HLSST and SLR - bridging the gap between GRACE and GRACE Follow-on

M. Weigelt, A. Jäggi, U. Meyer, D. Arnold,

A. Grahsl, K. Sośnica, Ch. Dahle, F. Flechtner

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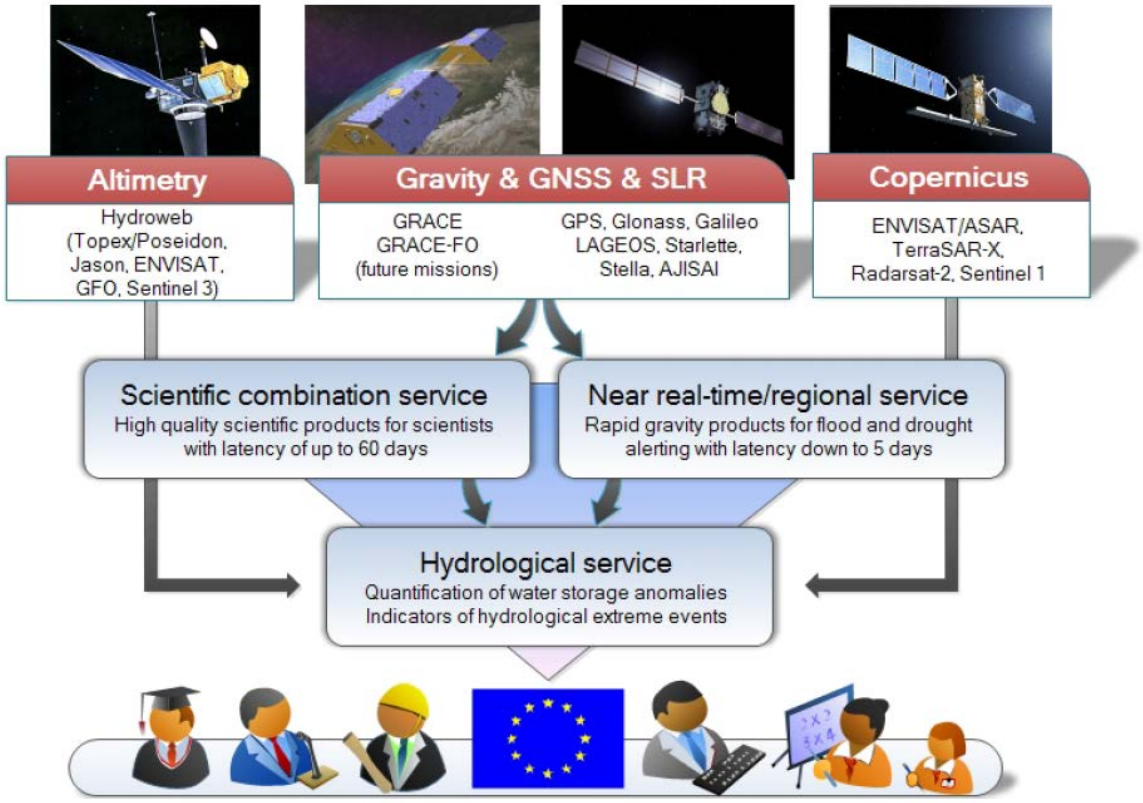
Relativistic geodesy and gravimetry with quantum sensors

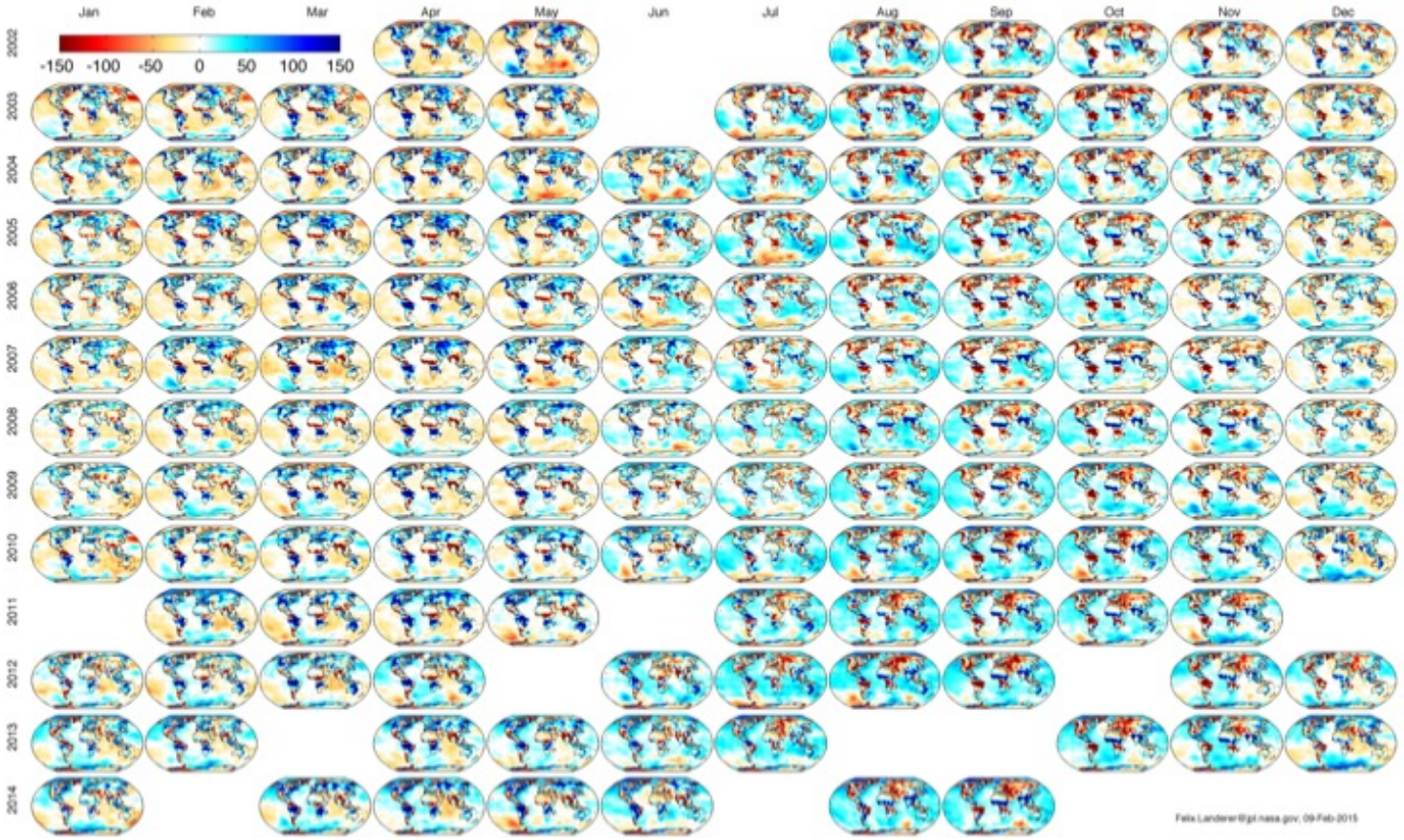
Motivation

- Combination of gravity field solutions from different sources for better gravity field solutions
- Bridging the gap between GRACE and GRACE-FO
- Cross-validating GRACE and GRACE-FO



Motivation

- Filling the gaps of GRACE



courtesy Felix Landerer using JPL mascons – Watkins et al. 2015

- Study multi-satellite environments (e.g. sampling)

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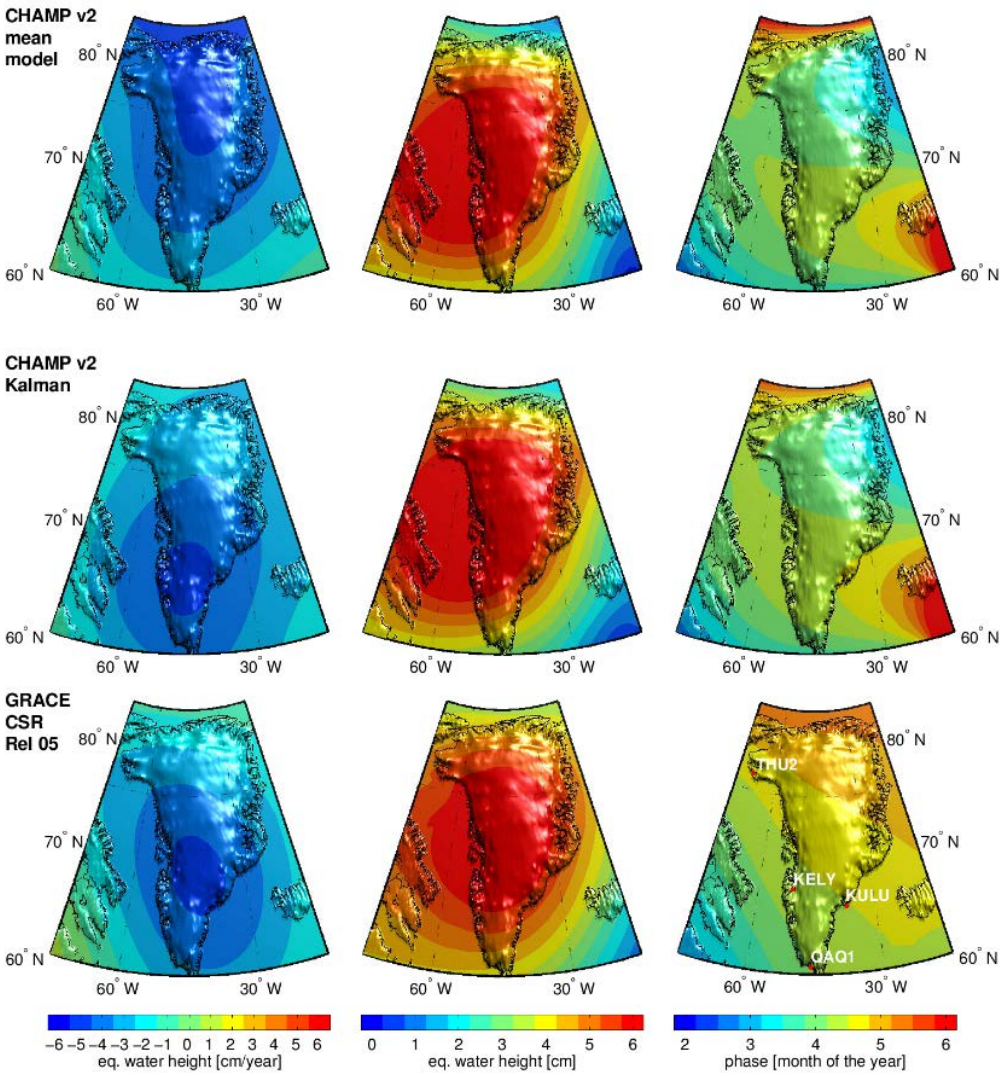
So far …

- Time-variable gravity from CHAMP
- Time-variable gravity from GOCE, e.g. Bouman et al. 2012
- Combination of solutions of various HLSST missions
- Combination HLSST + SLR
- Here we present an empirical method for combining HLSST data sets and an extend time series



Combining HLSST solutions

HLSST data processing

Approach:

- Kinematic orbits from AIUB, ITSG and IfE comprising 36 kinematic orbit products from 24 satellites
- Acceleration approach
- Accelerometer data used if feasible
- GRACE standard background models

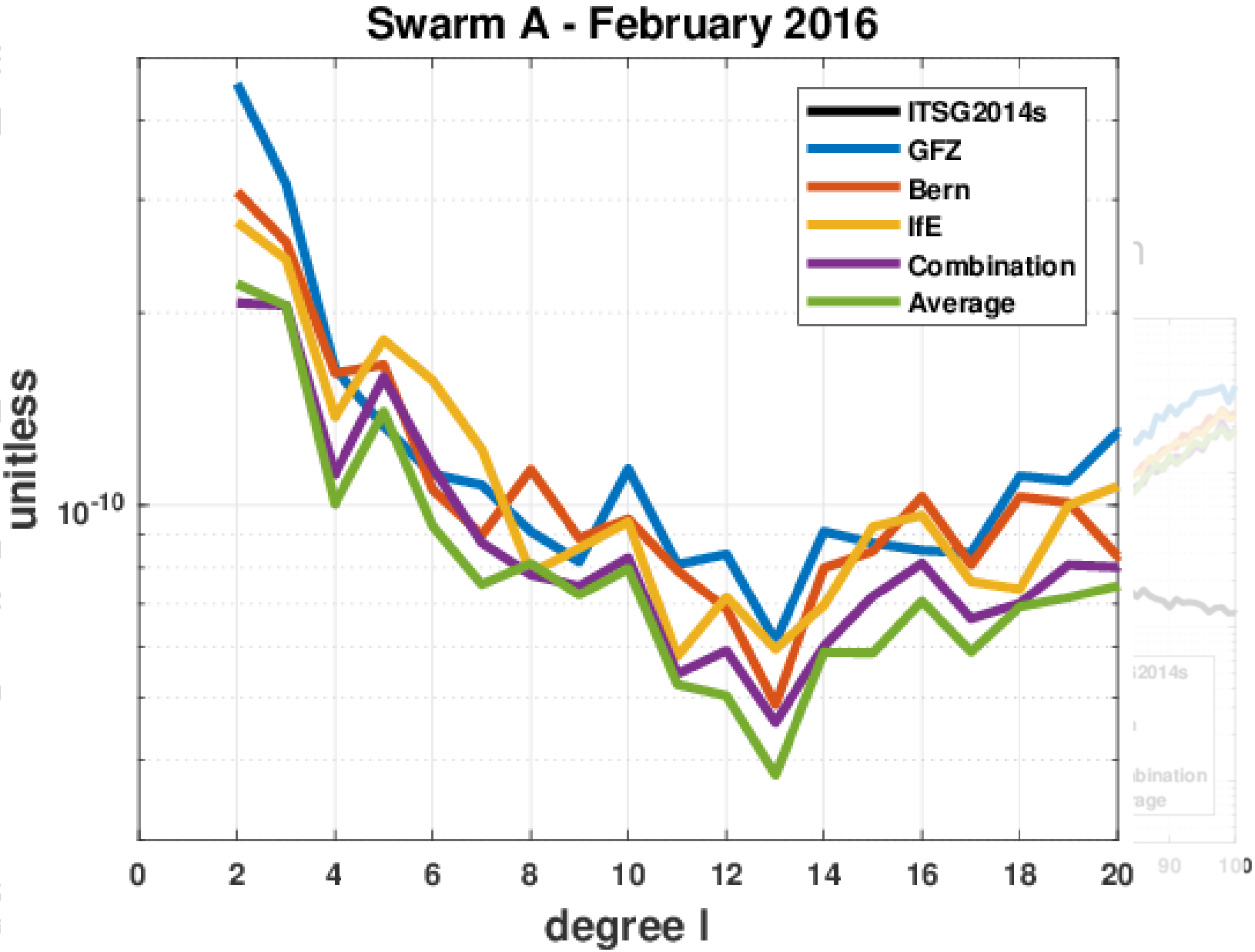
More details on e.g. orbit/gravity:

- Arnold et al. (Poster Nr. X3-104)
- Ren and Schön (Poster Nr. X3-105)
- Bezdek et al. (Poster Nr. X3.106)

Combination

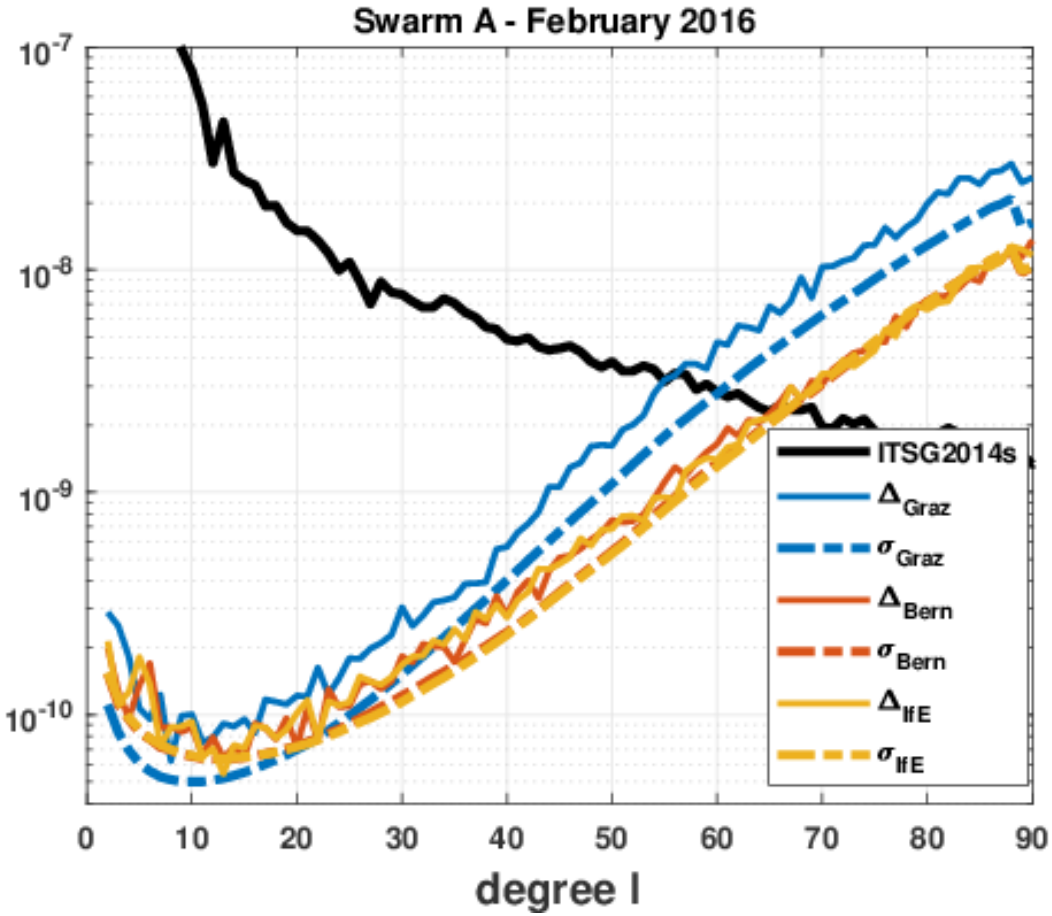
- Normal equation level
- Empirical stochastic error modelling based on residuals
- **Empirical relative weighting approach**
- No regularization and no a priori model / information

Empirical relative weighting



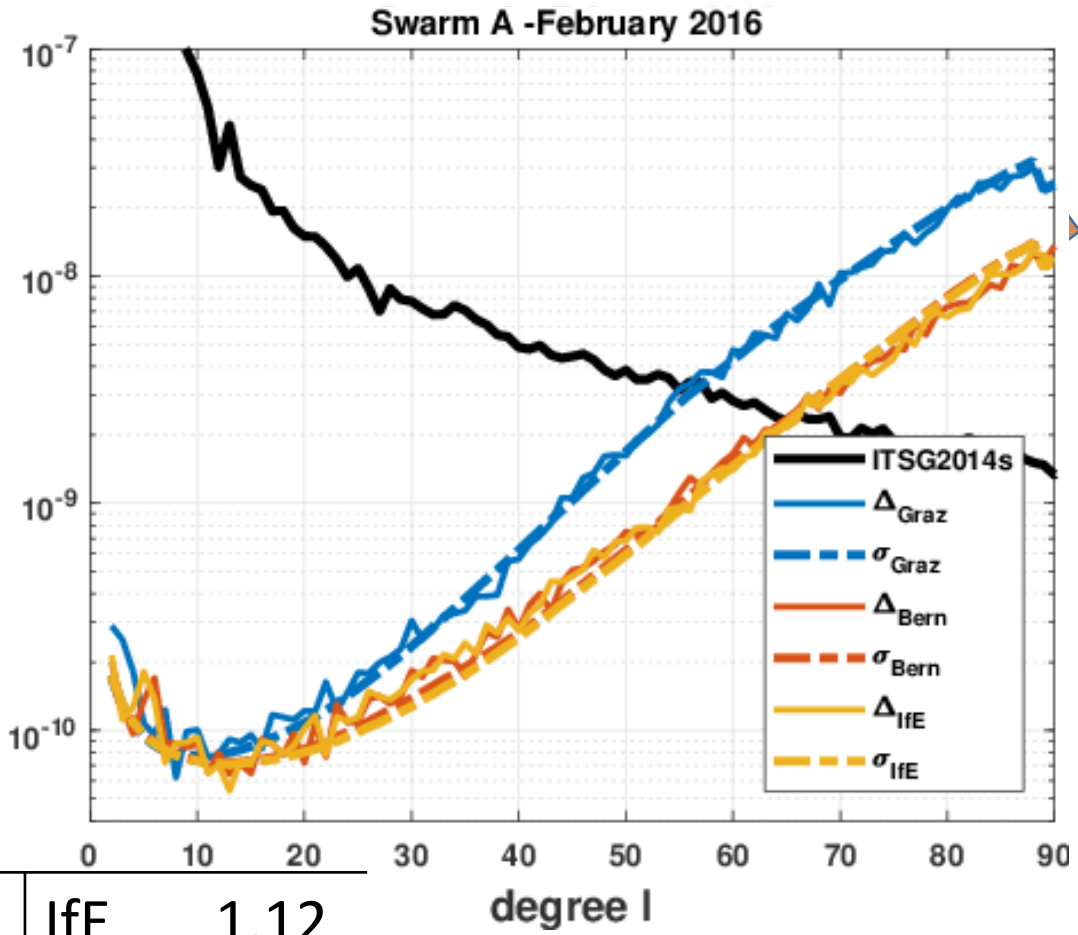
Empirical relative weighting

- Empirical stochastic error models well describe the shape of the difference curves but are biased.



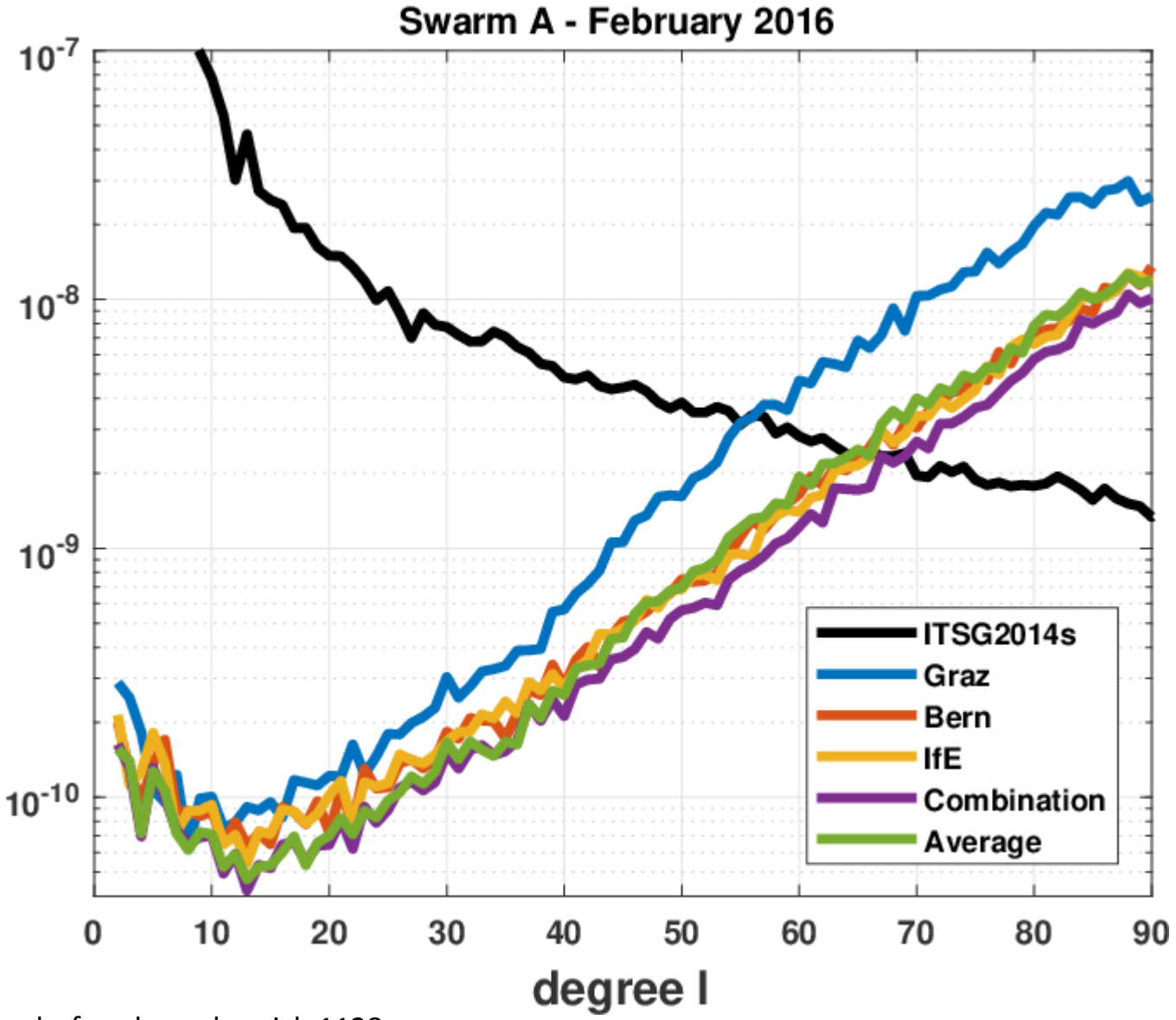
Empirical relative weighting

- Empirical stochastic error models well describe the shape of the difference curves but are biased
- Noise part can be used to derive an empirical scaling factor:



Graz	1.54	Bern	1.14	IfE	1.12

Empirical relative weighting



HLSST combination

- *Presented in 2012:*

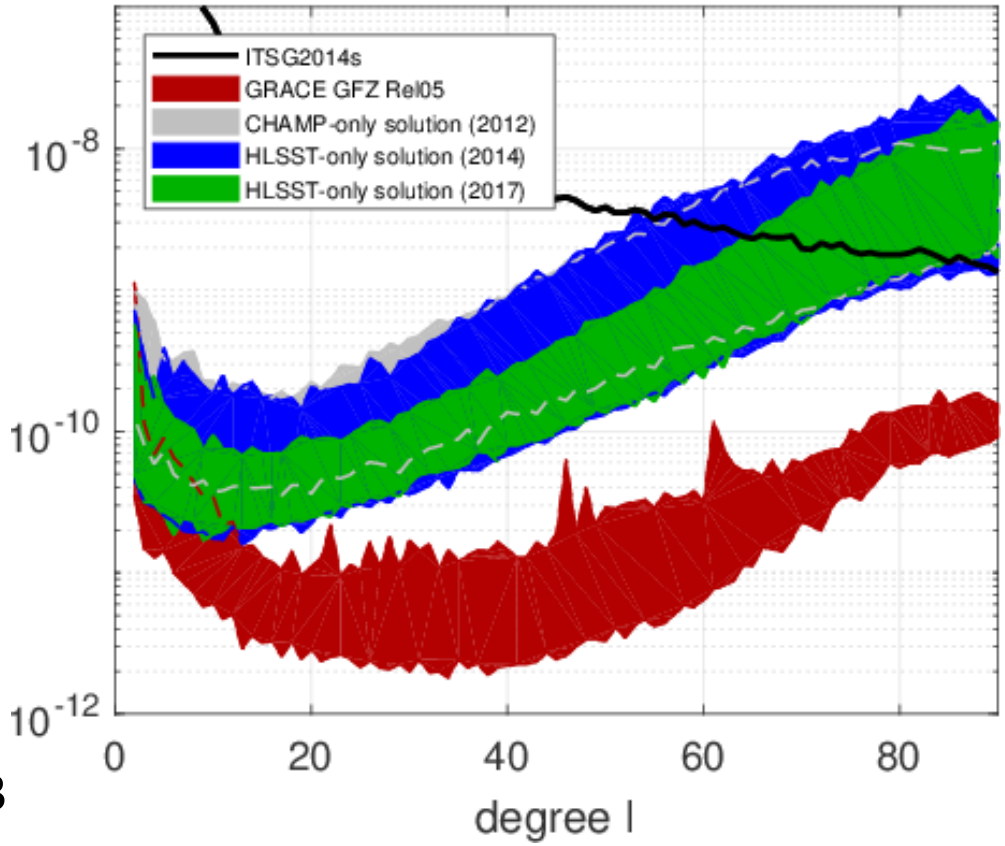
  CHAMP

- *Adding in 2014:*

GOCE	GRACE A	GRACE B
MetOpA	MetOpB	
TerraSAR X	TanDEM-X	
Swarm A	Swarm B	Swarm C

- *Adding in 2017*

SAC-C	Jason 1	Jason 2
Sentinel 1A/B	Sentinel 2A	Sentinel 3A
Cosmic 1	Cosmic 2	Cosmic 3
Cosmic 4	Cosmic 5	Cosmic 6



Combining HLSST + SLR solutions

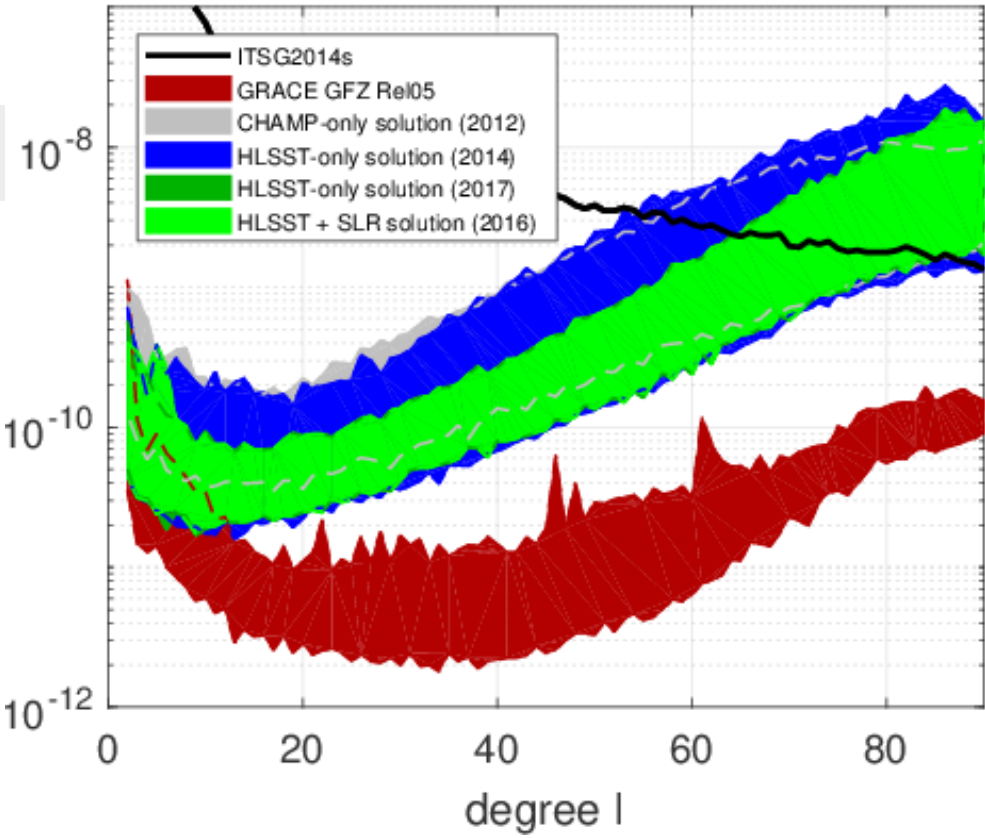
HLSST + SLR combination

SLR:

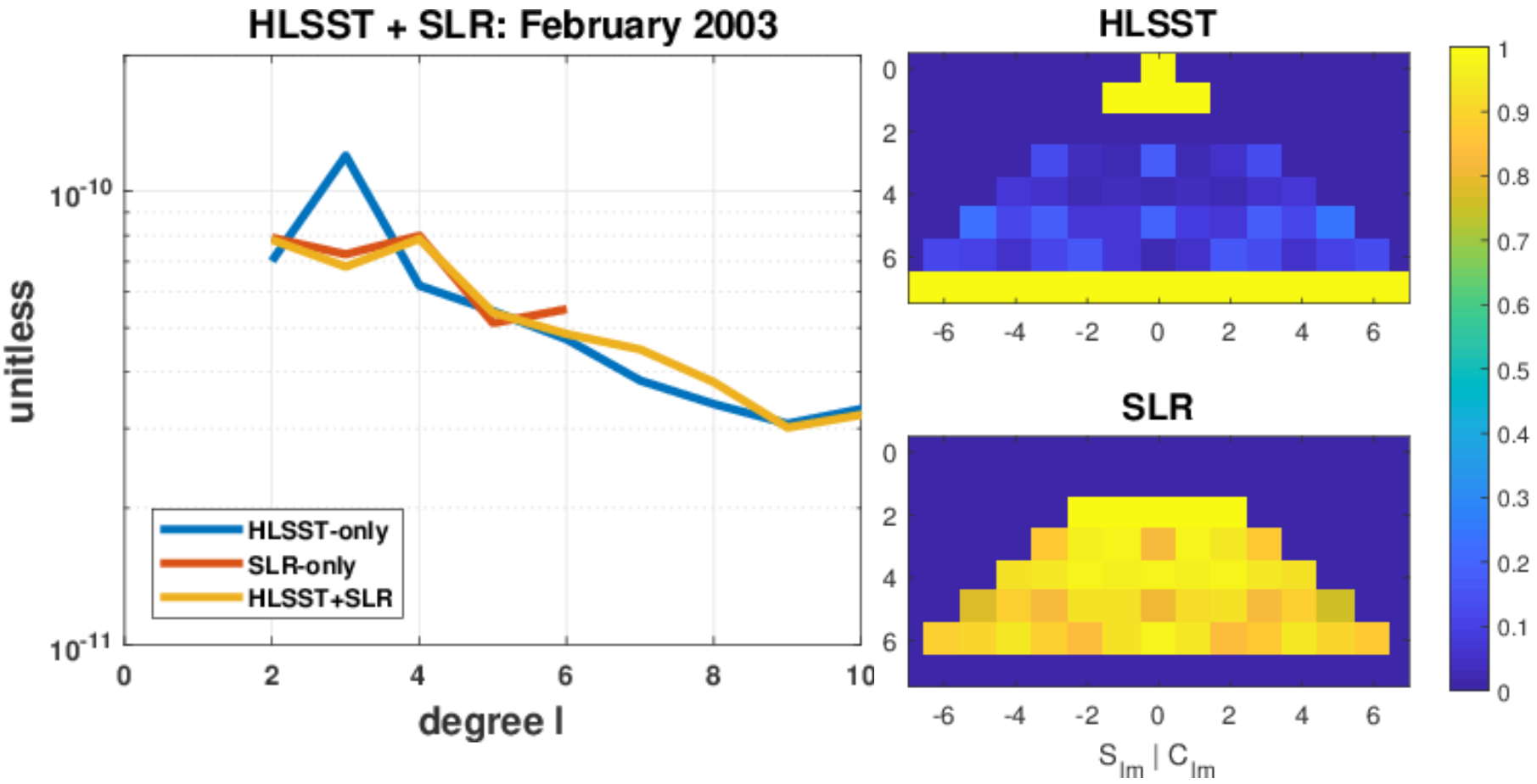
- 9 satellites

Lageos 1	Lageos 2	LARES
Starlette	Stella	Larets
AJISAI	Beacon-C	Blits

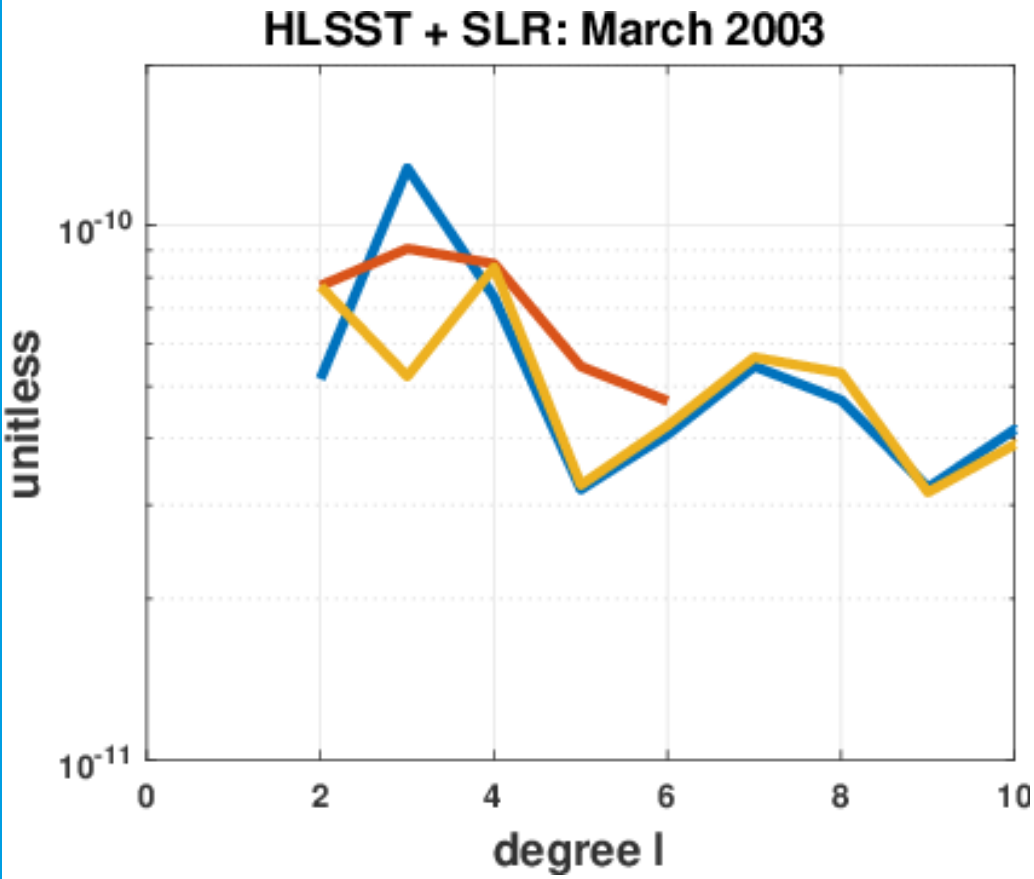
- Estimation of gravity parameters together with station coordinates, ERP, geocenter and range biases
- Combination at the normal equation level (weighting !)

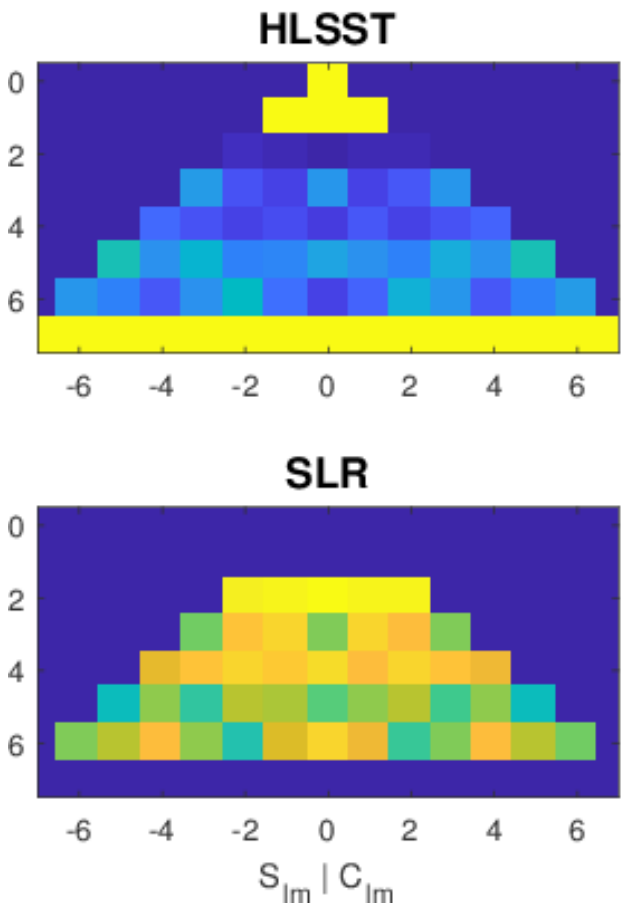


HLSST + SLR combinations



HLSST + SLR combinations





Time-Variable Gravity Field

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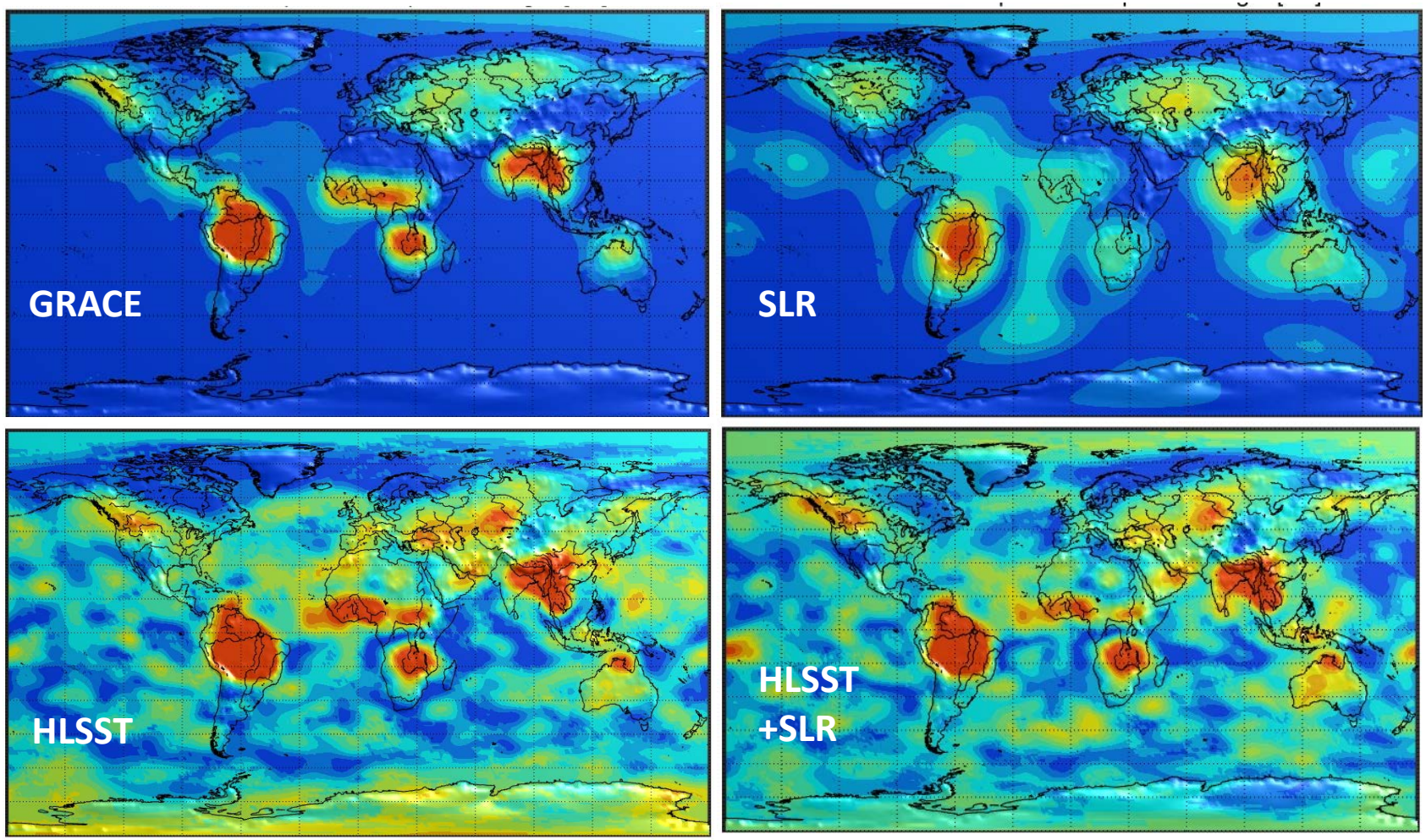
Mean annual amplitude

Gaussian filter 750 km



Equiv. water [cm]

0 1 2 3 4 5 6 7 8 9 10 11 12

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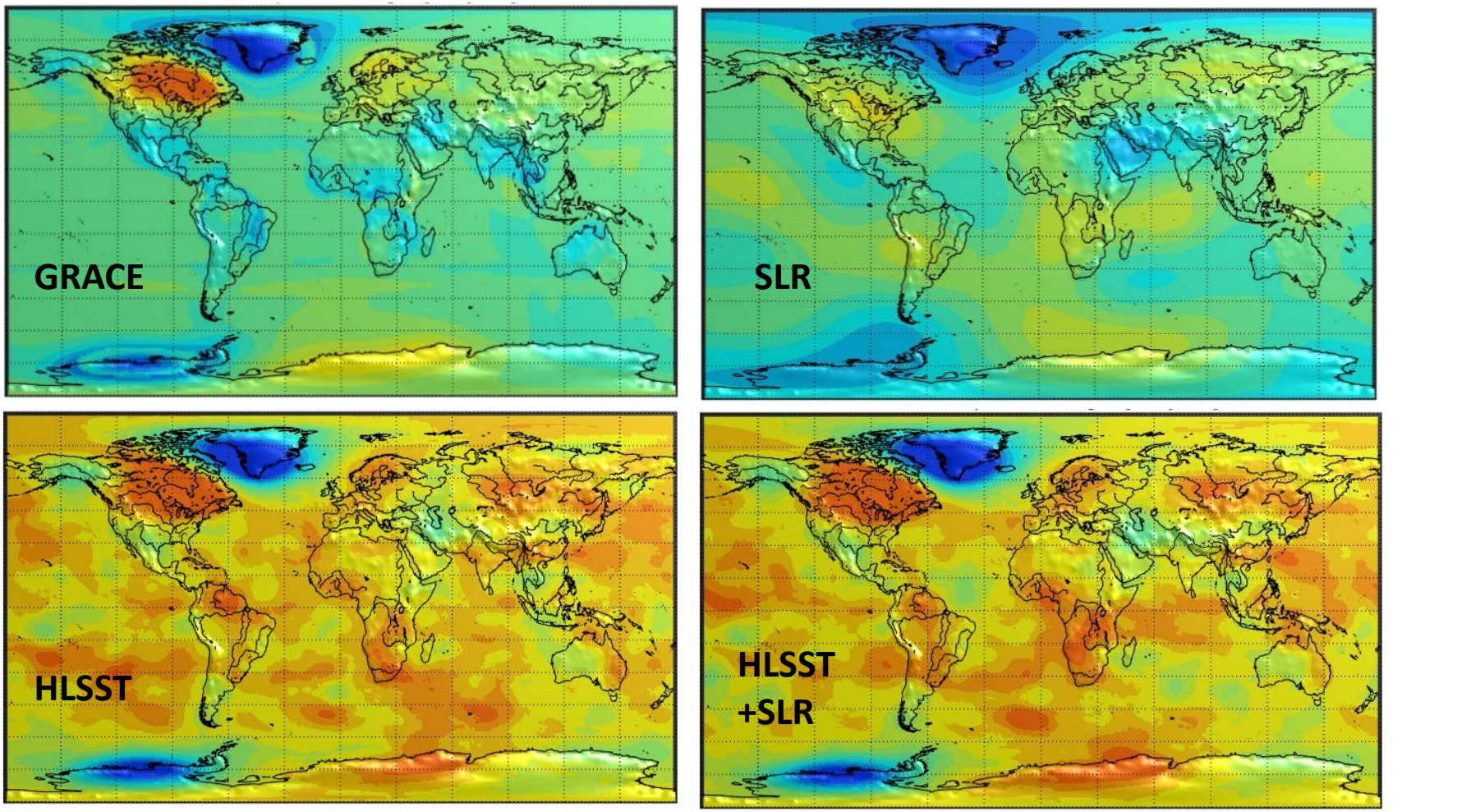
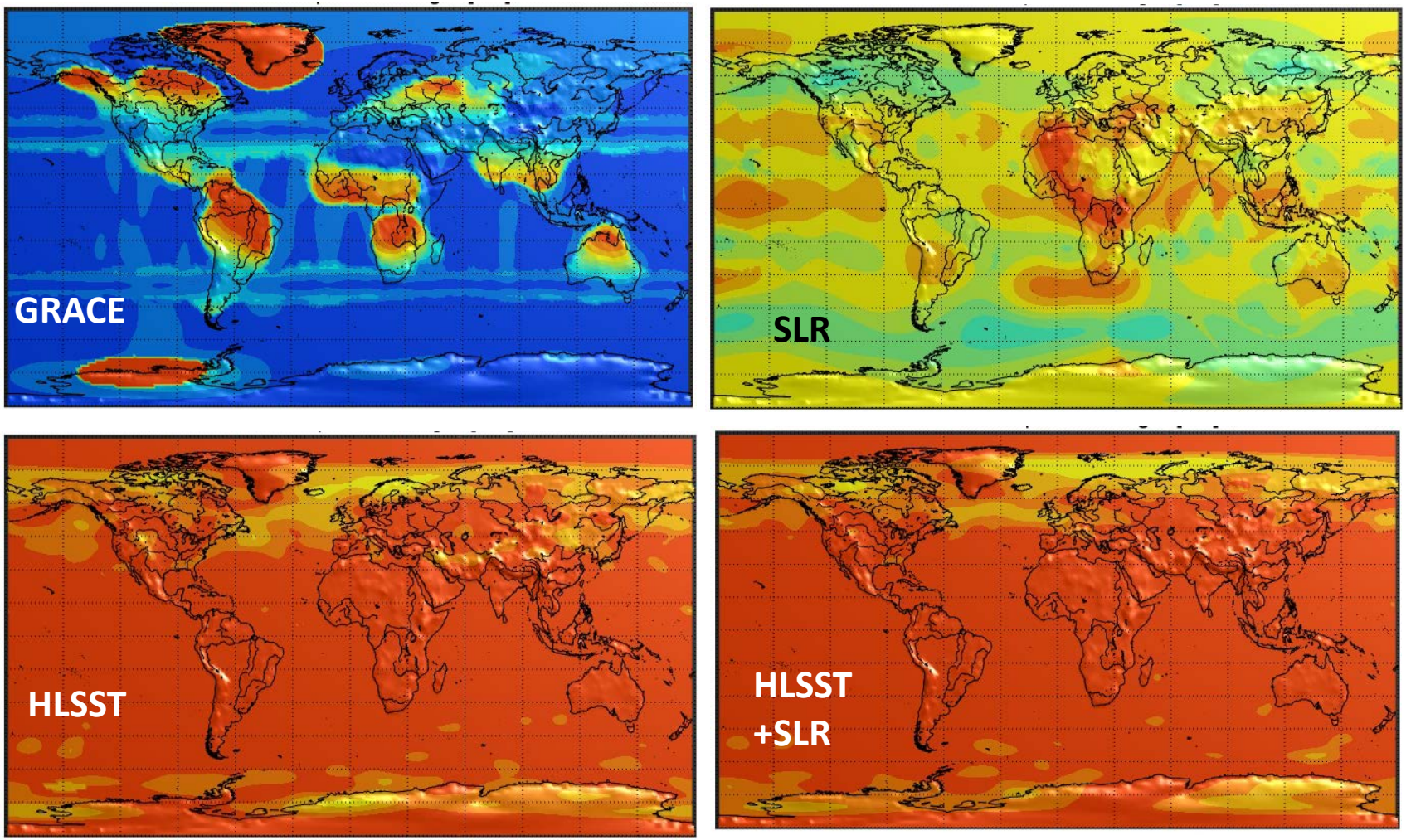
Trend

Gaussian filter 750 km



RMS of the residual time series

Gaussian filter 750 km



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Conclusions

- Mutual benefit by combining HLSST and SLR:
  - SLR improves (dominates) the very-long wavelength.
  - HLSST provides the higher spatial resolution.
- HLSST + SLR solutions may be best suited for detecting inter-annual and annual variations.
- Short-term variations are not observable due to the limited spatial resolution and the higher noise level of the solutions.