Bridging the gap – linking GRACE and GRACE-Follow On by hlSST and SLR

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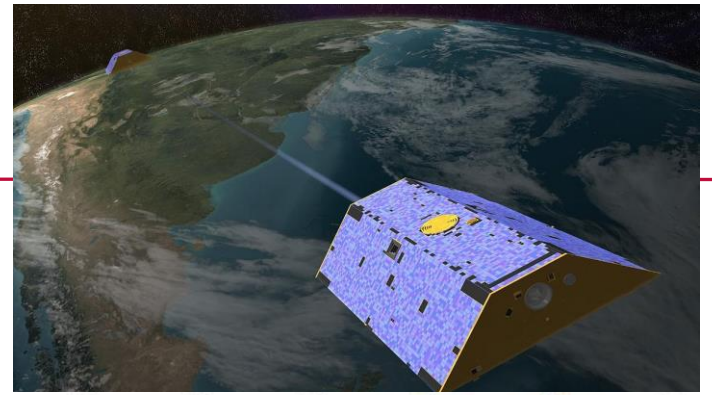
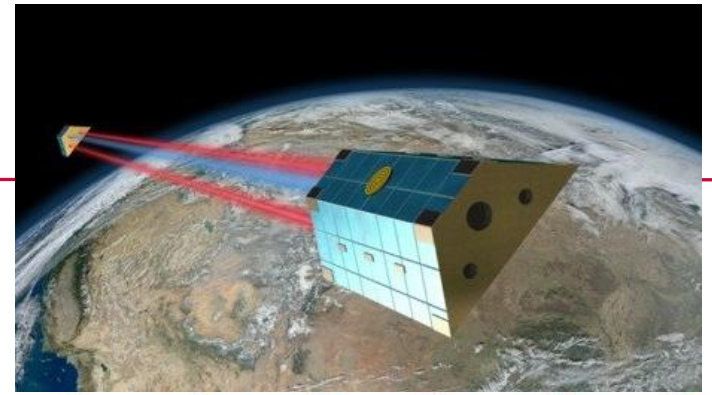
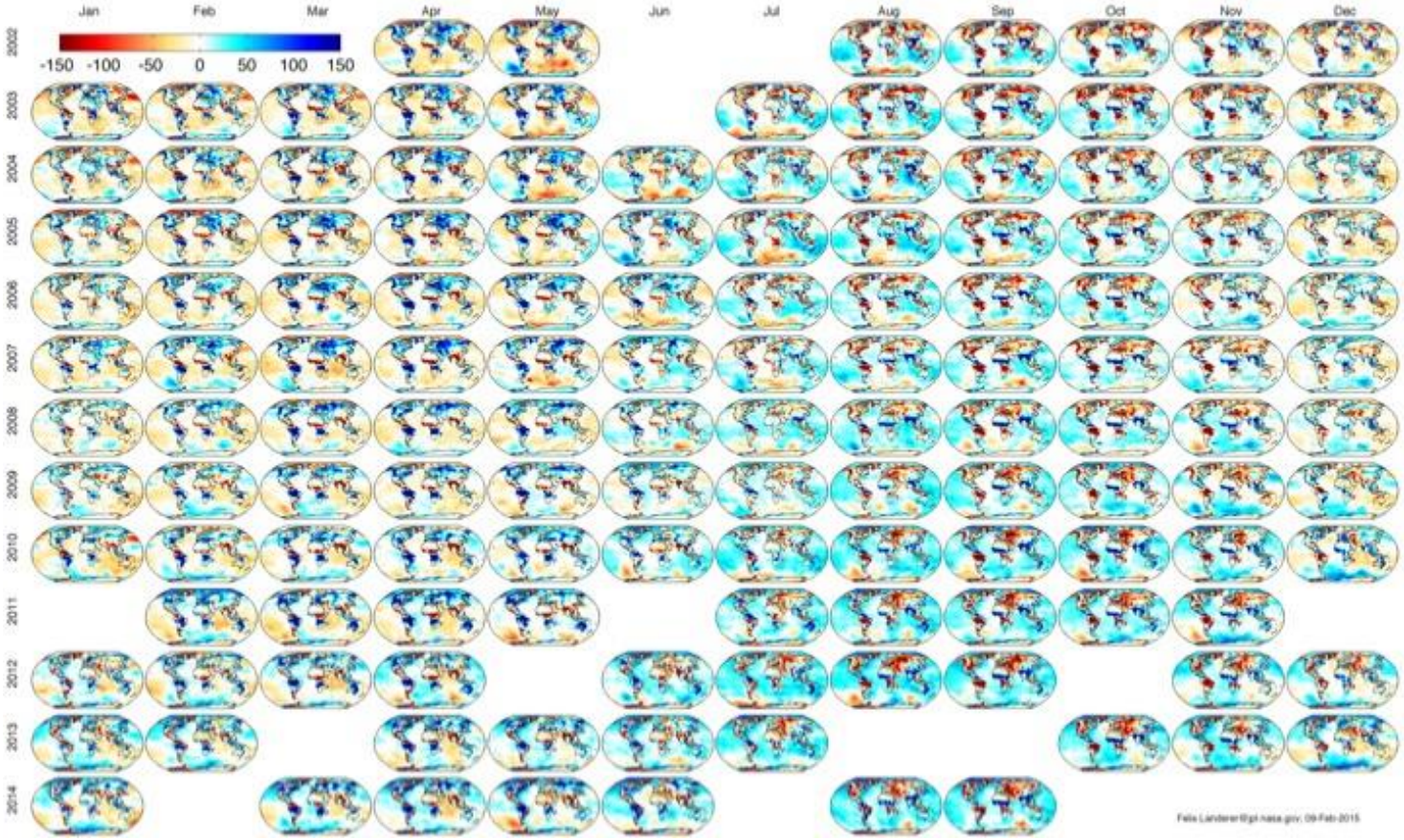
Motivation

- Bridging the gap between GRACE and GRACE-FO
- Bridging the gaps of GRACE
- Cross-validating GRACE and GRACE Follow-On
- Combination of gravity fields from various sources for improved recovery
- Study multi-mission multi-satellite environments







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

hlSST data processing

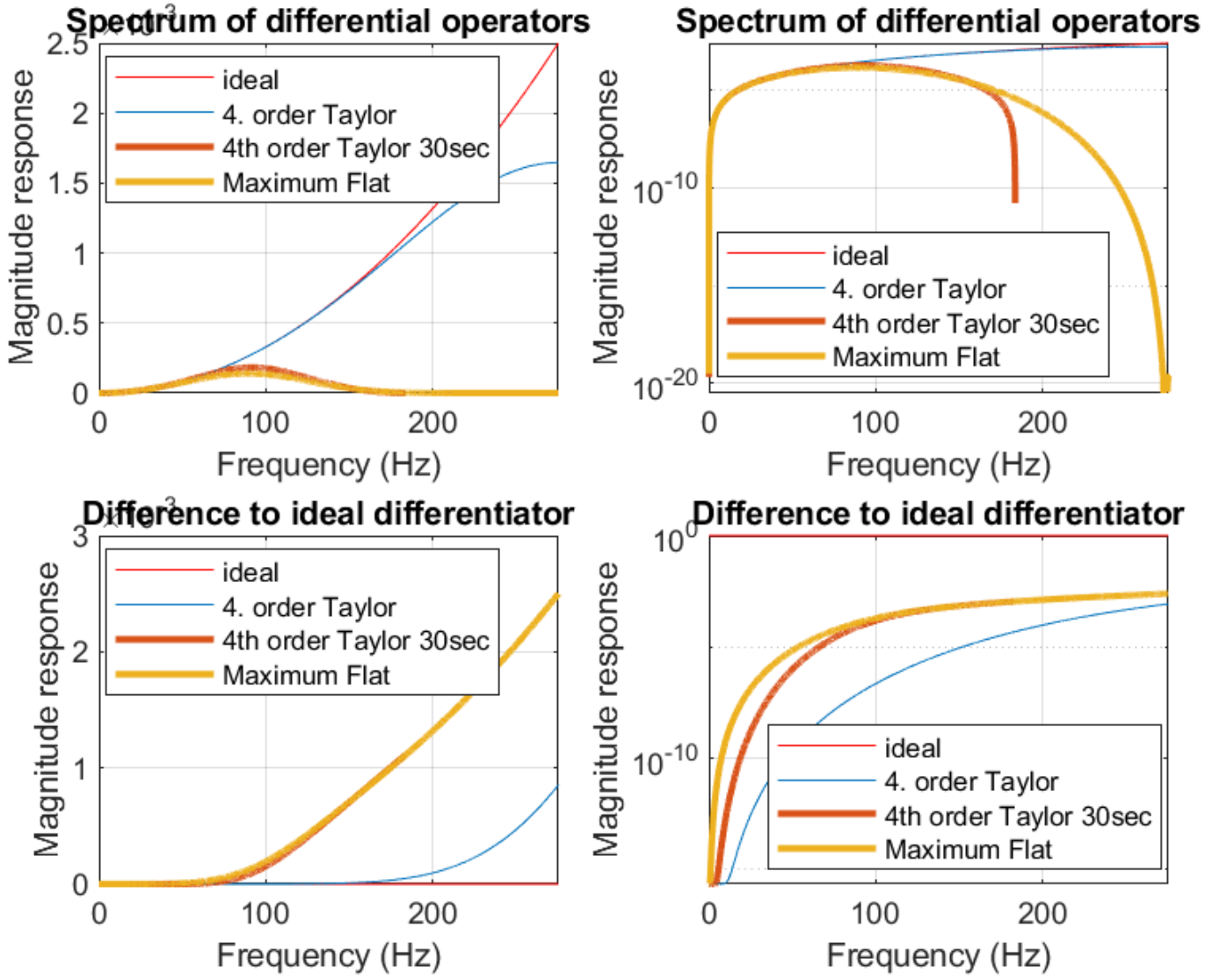
Acceleration approach and background models

- Kinematic orbits from
  - Astronomical Institute, University Bern
  - Institute for Geodesy, Graz
  - Institute for Geodesy, Hannover
  - European Space Agency

  totalling to 41 kinematic orbit products from 27 satellites.
- Accelerometer data used for CHAMP, GRACE and GOCE
- Acceleration approach and combination on the normal equation level using variance component estimation

- Background models
  - JPL Ephemeris DE421
  - Solid Earth tides (IERS Conventions)
  - Solid Earth pole tides (IERS Conventions)
  - Ocean tides (FES2014b)
  - Ocean pole tides (IERS Conventions)
  - Atmospheric tides (AOD1B RL06)
  - Relativistic corrections (IERS conventions)
  - AOD1B dealiasing product RL06

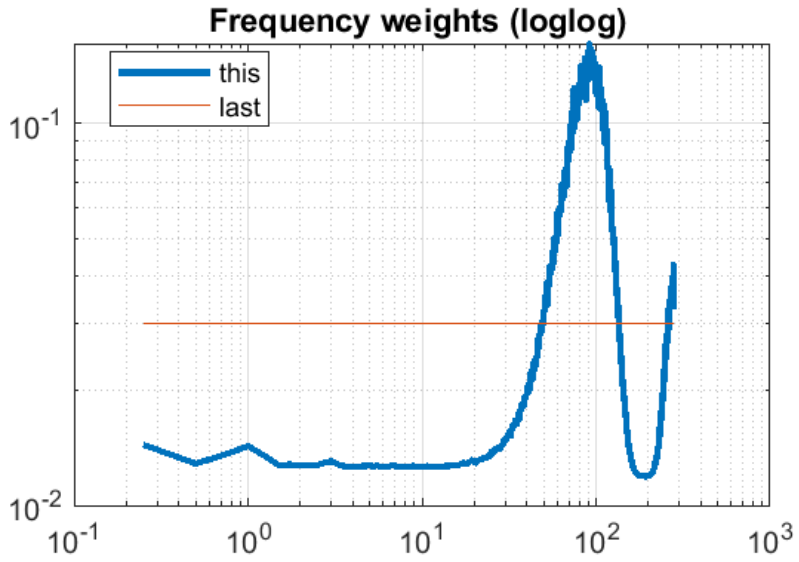
A new differentiator

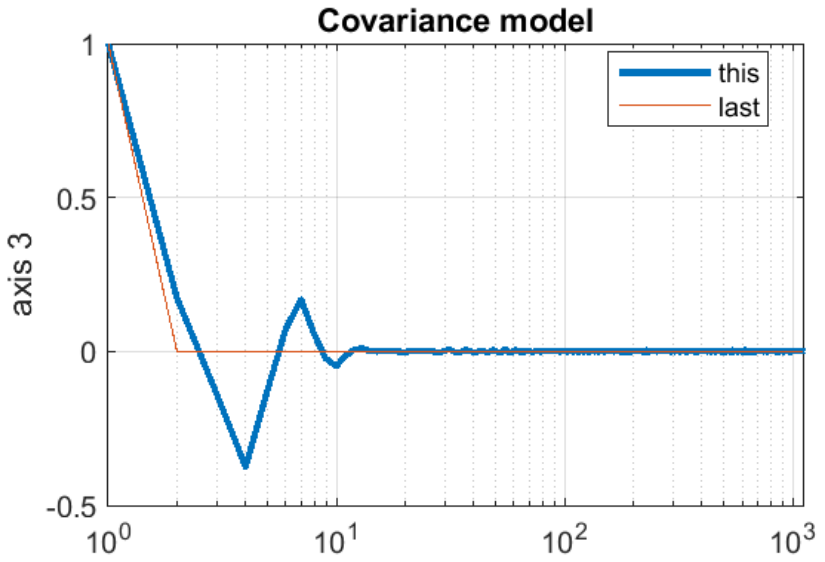


- Differentiation amplifies noise.
- Low-pass filtering properties of differentiators are used to suppress noise
- Test showed that for sampling >30s a time-shifted 30s filter is optimal.
- M. S. Hosseini and K. N. Plataniotis, “Finite differences in forward and inverse imaging problems–maxpol design,” (2017).

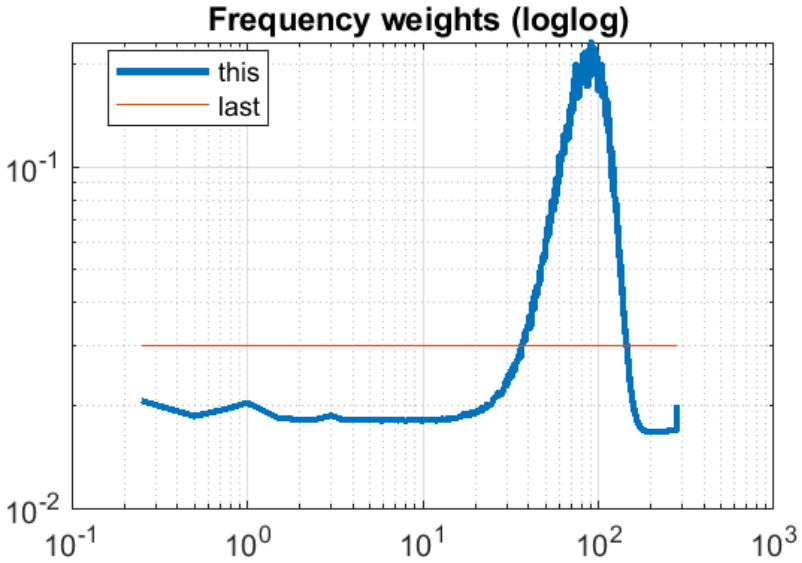
Impact on the estimated noise spectrum: here for GRACE A

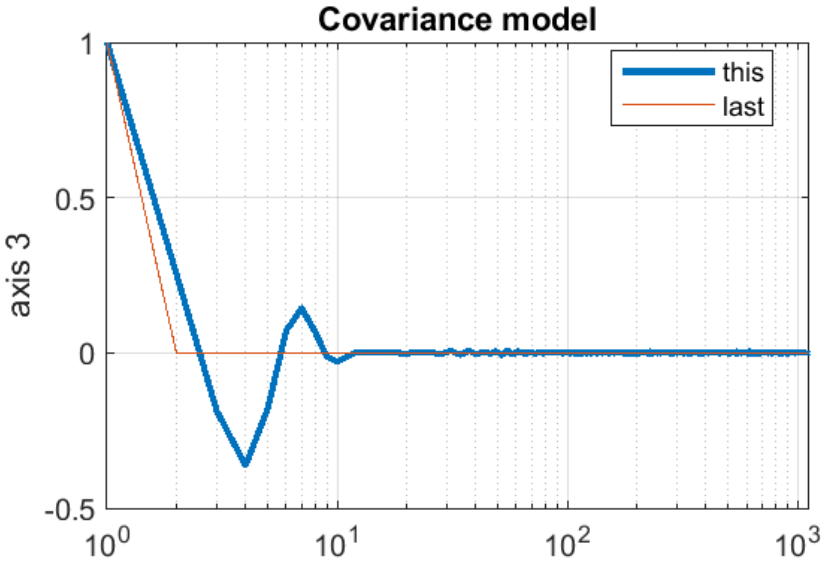
30 sec time-shifted





Maximum Flat





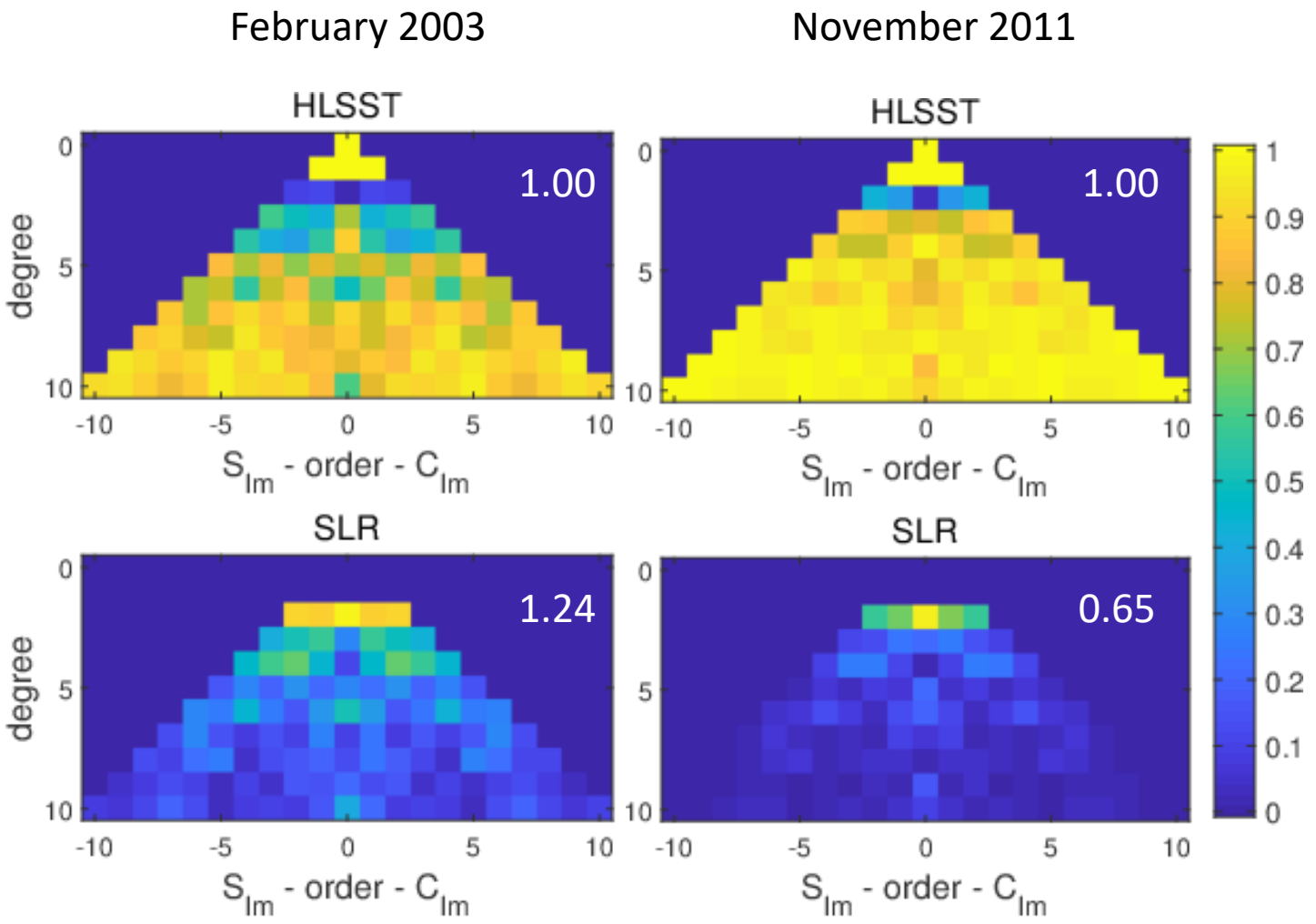
Key elements of the data processing

Combination with satellite laser ranging

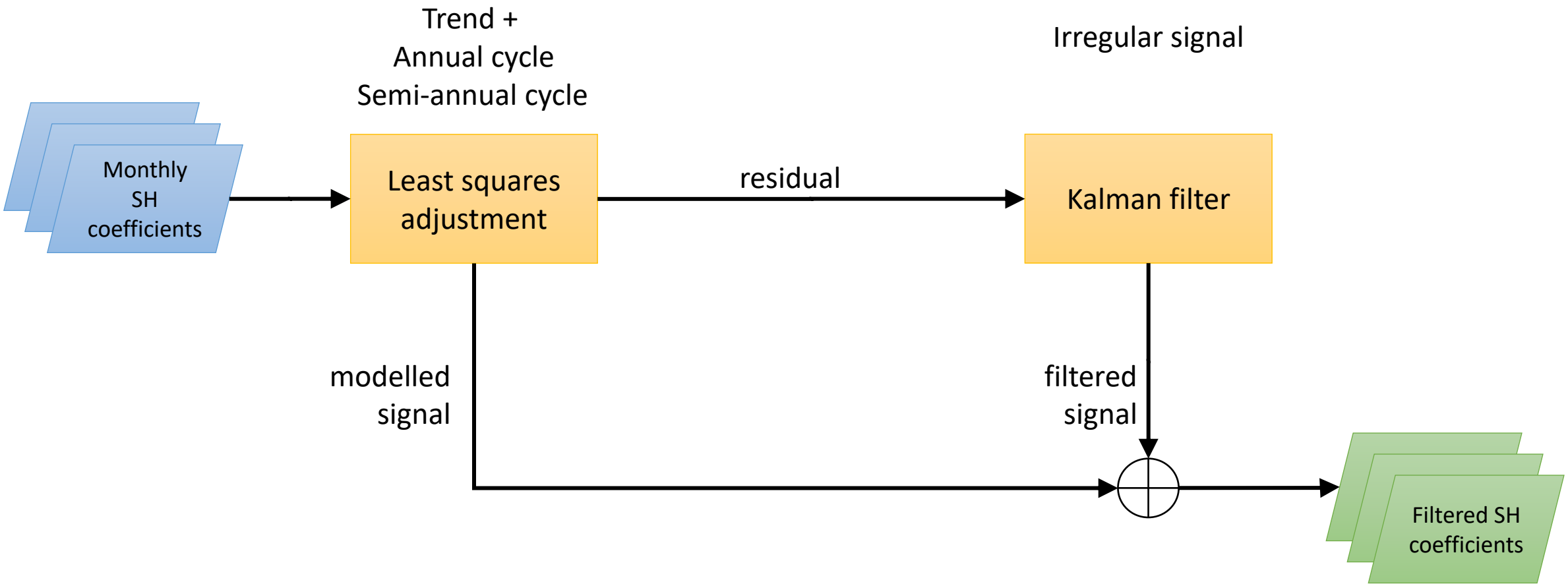
- 9 satellites

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

- Combined estimation:
  - gravity parameters till degree 10,
  - station coordinates,
  - Earth rotation parameter,
  - geocenter,
  - range biases
- Combination at the normal equation level using variance component estimation



Temporal filtering



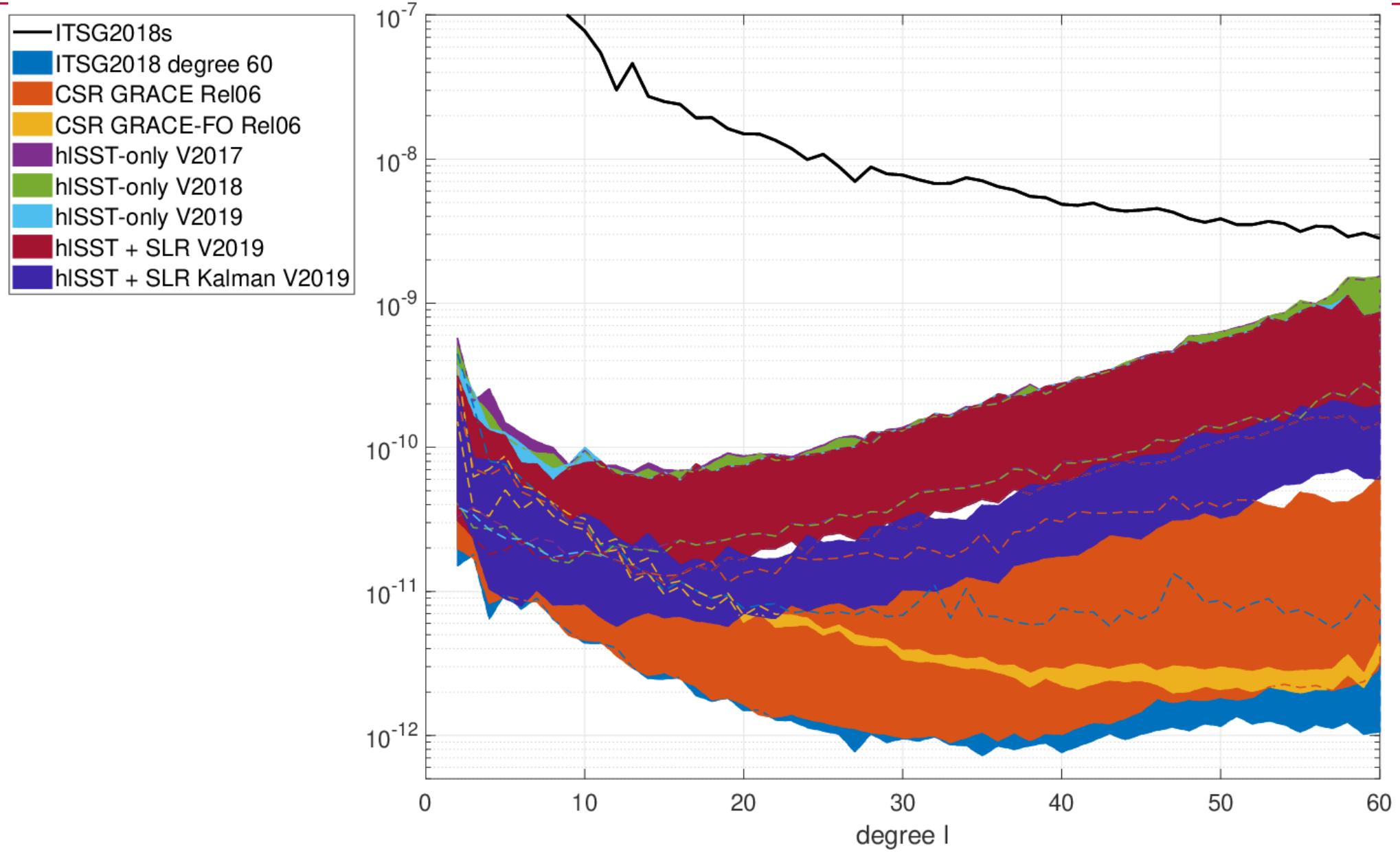
Kalman filter:

- continuous Wiener process acceleration (CWPA) model
- accelerations as white noise model

Difference degree RMS w.r.t. GOCO05s

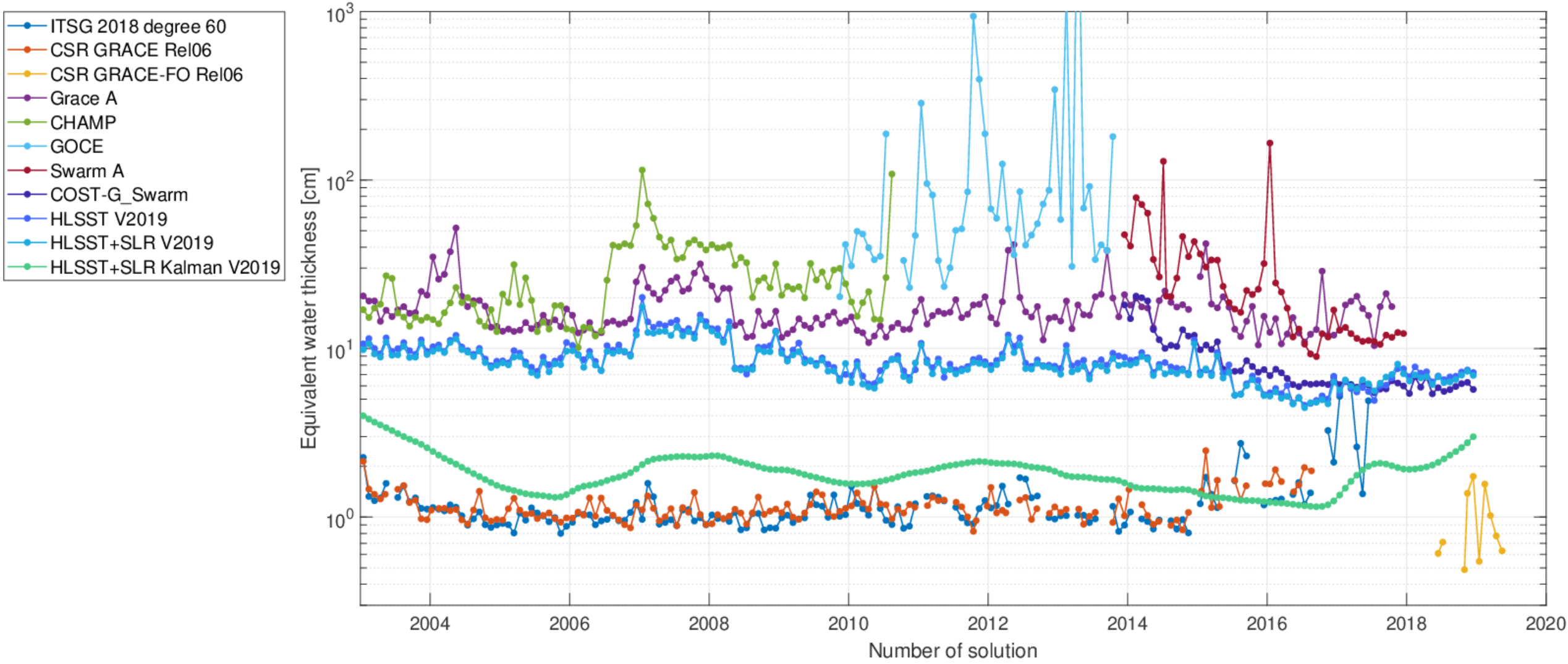
error model
VCE error model
new VCE error model

Temporal filtering



Spatial RMS over ocean areas

Gaussian filter 750 km

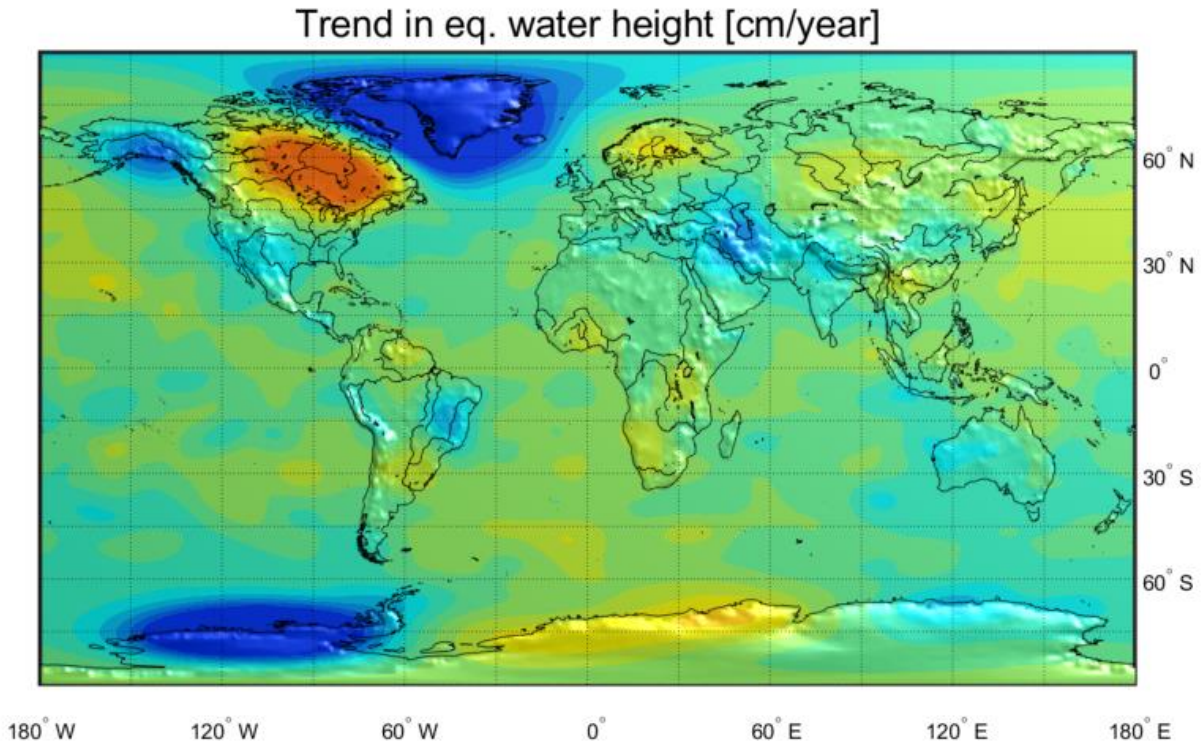


Temporal signal evaluation

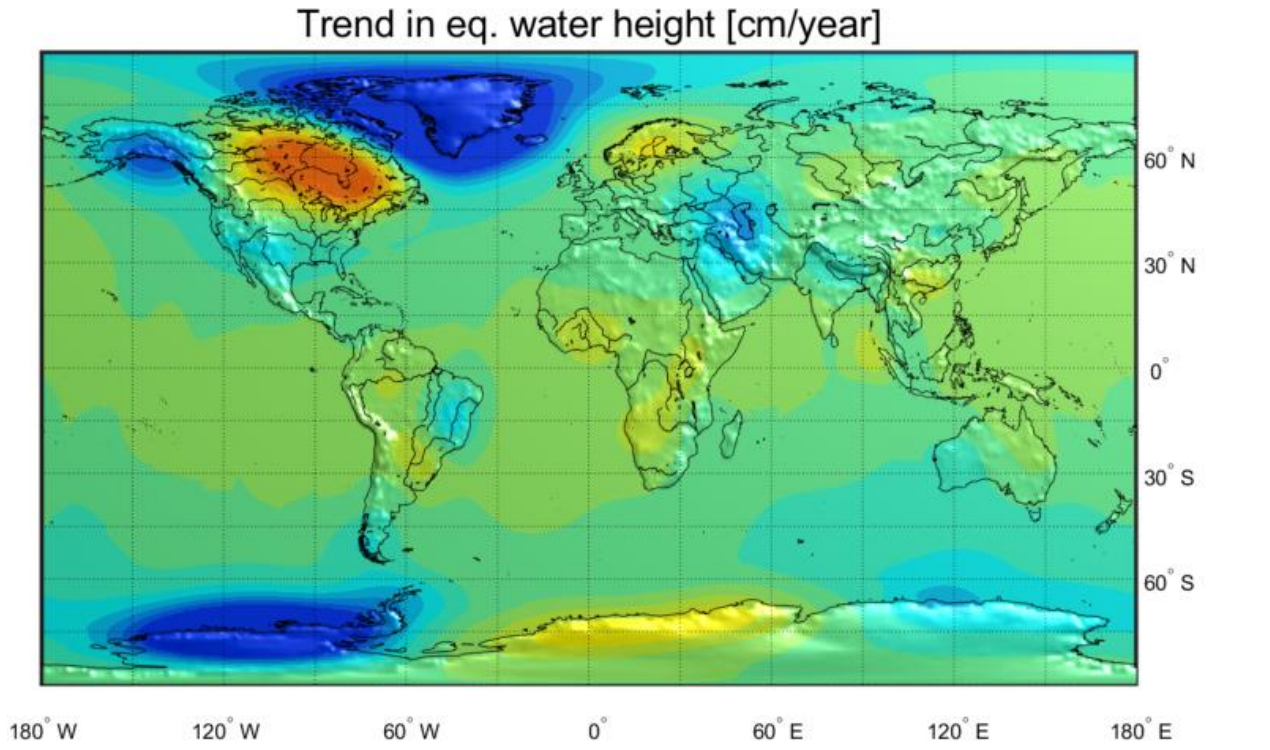
Trend

Gaussian filter 750 km

hlSST+SLR Kalman 2019



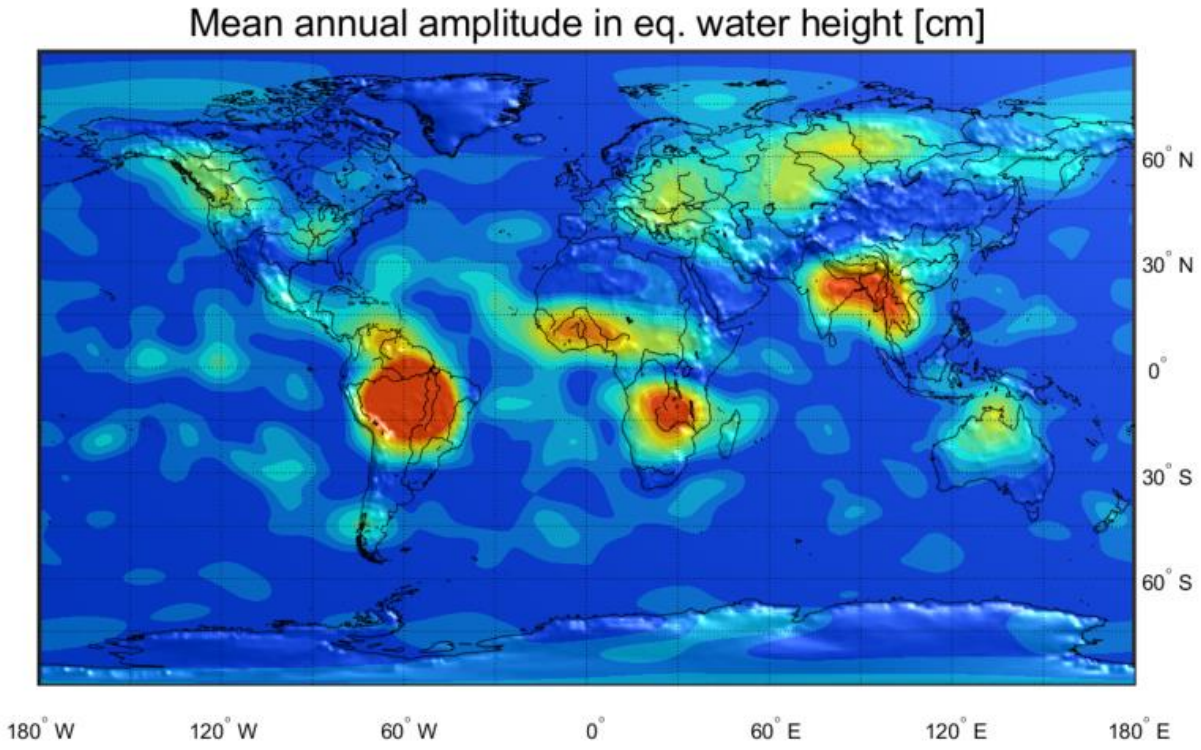
GRACE CSR Rel06



Annual signal amplitude

Gaussian filter 750 km

hlSST+SLR Kalman 2019



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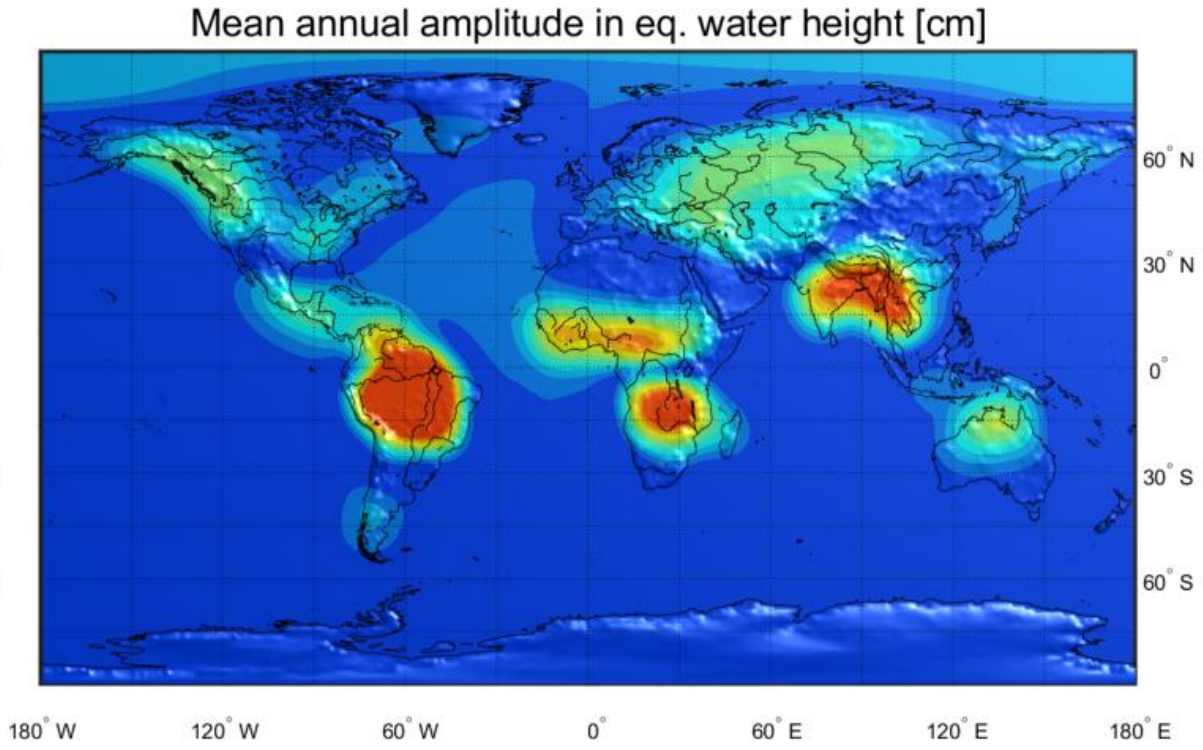
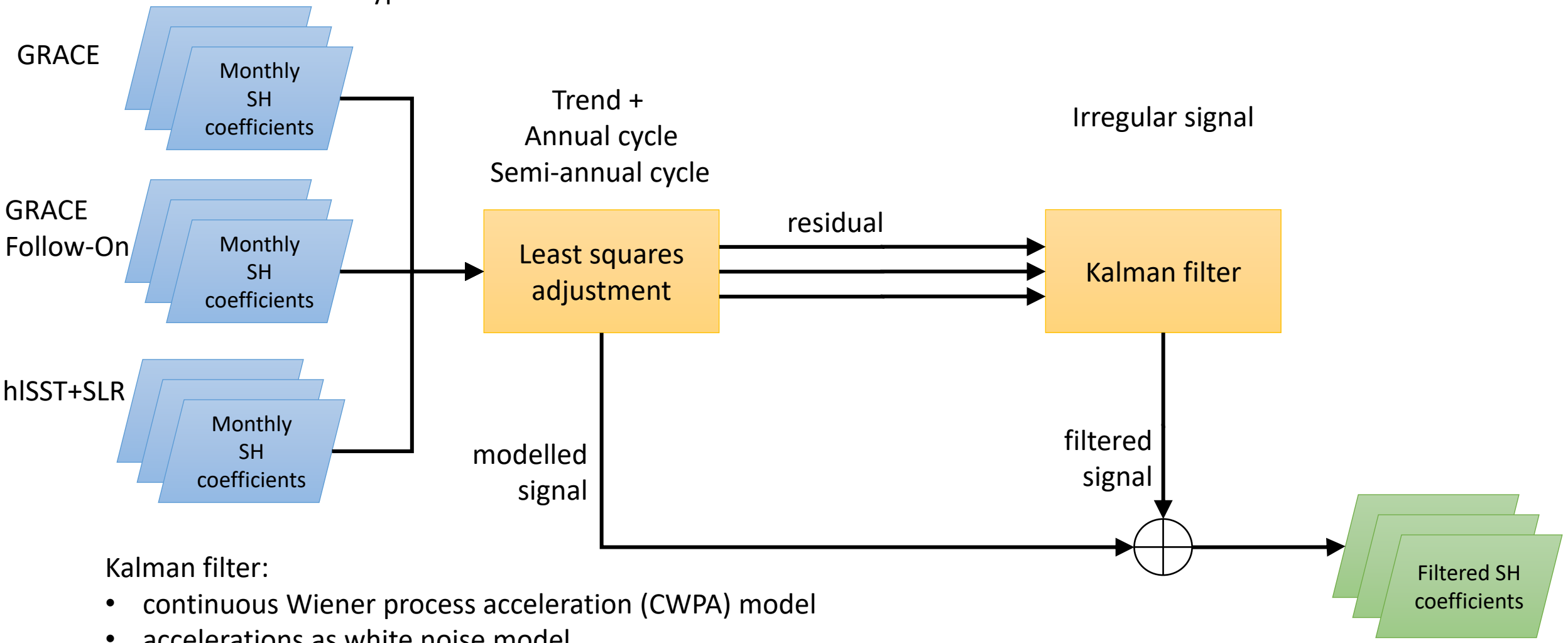


Bridging the gap

Filtering + Combination

Hypothesis: combine various data sets within the same Kalman filter environment



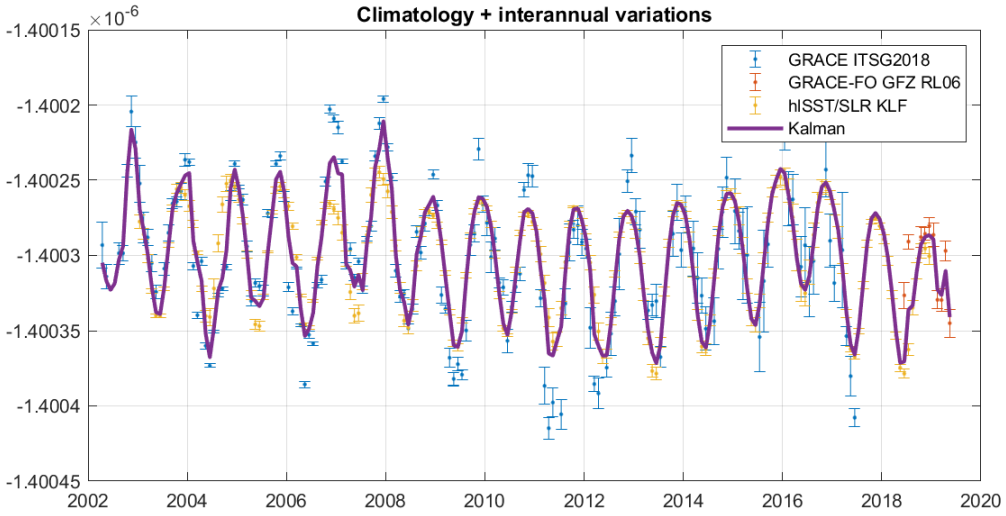
Kalman filter:

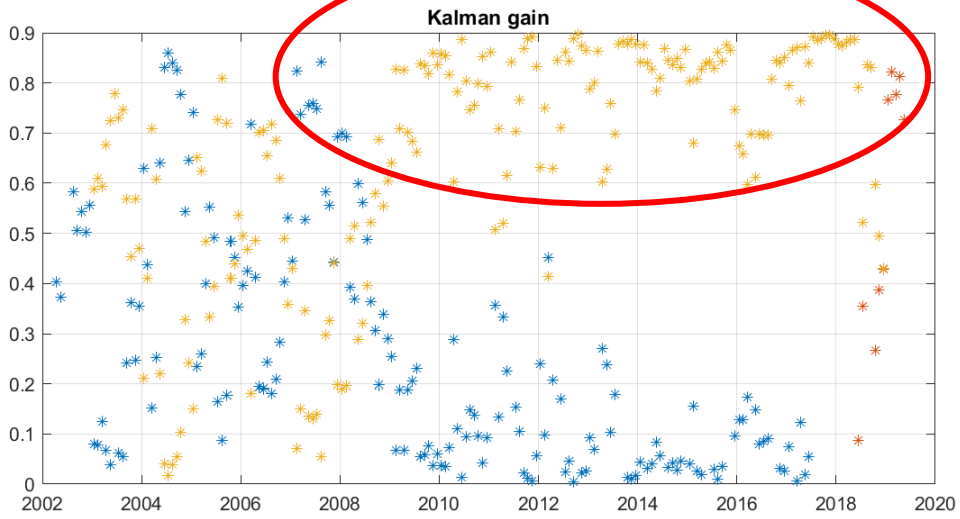
- continuous Wiener process acceleration (CWPA) model
- accelerations as white noise model

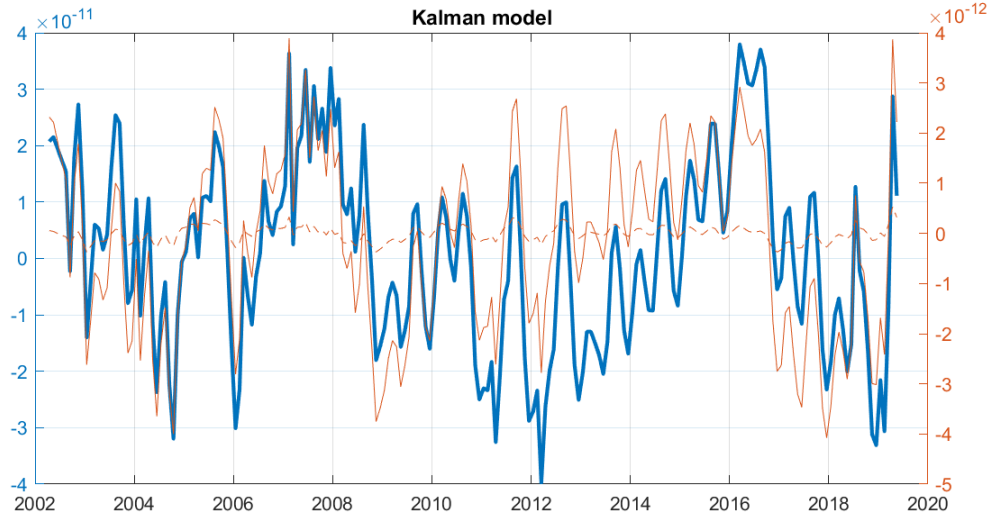
Coefficient-wise combination S_{22}

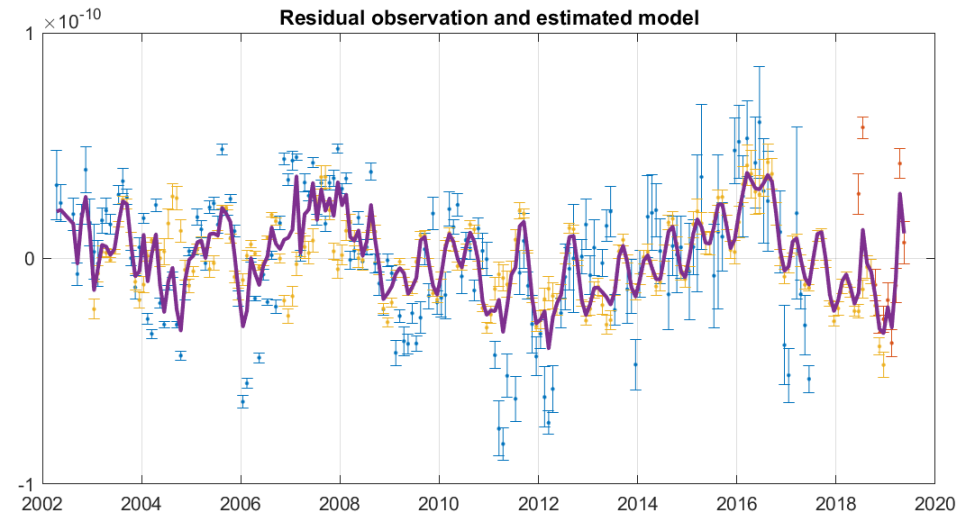
Strong weight on hlSST+SLR solution due to low variability

Coefficient $S_{2,2}$



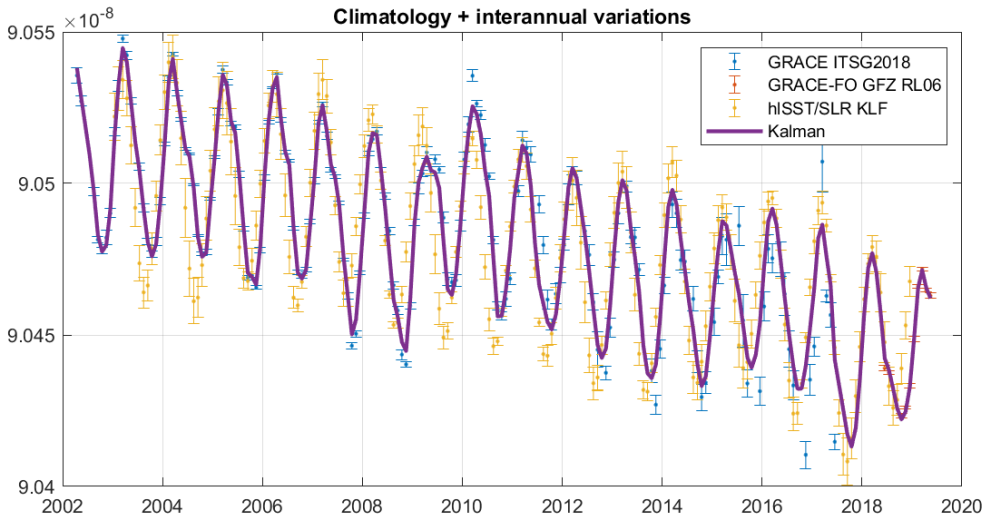


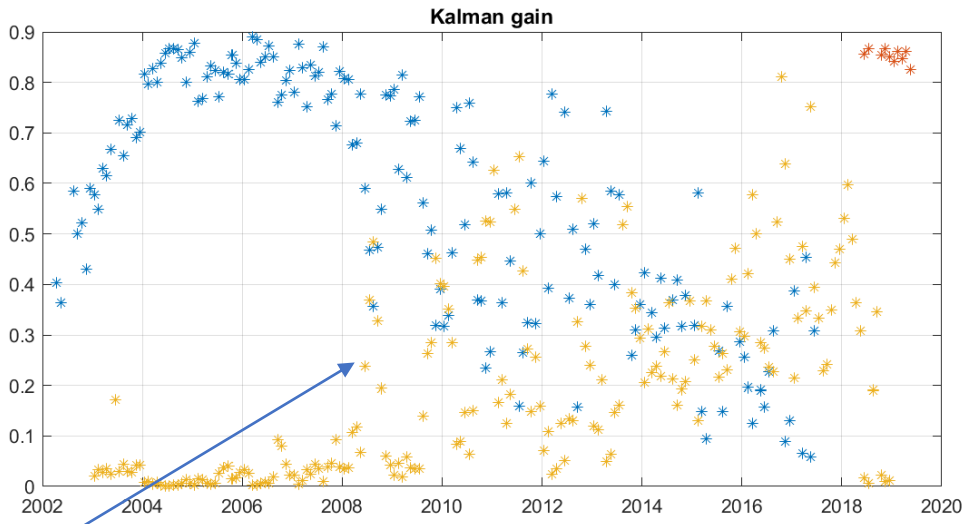




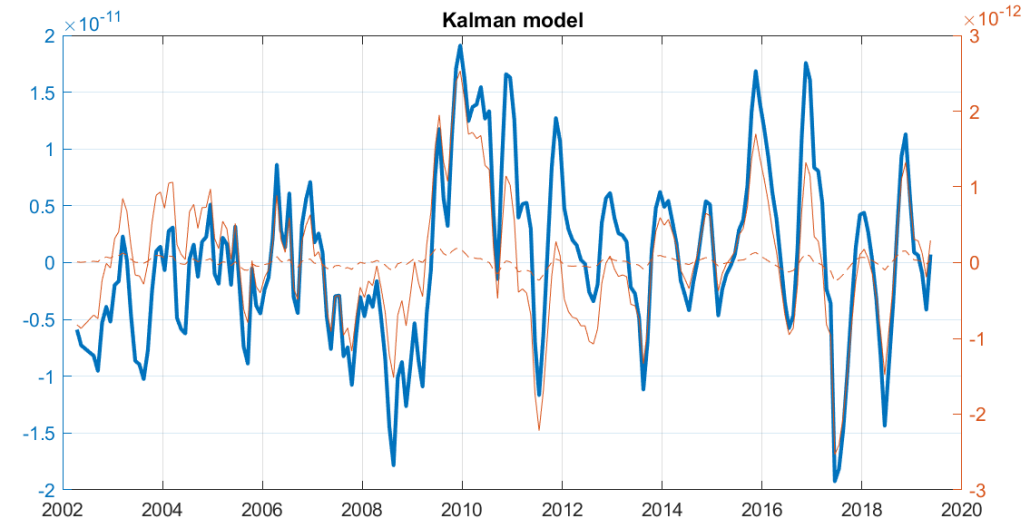
Coefficient-wise combination C_{70}

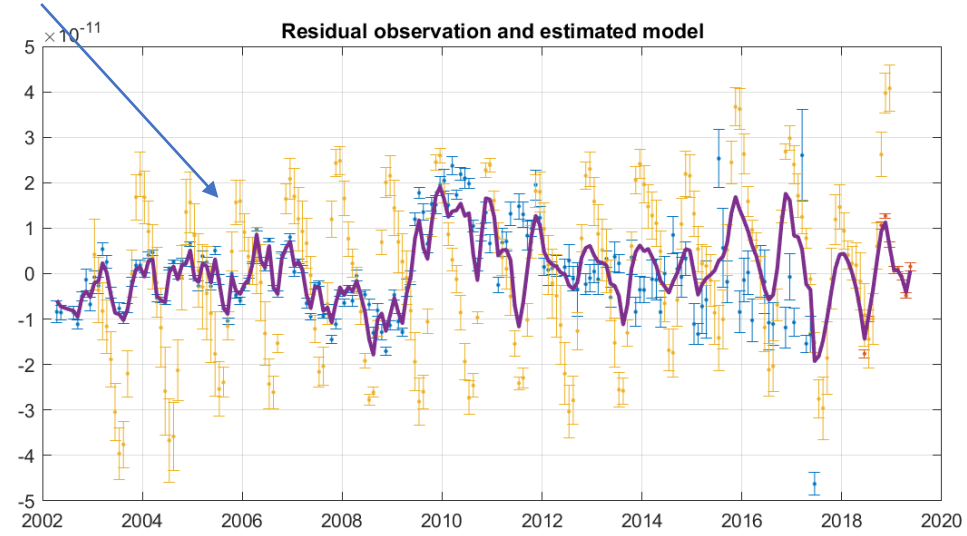
Coefficient $C_{7,0}$





Introduction of systematic errors in the hlSST+SLR solution





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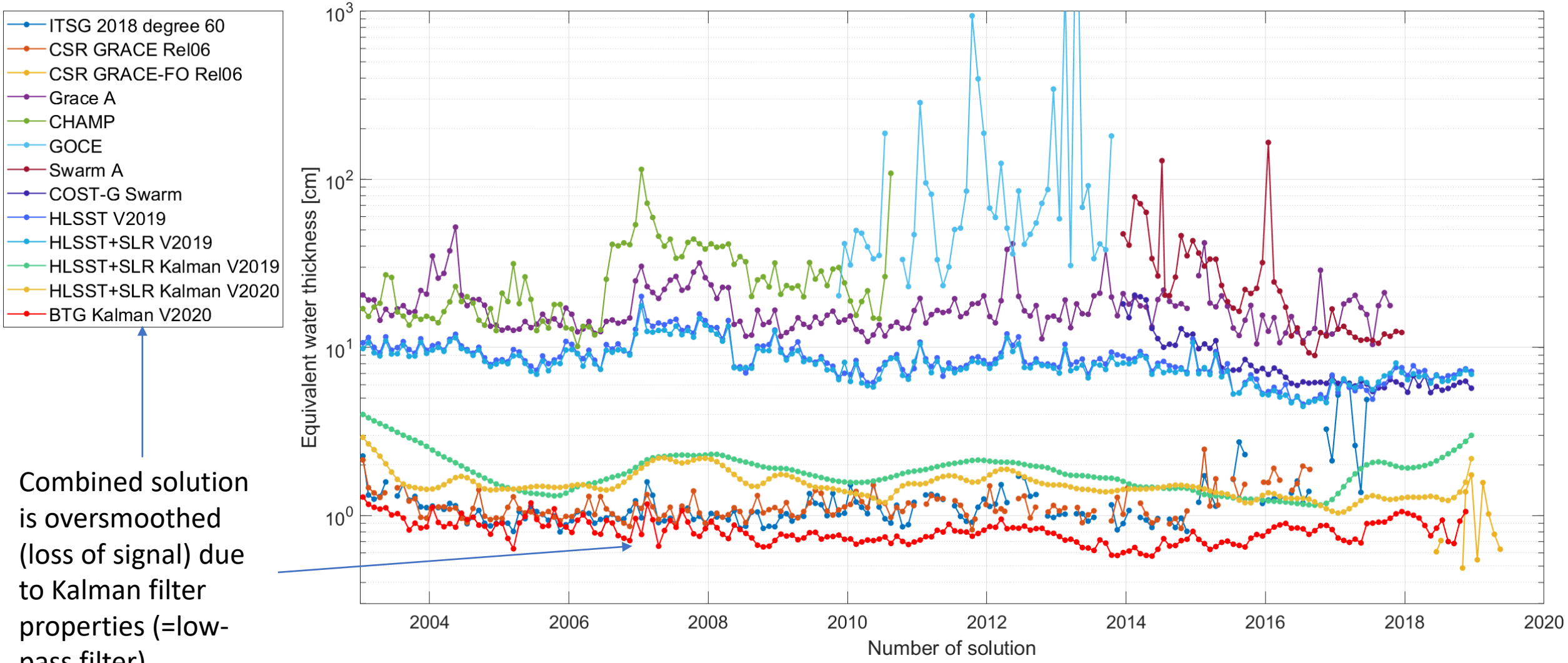

Combined solution is oversmoothed (loss of signal) due to Kalman filter properties (=low-pass filter)

Conclusion

Conclusions

- Mutual benefit by combining HLSST and SLR:
  - SLR improves (dominates) the degree-2 coefficients
  - 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.
- Combination of GRACE, GRACE Follow-On and hlSST+SLR in the Kalman-filter environment is inferior in periods where GRACE and GRACE Follow-On data is available caused by an oversmoothing due to the Kalman-Filter properties.

Logo 1