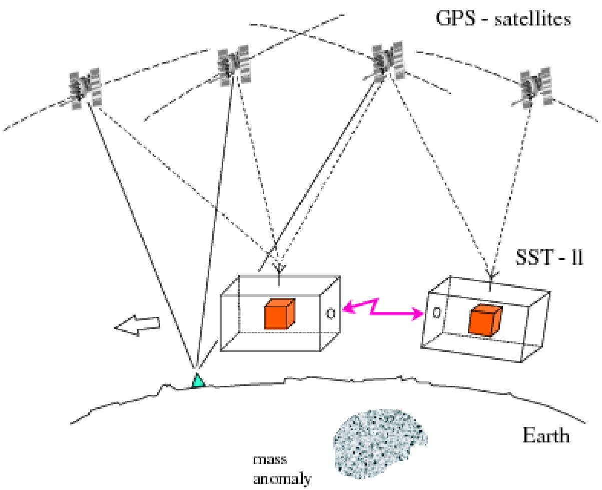
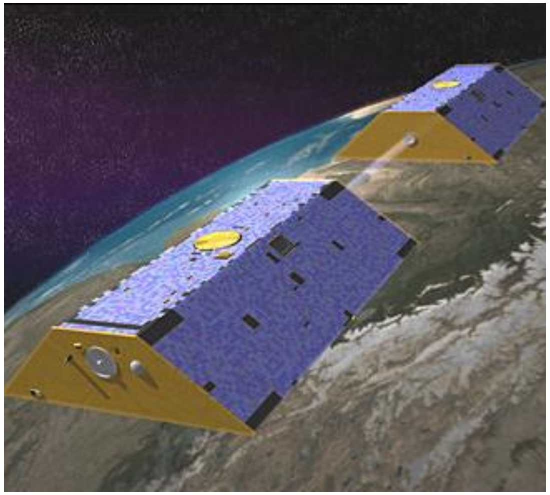
GRACE and GRACE Follow-On

low-low-SST





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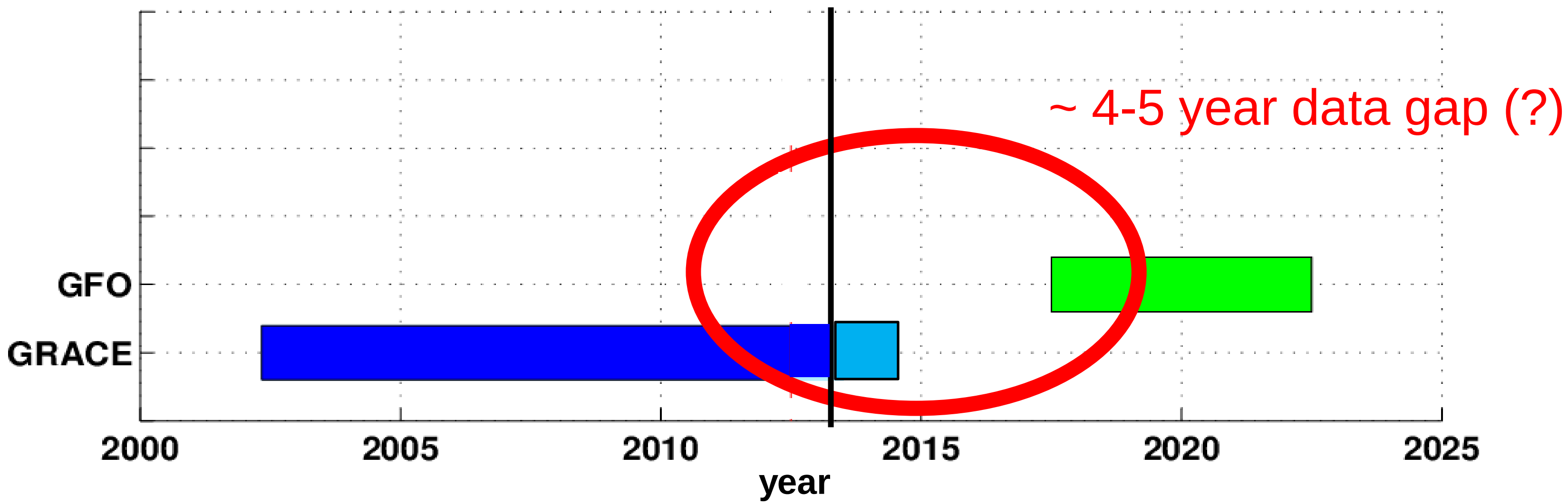
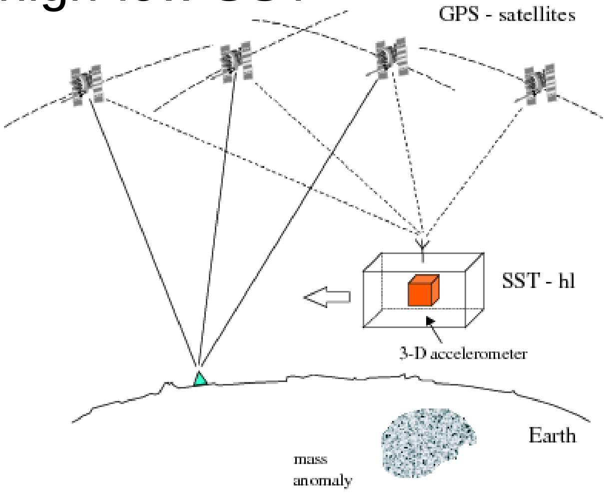
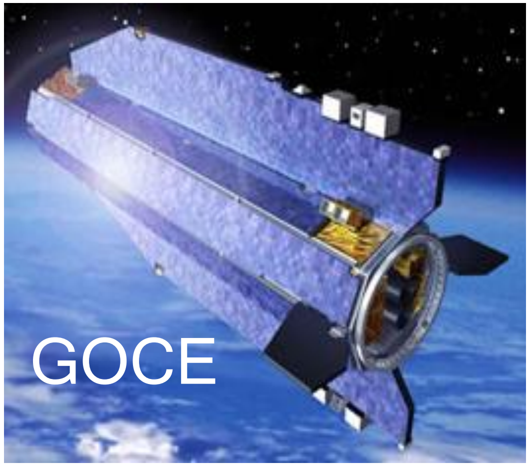
- K-Band (Laser)
- GPS
- Accelerometer



Other gravity field missions

high-low SST





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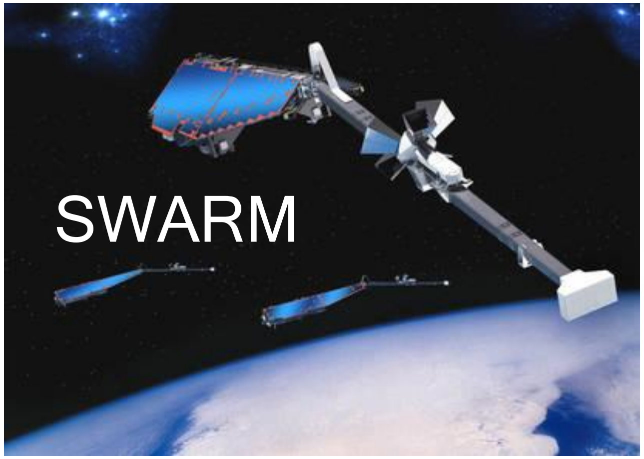

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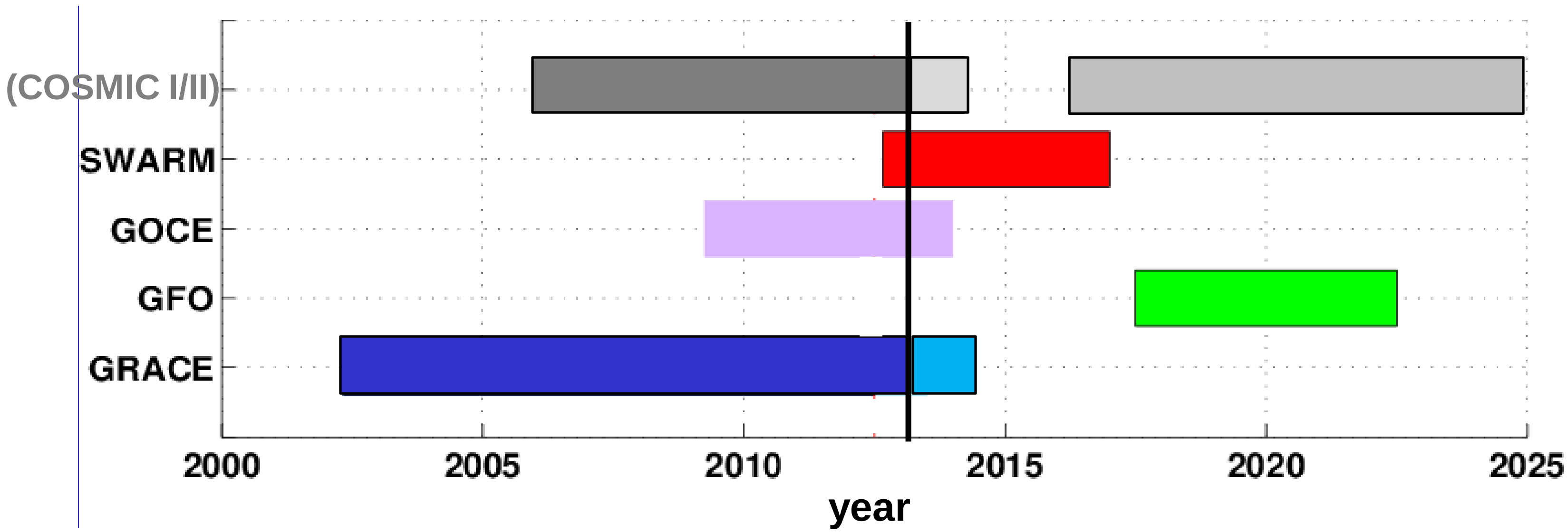
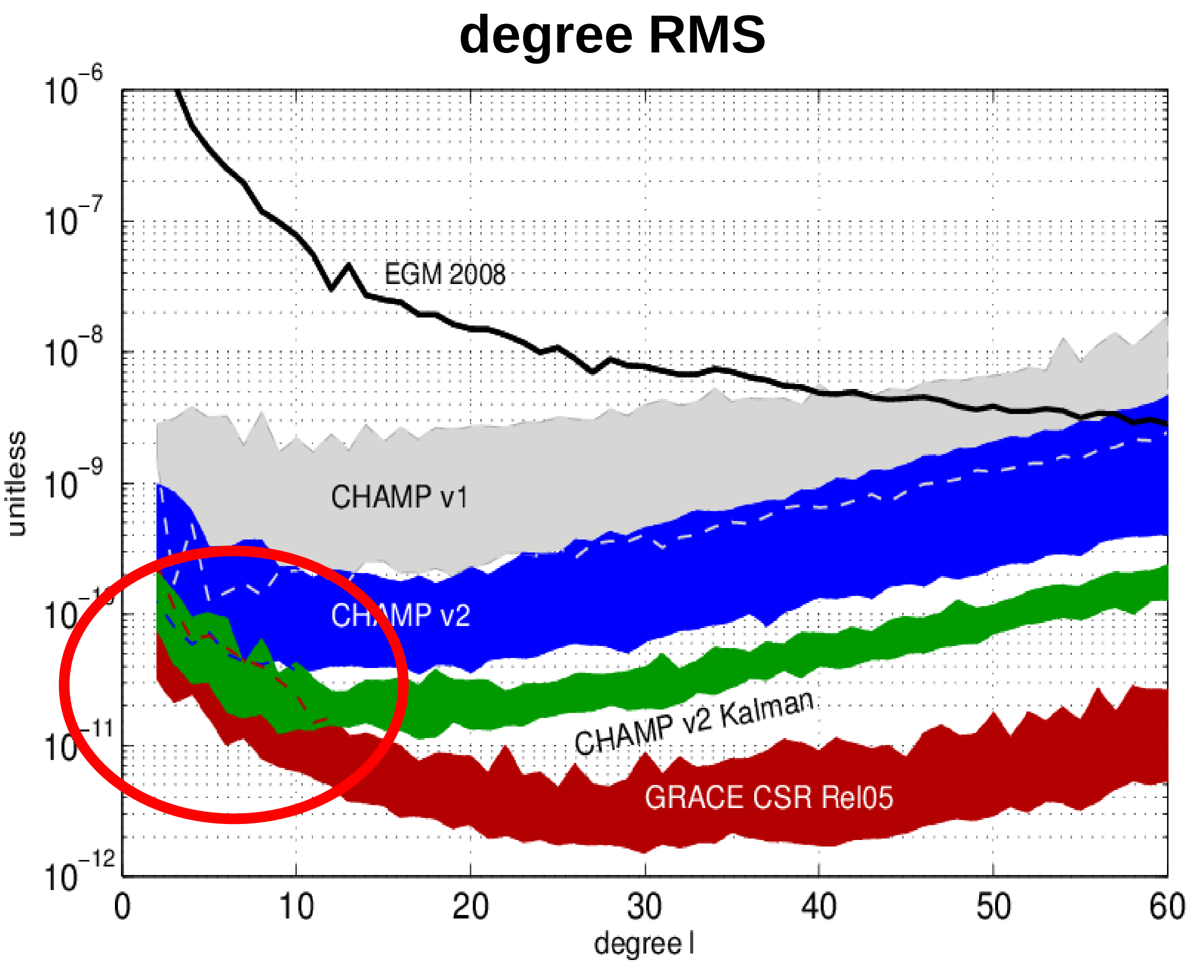


CHAMP reprocessing



(source: Weigelt et al. 2012)

GPS positions

- 10 s sampling
- empirical absolute antenna phase center model

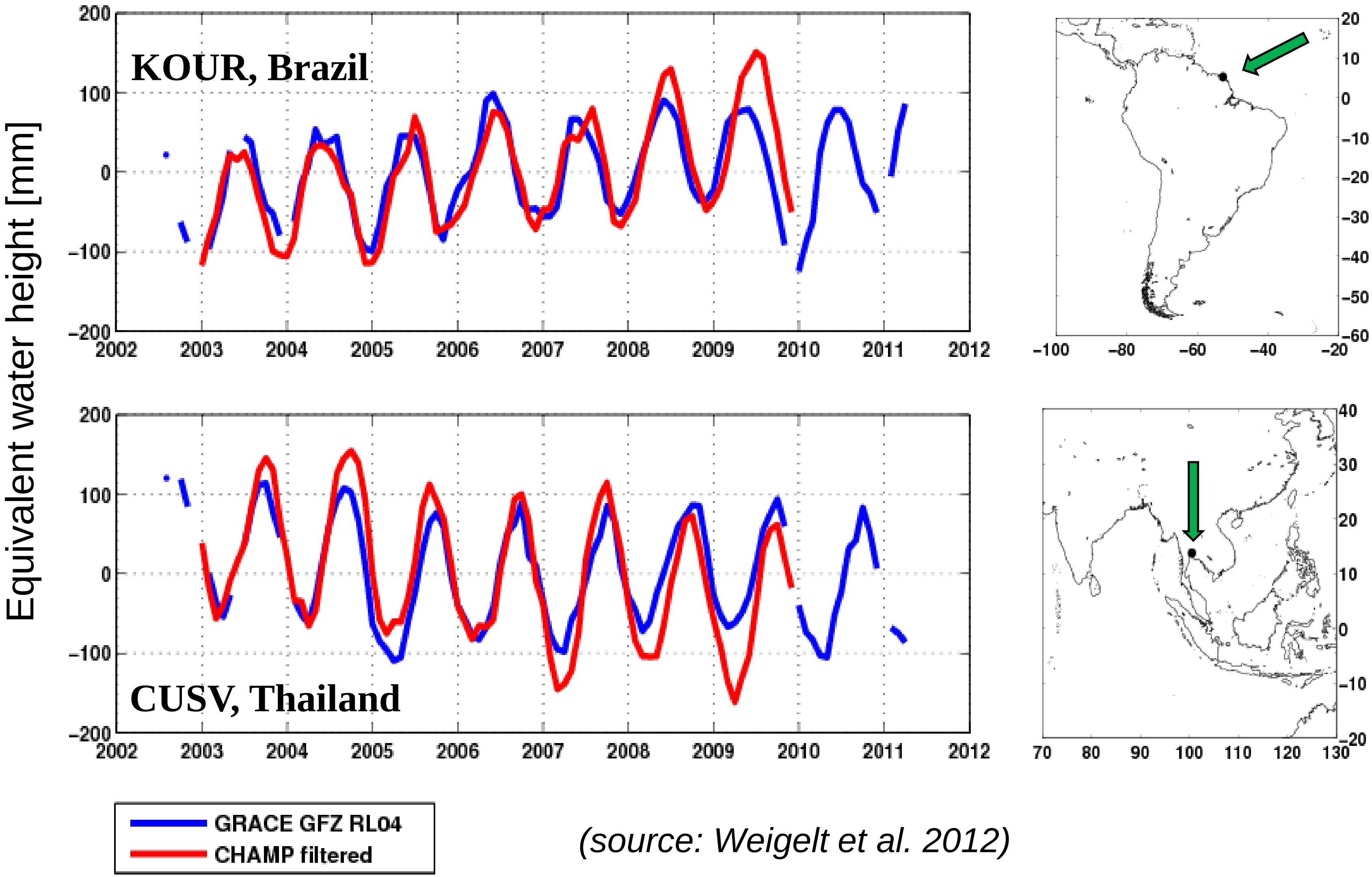
Approach

- acceleration approach
- no regularization and no *a priori* information

Kalman filter:

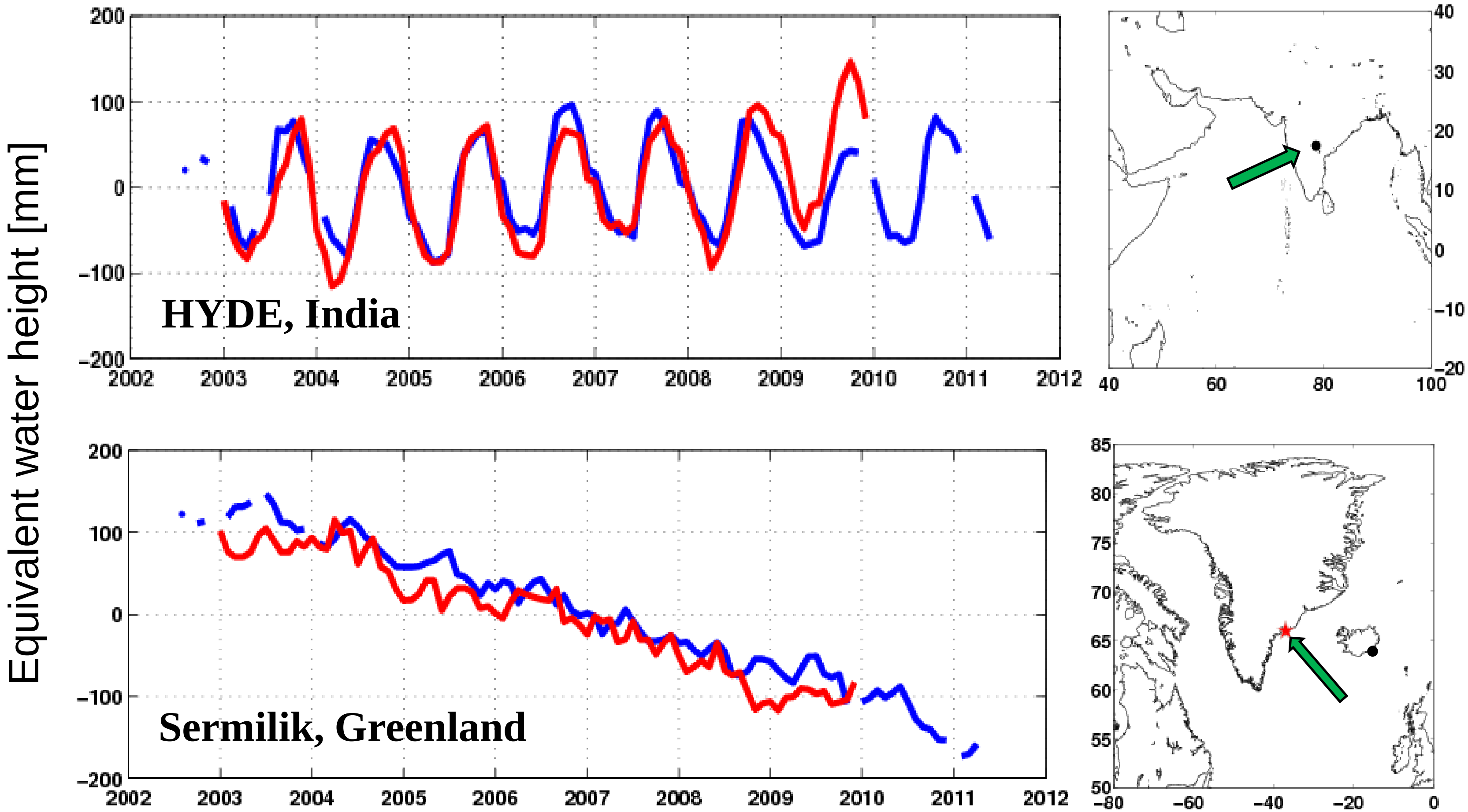
- prediction model:
  - trend
  - mean annual signal

CHAMP results – time series



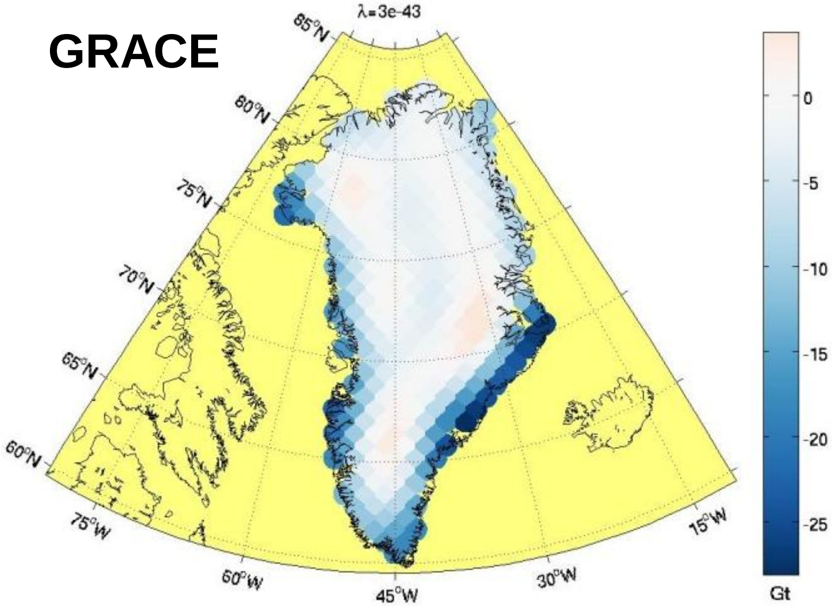
(source: Weigelt et al. 2012)

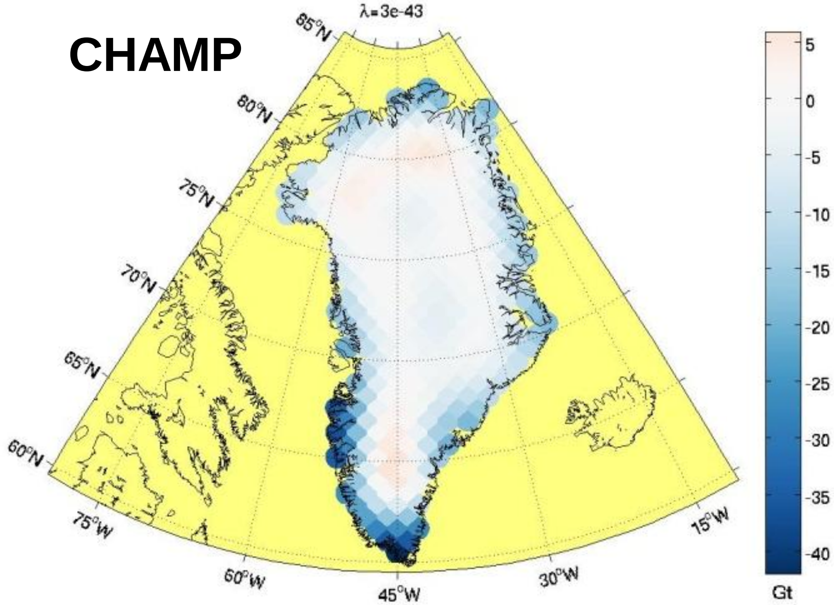
CHAMP results – time series



(source: Weigelt et al. 2012)

CHAMP results – ice mass loss



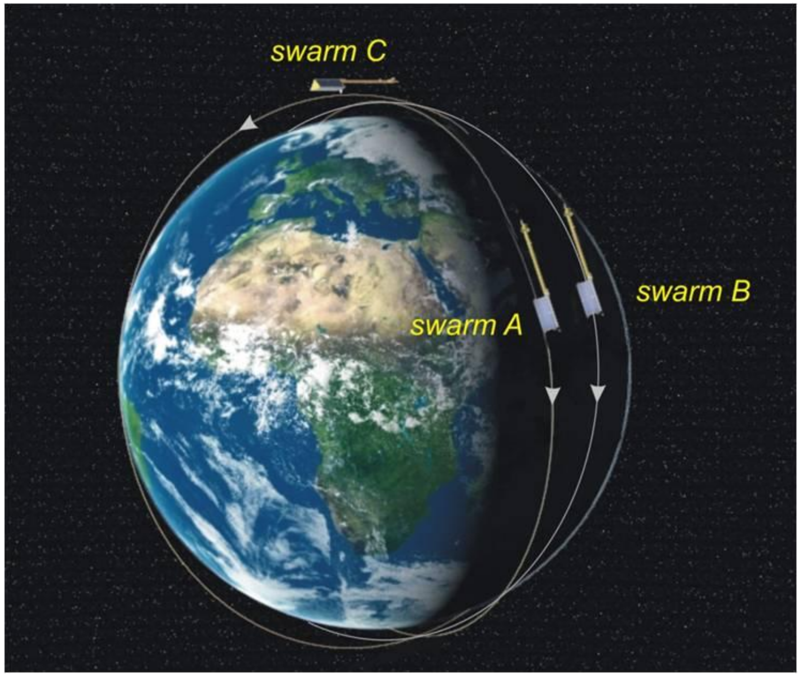


Change rates [Gt/yr] from point mass approach (no GIA correction applied)

(source: Baur (2012))

	Spectral resolution	GRACE	CHAMP	Error (%)
1	60	-223	-267	20
2	30	-222	-252	14
3	20	-218	-242	11
4	10	-203	-211	4

SWARM mission



(source: ESA (2004))

SWARM main goals

- magnetic field
- ionosphere/thermosphere probing

SWARM lifetime

- (planned) lauch: Dec. 2013
- 4-5 years nominal lifetime

SWARM orbit parameters

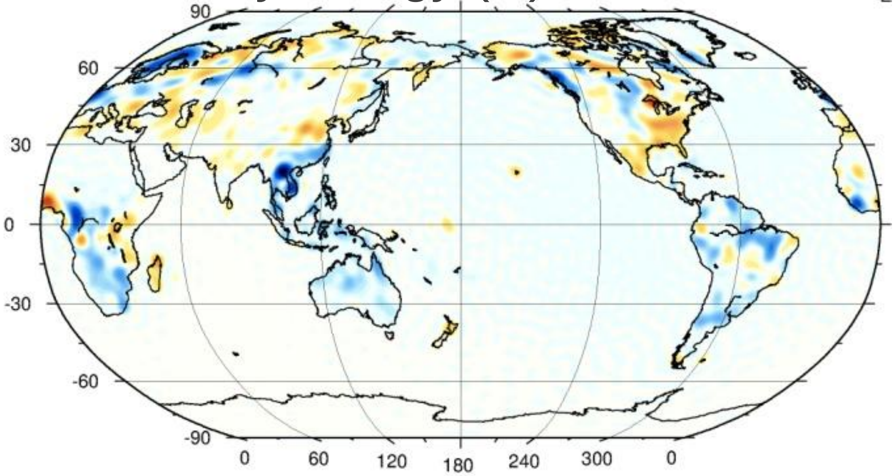
satellite A: h ≈ 455 - 330 km
$I = 87.3°$; $M_0 = 0°$; $\Omega_0 = 0°$

satellite B: h ≈ 455 - 330 km
$I = 87.3°$; $M_0 = 0.5°$; $\Omega_0 = 1.4°$

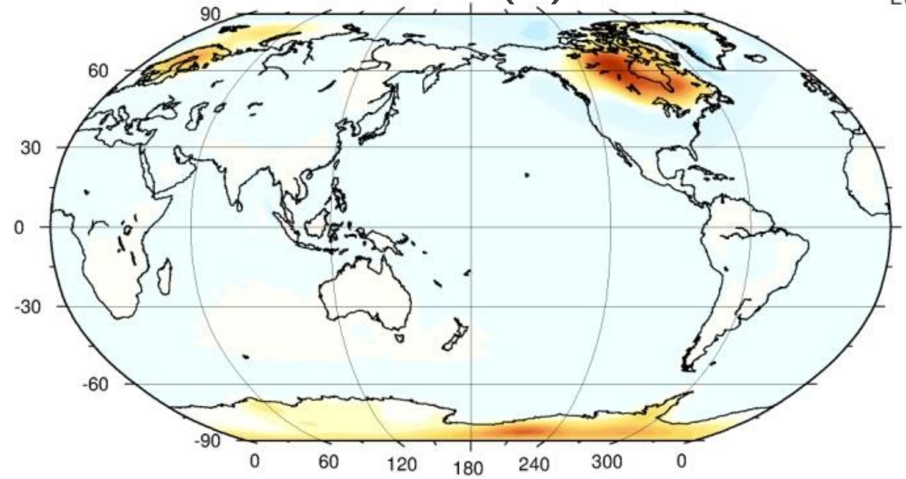
satellite C: h ≈ 530 - 515 km
$I = 88°$; $M_0 = 0°$; $\Omega_0 = 0°$

Trends of input mass fields

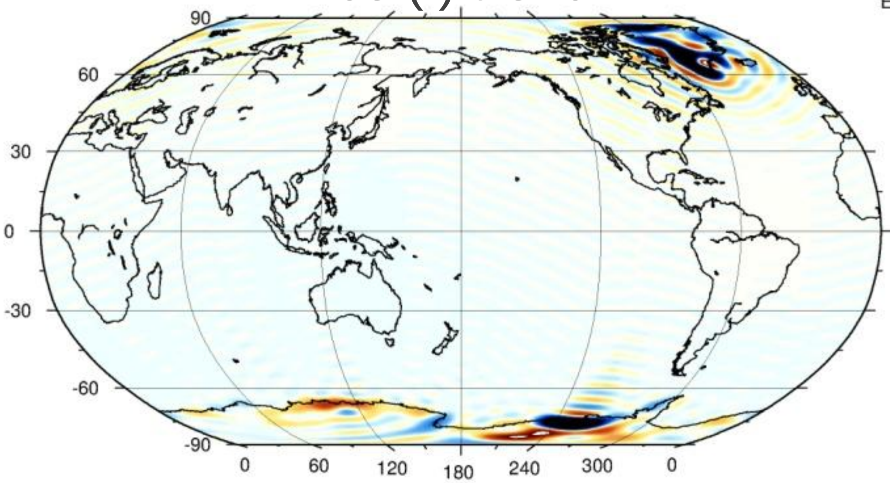
hydrology (H) trend



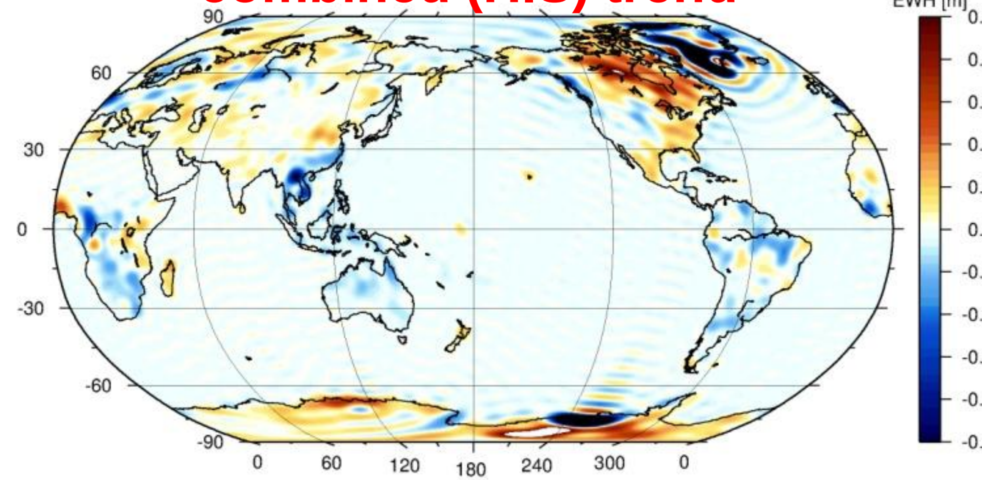
solid Earth (S) trend



ice (I) trend



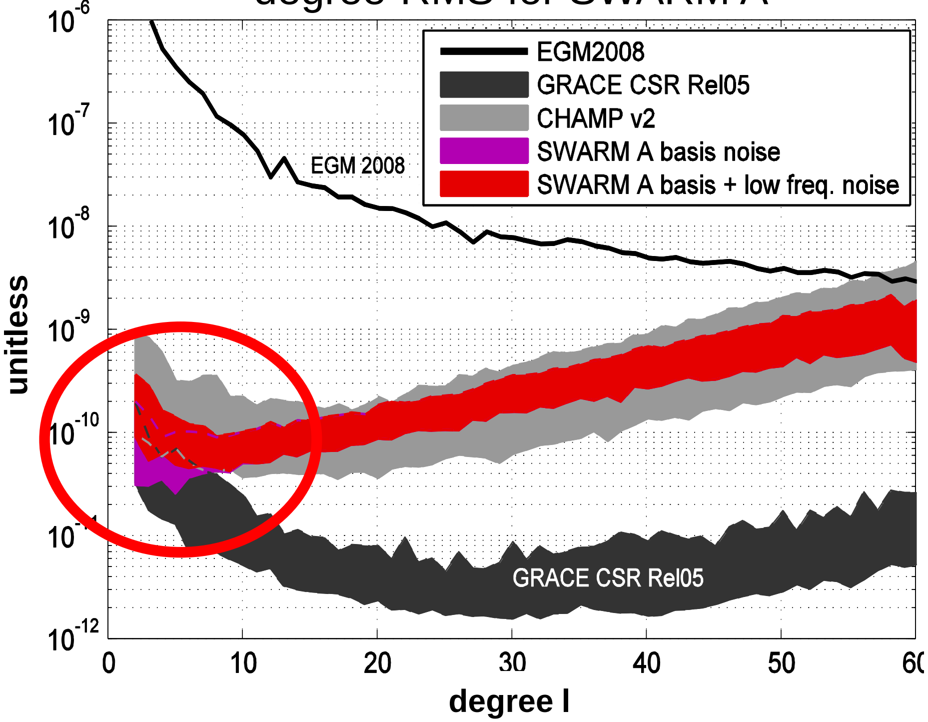
combined (HIS) trend



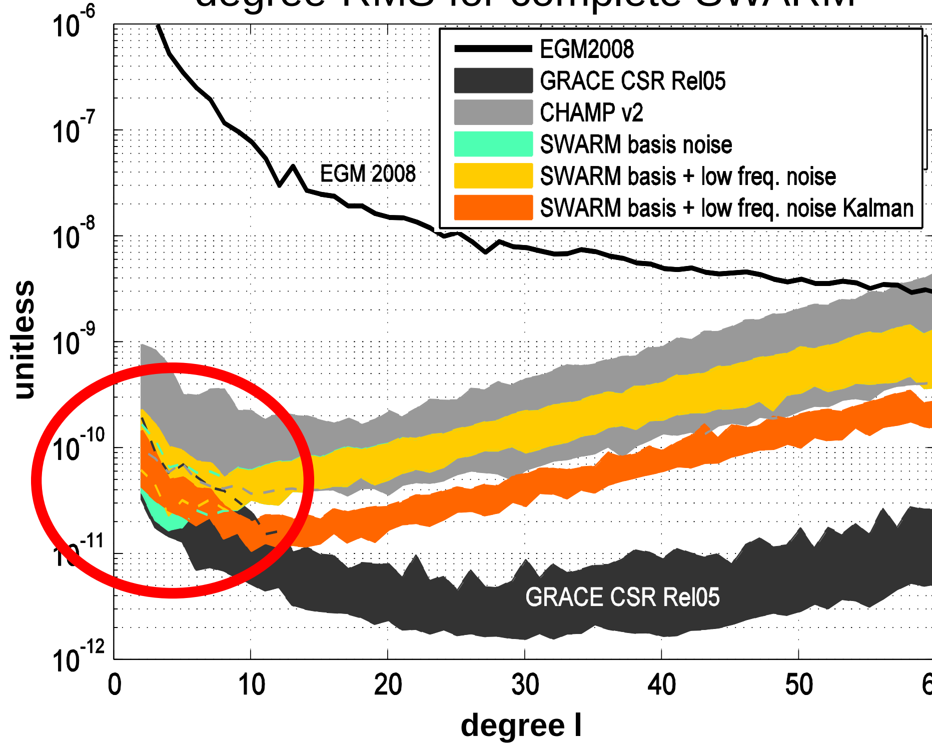
time-period J2000 - J2004; L_{max} = 60; AOHIS fields from Gruber et al. 2011, H from MERRA

SWARM vs. CHAMP and GRACE solutions

degree-RMS for SWARM A



degree-RMS for complete SWARM



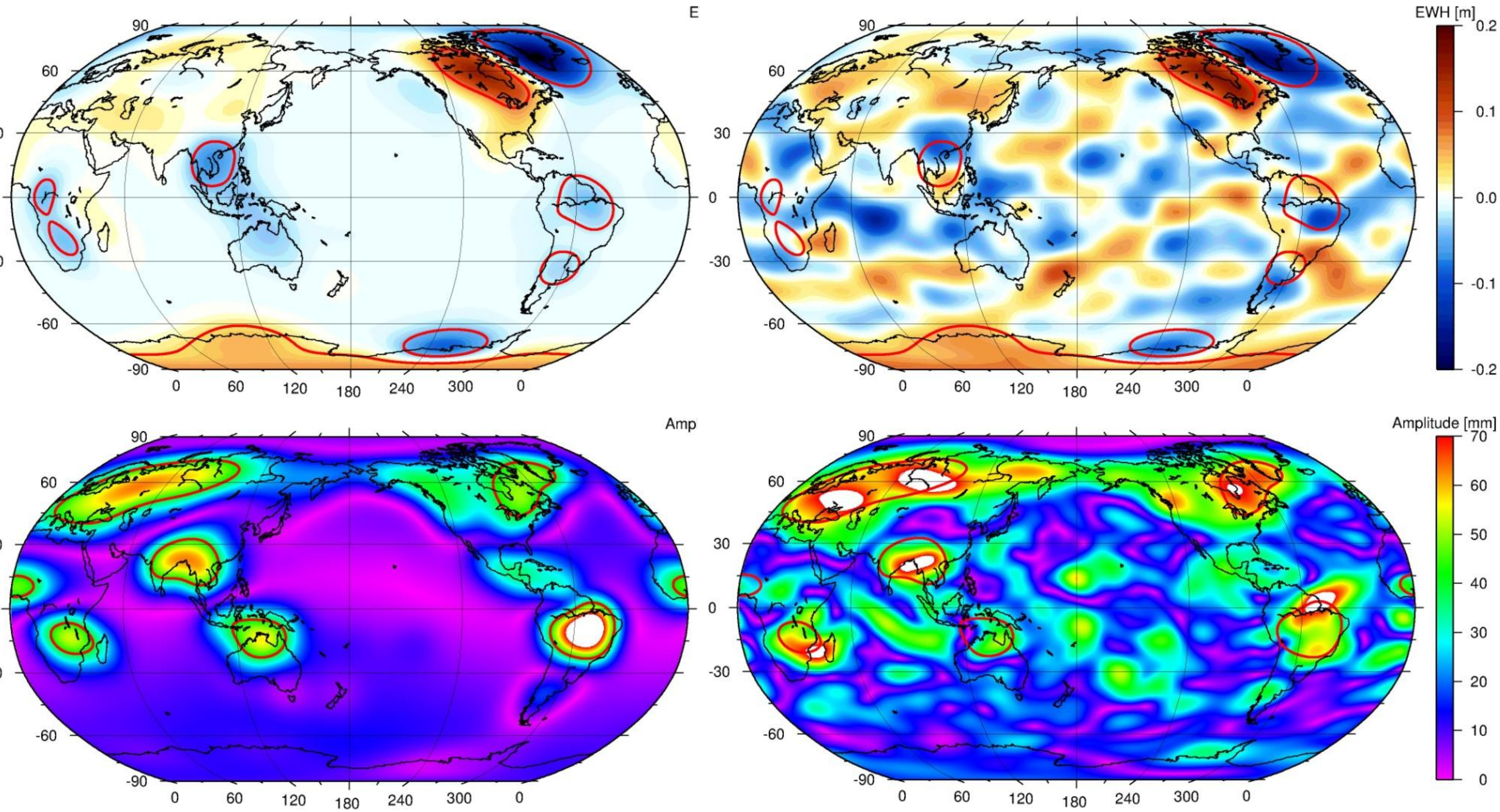
maximum degree:	$L = 60$
sampling-time:	$\Delta t = 5$ s
background errors:	30% of AOHIS
tidal error:	EOT08a – GOT4.7
orbit noise:	$\sigma_X = 4$ cm, coloured

SWARM trend/annual amplitude

Input fields (HIS) | **SWARM basis + low. freq. noise**

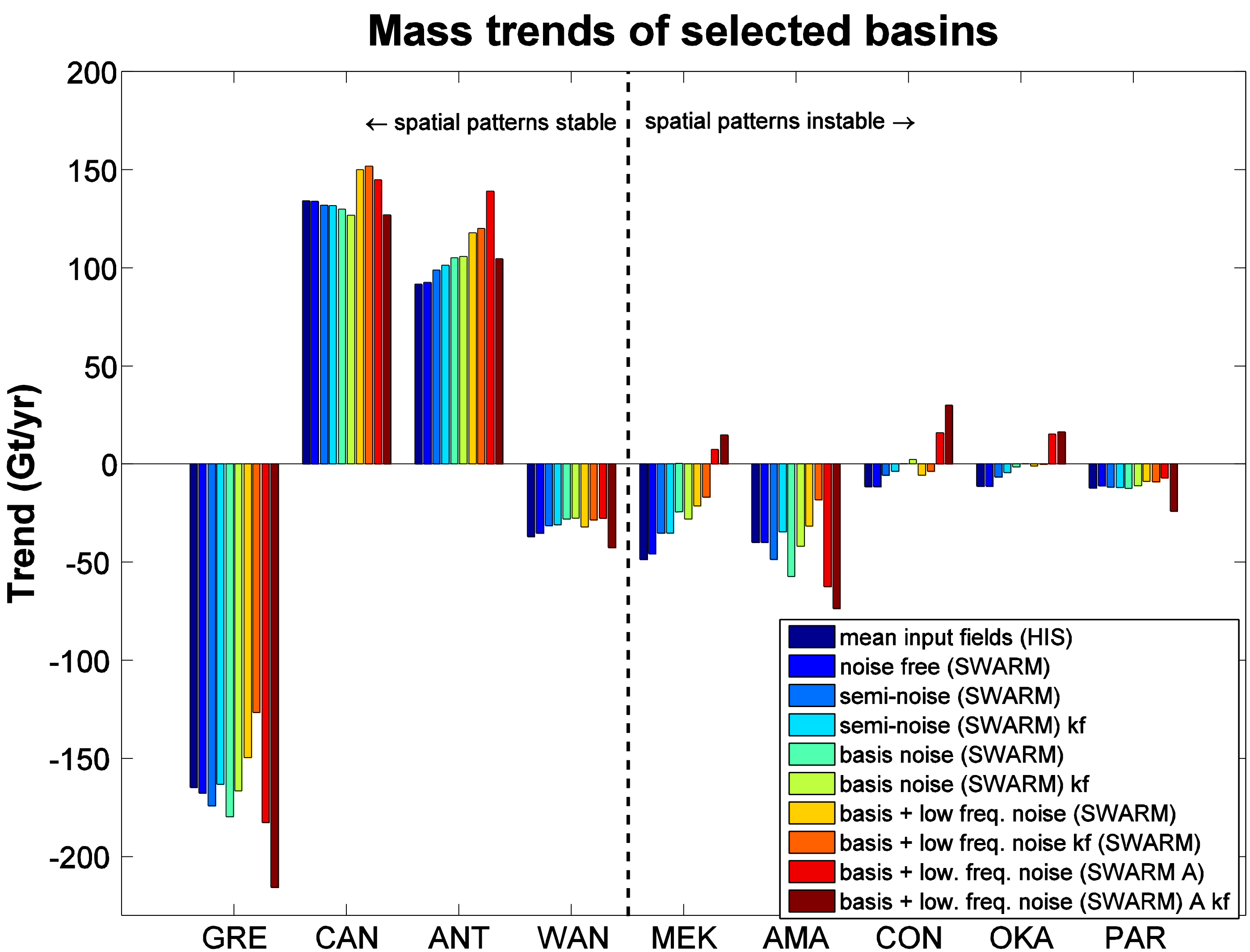
trend

annual amplitudes



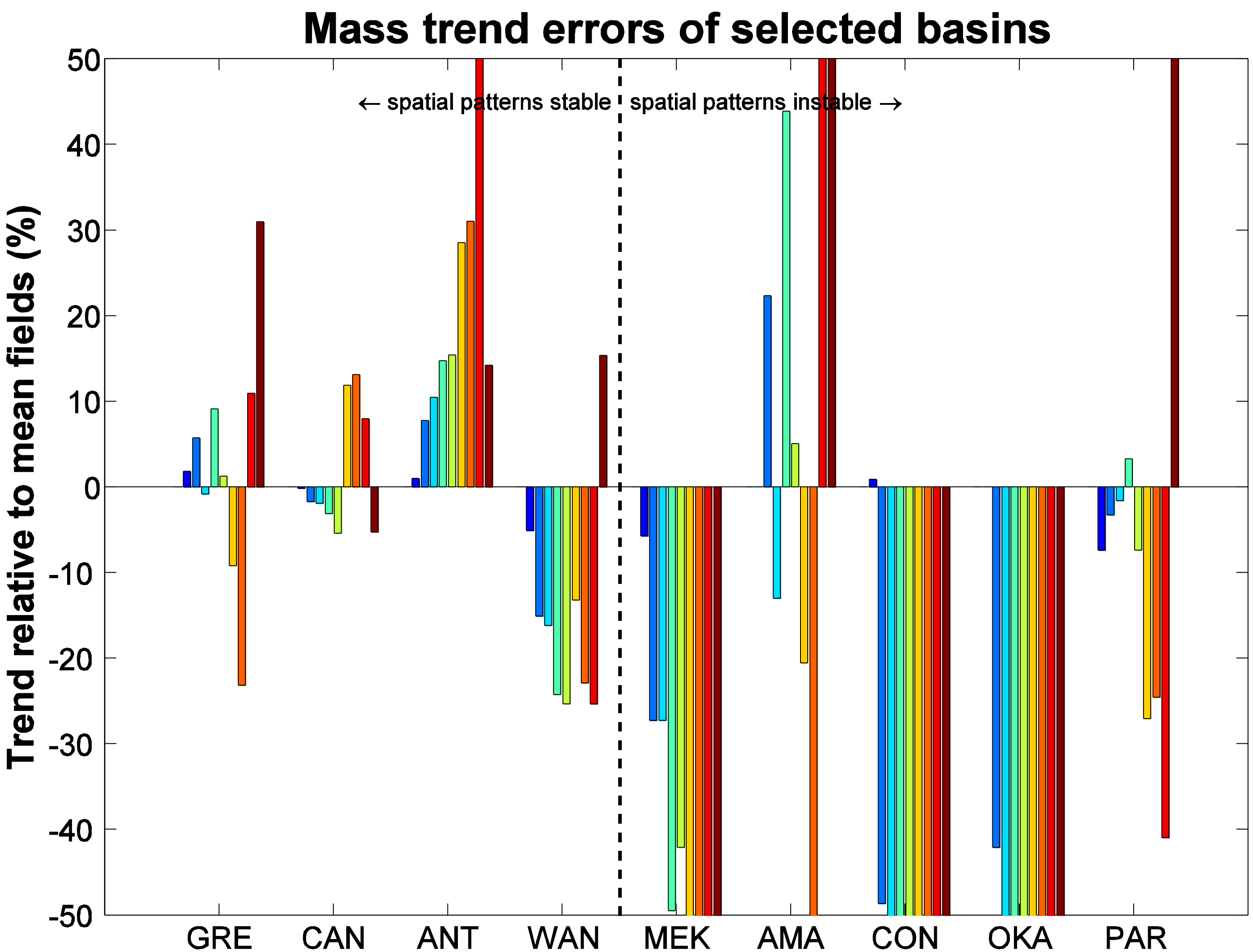
Gaussian smoothing (spatial averaging) with a radius of 1000 km applied

SWARM basin mass trends



Greenland (**GRE**)
Canada (**CAN**)
Amazon (**AMA)**
Antarctica (**ANT**)
West-Antarctica (**WAN**)
Mekong (**MEK**)
Okawango (**OKA**)
Congo (**CON**)
Parana (**PAR**)

SWARM basin mass trend errors



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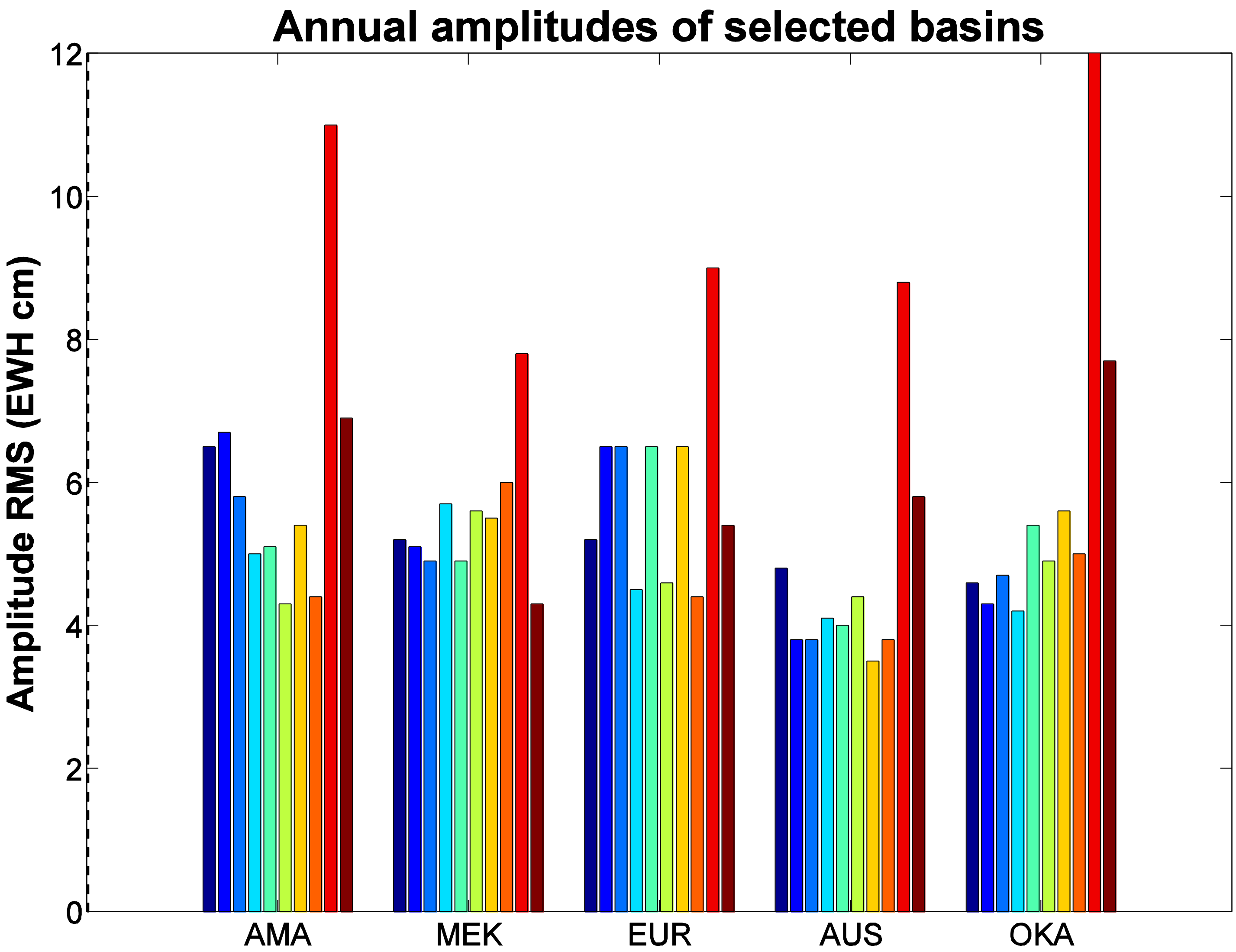
Congo (**CON**)
Parana (**PAR**)

SWARM basin annual amplitudes



Amazon (**AMA)**

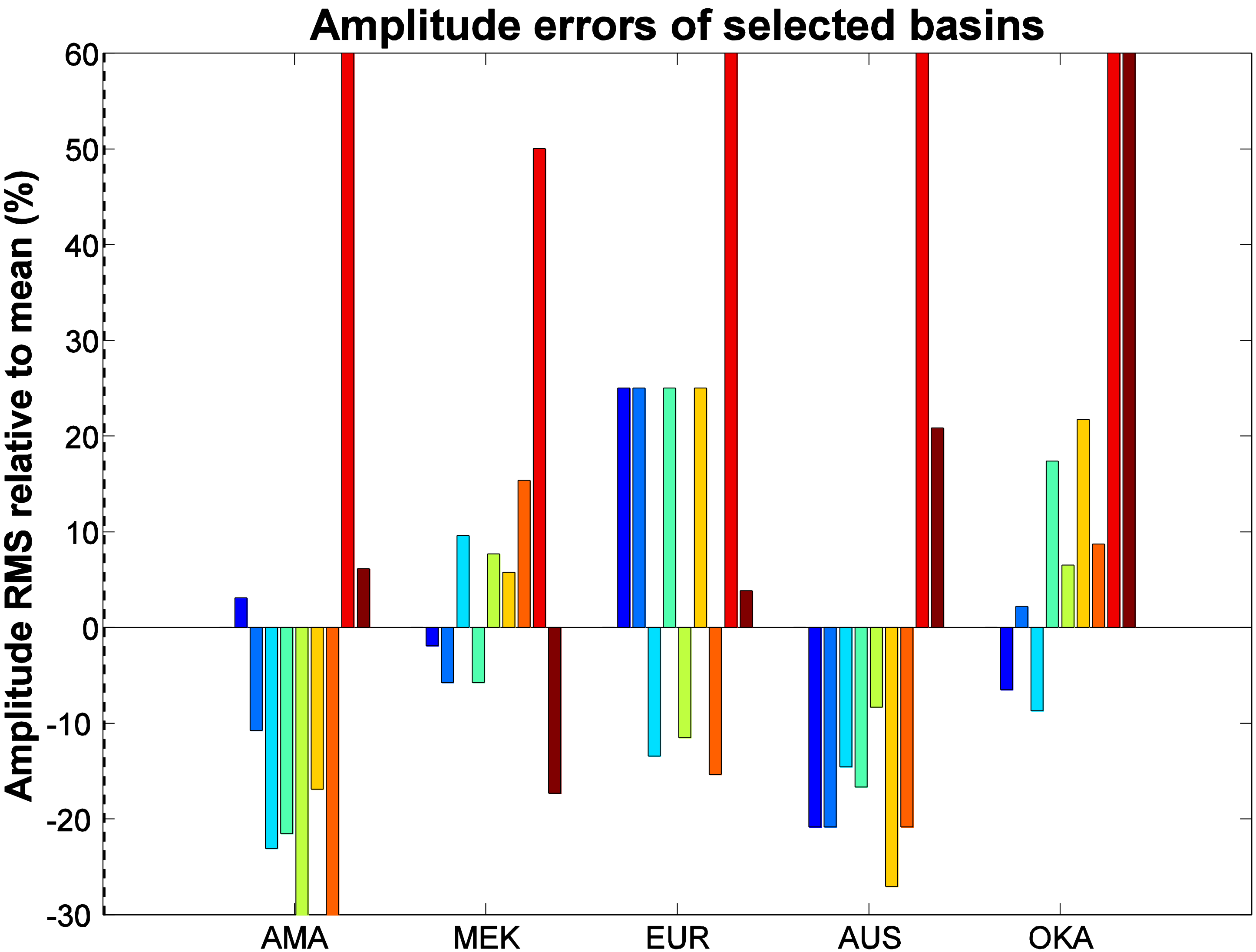
Mekong (**MEK**)

Eurasia **(EUR)**

Australia **(AUS)**

Okawango (**OKA**)

SWARM basin annual amplitude errors



Amazon (**AMA)**
Mekong (**MEK**)
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Australia **(AUS)**
Okawango (**OKA**)

Results/conclusions

- SWARM (CHAMP) and GRACE solutions overlap for low degrees

  → *sensitivity of hl-SST to long wavelength time-variability*

- CHAMP results demonstrate that mass trend estimation is possible from hl-SST

- basins with strong signals (e.g. GRE, CAN, ANT) show in our SWARM simulations little affected spatial patterns and normal signal strength

  → *estimation within 10% - 30% (Greenland: 10%).*

- Kalman-filtering is able to reduce errors of solutions with larger error source (e.g. CHAMP,SWARM 'basis + low freq. noise'), but might also reduce signals, especially for scenarios of lower noise.

- We conclude that SWARM is likely able to see time variable gravity field patterns, especially where the signals are strong.

→ *valuable source of information for GRACE/GFO gap filling*.

References

Baur O (2013) Greenland mass variation from time-variable gravity in the absence of GRACE. Geophys. Res. Let. 40, 1-5, doi:10.1002/grl.50881, 2013

ESA (2004) SWARM – The Earth‘s Magnetic Field and Environment Explorers. ESA SP-1279(6), ESA/ESTEC, Noordwijk, The Netherlands

Gruber T et al. (2011) Simulation of the time-variable gravity field by means of coupled geophysical models. Earth System Science Data, 3:19–35, doi:10.5194/essd-3-19-2011.

Weigelt M, Jäggi A, Prange L, Chen Q, Keller W, Sneeuw N (2012) Time variability from high-low SST - filling the gap between GRACE and GFO. International Symposium GGHS, 9-12 Oct 2012, Venice, Italy.

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