GNSS processing with the raw observation approach in the context of gravity field recovery

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GNSS processing on a global scale

Raw observation approach → Paper with all the details coming soon™

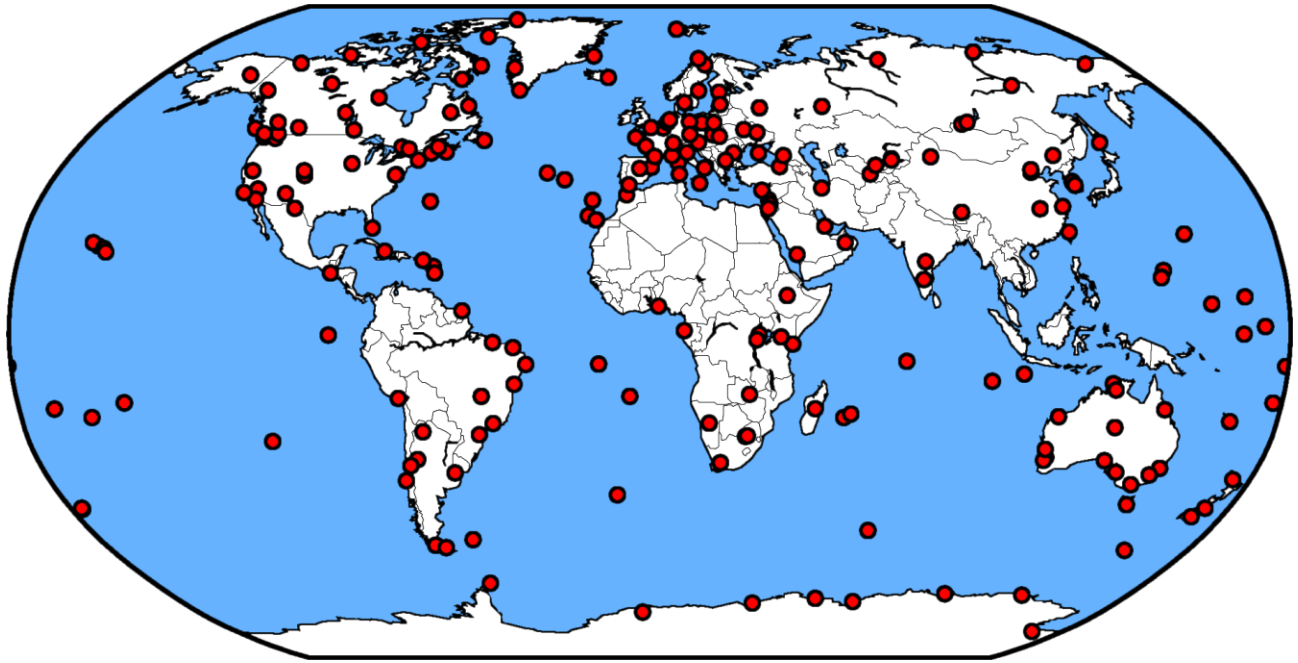
- Use all available observations…
- … as they are observed by the receiver…
- … in a common least squares adjustment.

Processed data

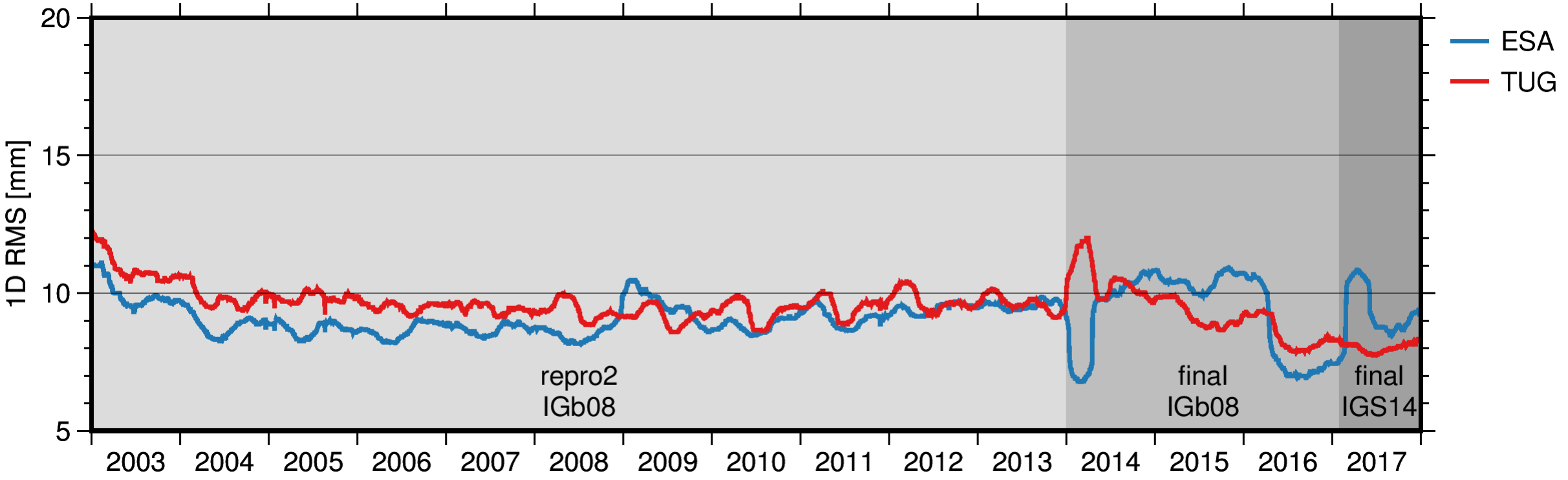
- 15 years from 2003 to 2017
- IGS14 station network
- GPS constellation
- Dual-frequency code and phase (L1, L2)

Processing

- Consistent over full time series
- Daily 24 h solutions
- State-of-the-art models
- igs14.atx antenna calibrations



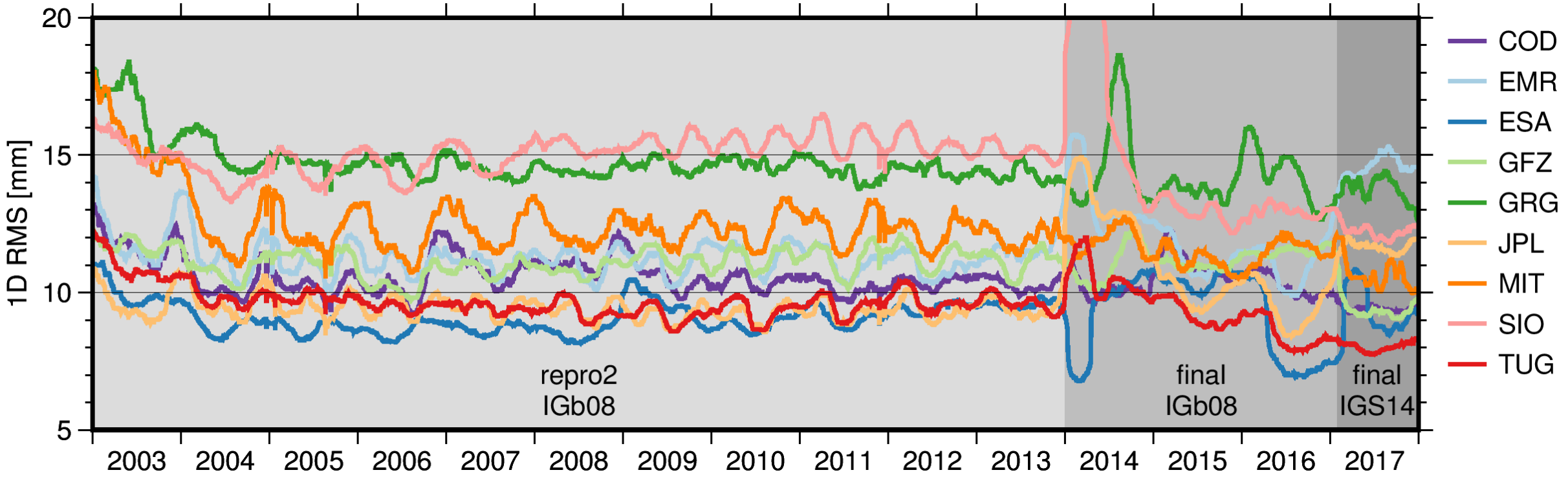
Daily GPS orbit RMS relative to IGS combination



Orbits synchronized between all institutions
(reference frame differences corrected, outage periods removed)

91-day median-filtered for clarity

Daily GPS orbit RMS relative to IGS combination



Orbits synchronized between all institutions
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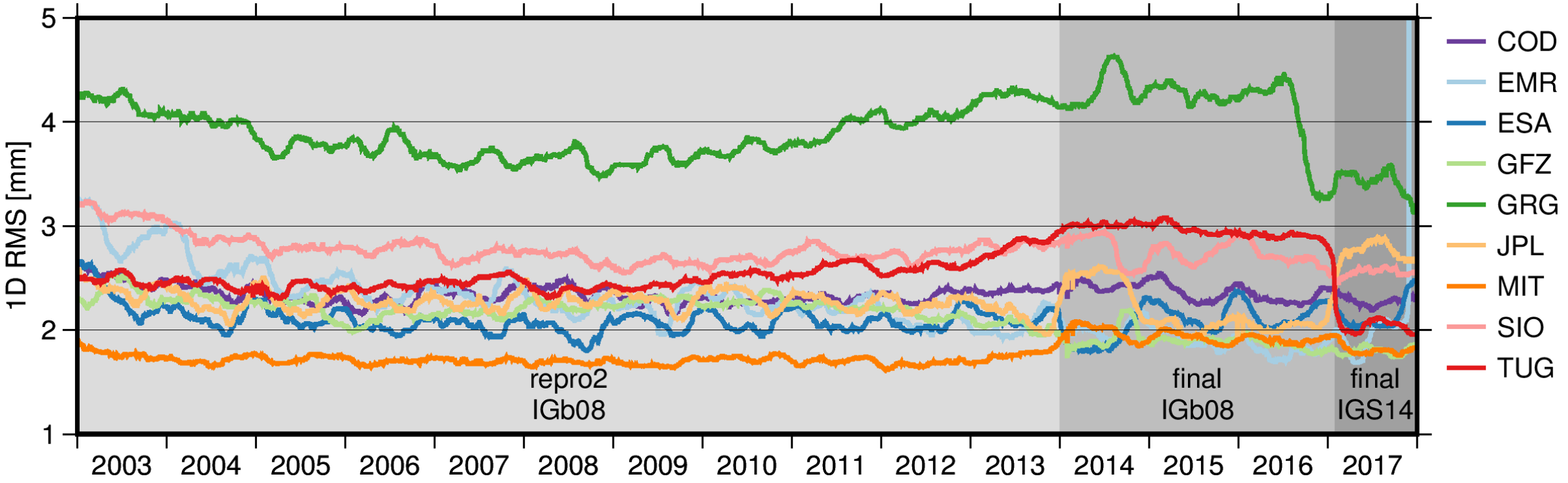
Daily station position RMS relative to IGS combination

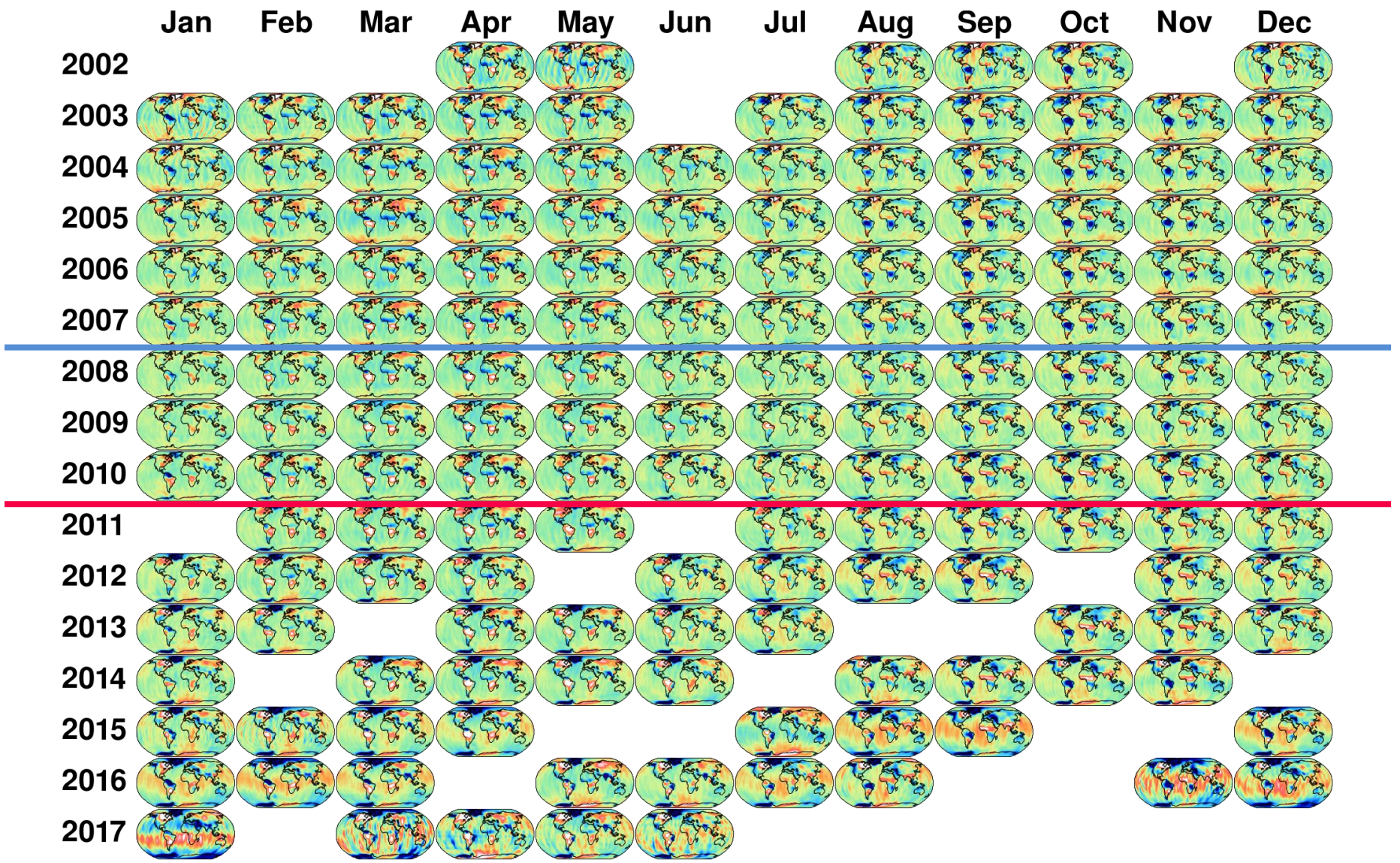


All IGS14 stations processed by individual institution used
(reference frame differences corrected, outlier removal based on robust 3σ-level)

91-day median-filtered for clarity

Application: Recovery of time-variable gravity

Gravity Recovery And Climate Experiment (GRACE)



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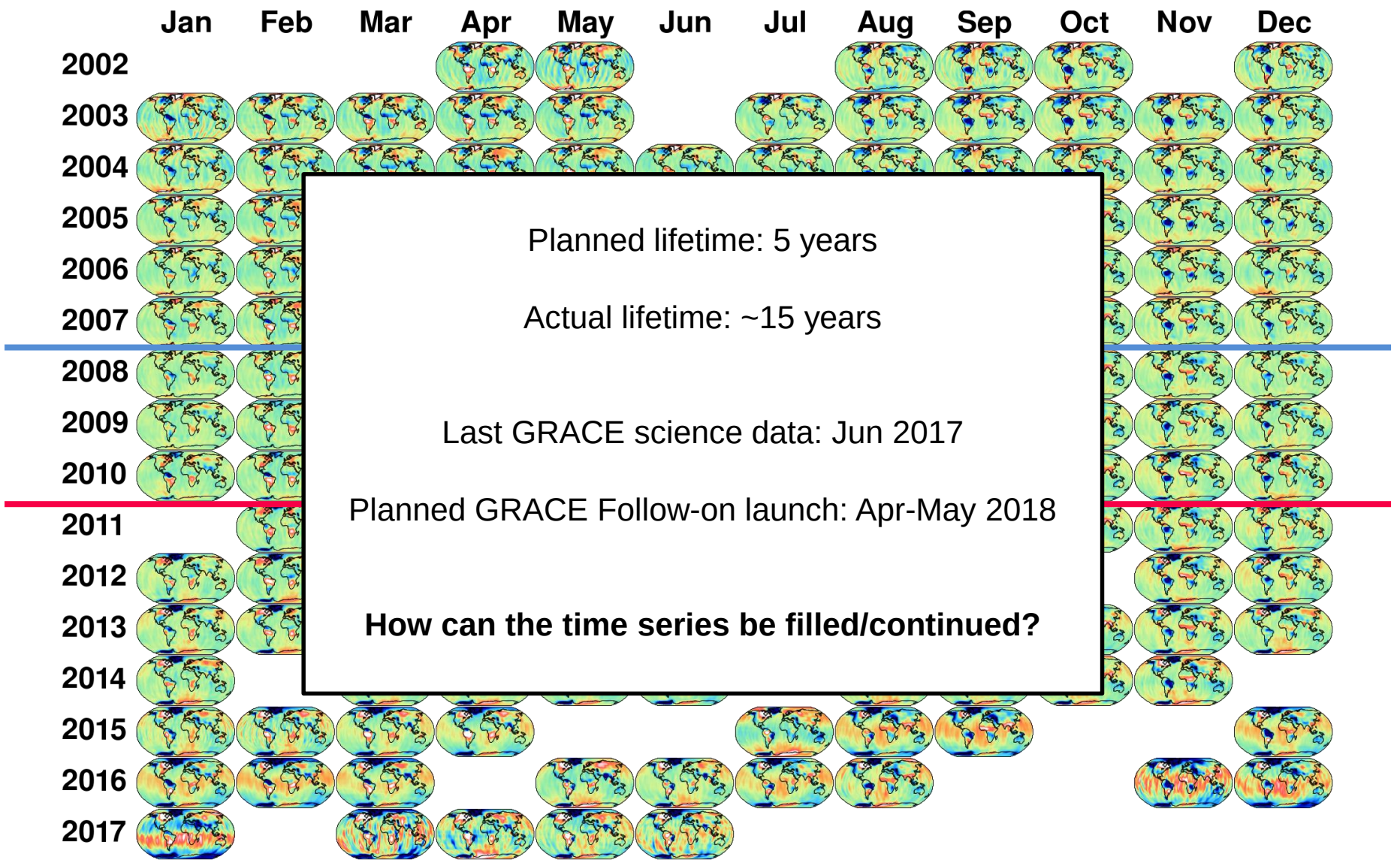


High-low satellite-to-satellite tracking (hlSST)

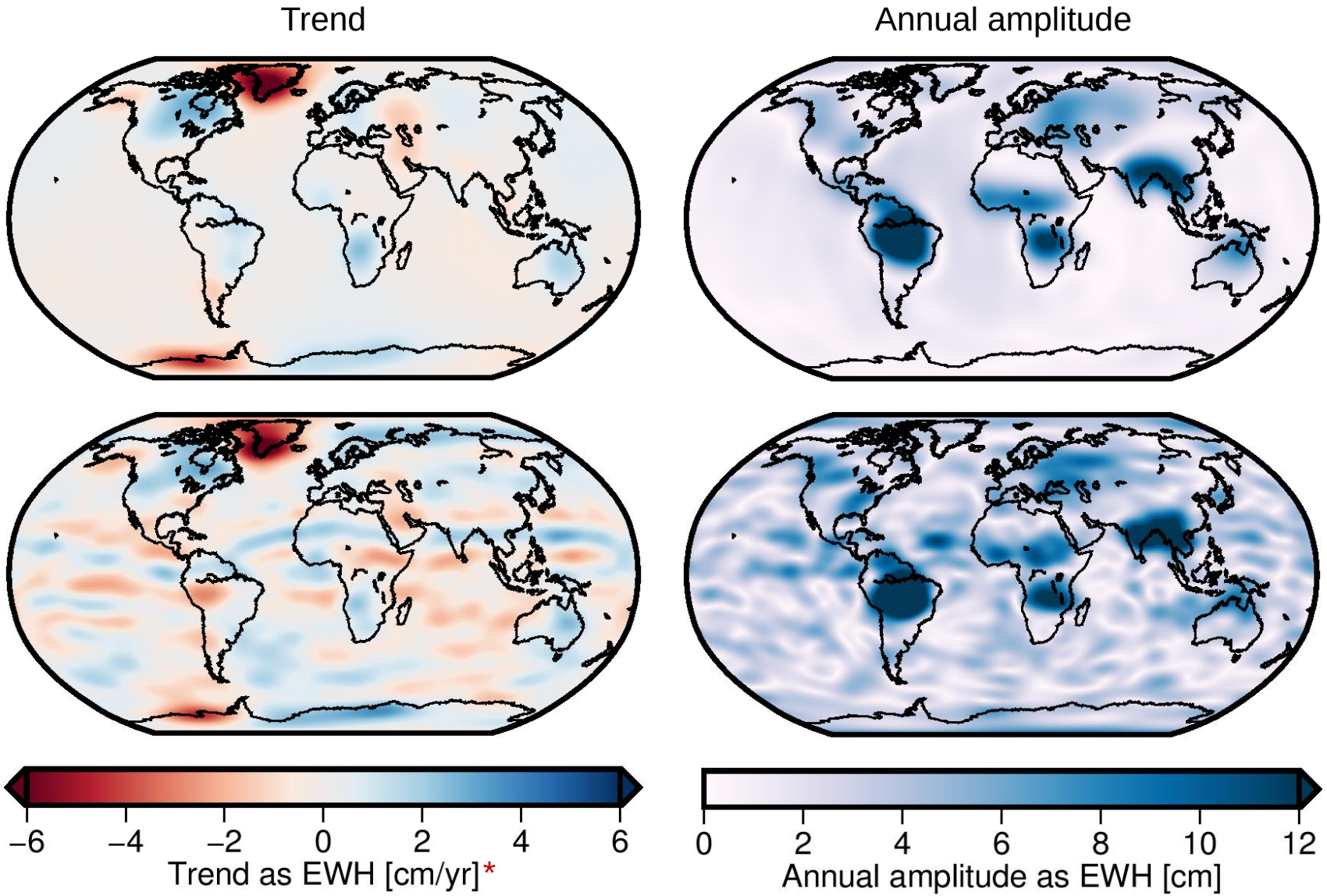
Almost all low Earth orbit (LEO) satellites with a high-quality GNSS receiver can be used.

Satellite missions

- CHAMP
- GRACE
- GOCE
- Swarm
- MetOp
- TerraSAR-X / TanDEM-X
- FORMOSAT-3 / COSMIC
- SAC-C
- Jason
- C/NOFS
- Sentinel
- …

Sources: NASA, ESA, GFZ, CONAE, USAF

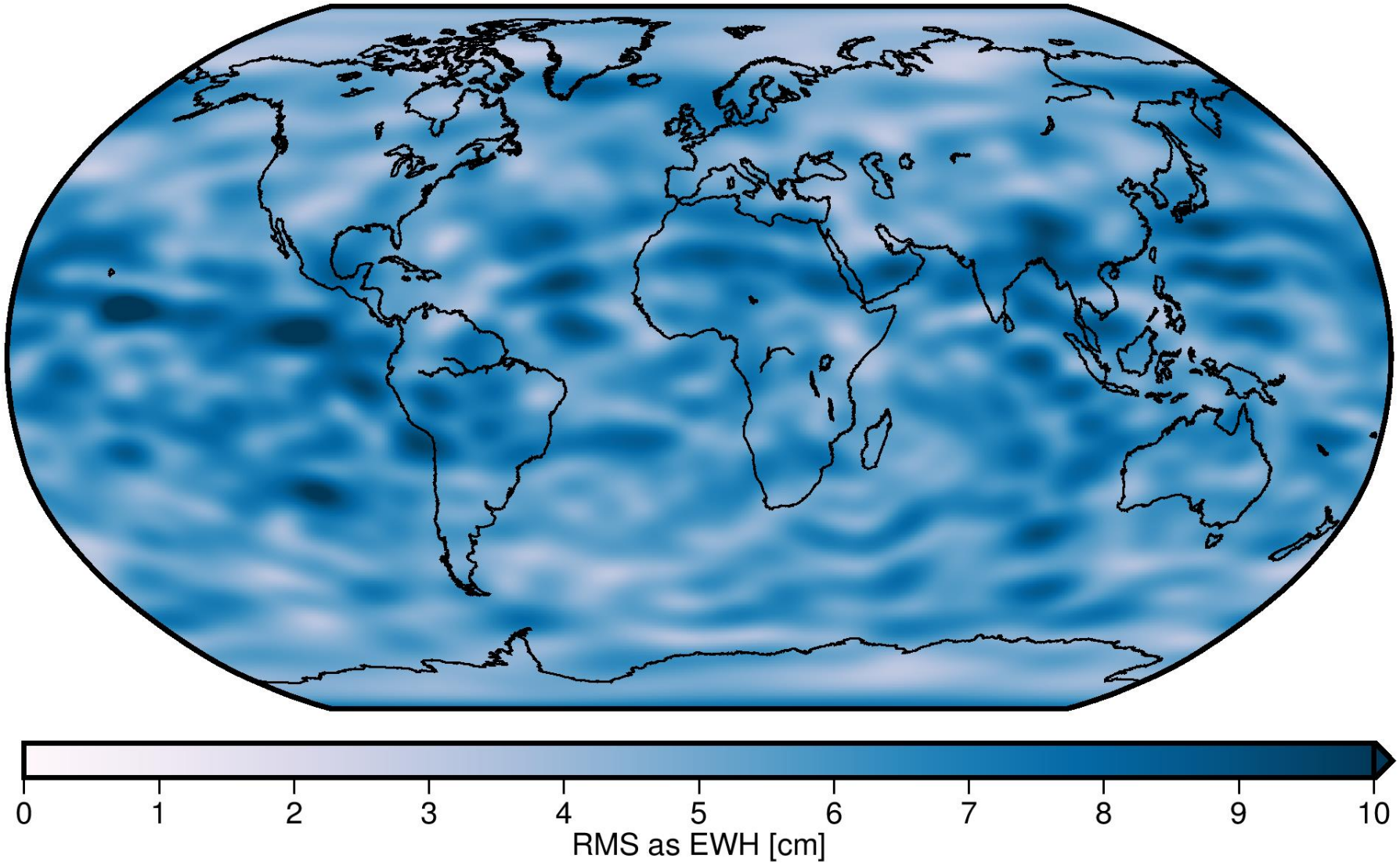
Time-variable gravity – trend and annual signal (2010-2011)



750 km Gaussian filter applied

* Equivalent water height

Agreement between hlSST and GRACE (2010-2011)



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Application: Recovery of time-variable gravity

Current project: Combined analysis of kinematic orbits and loading observations to determine mass redistribution

CAKAO

Aim: Improve recovery of time-variable gravity by combining

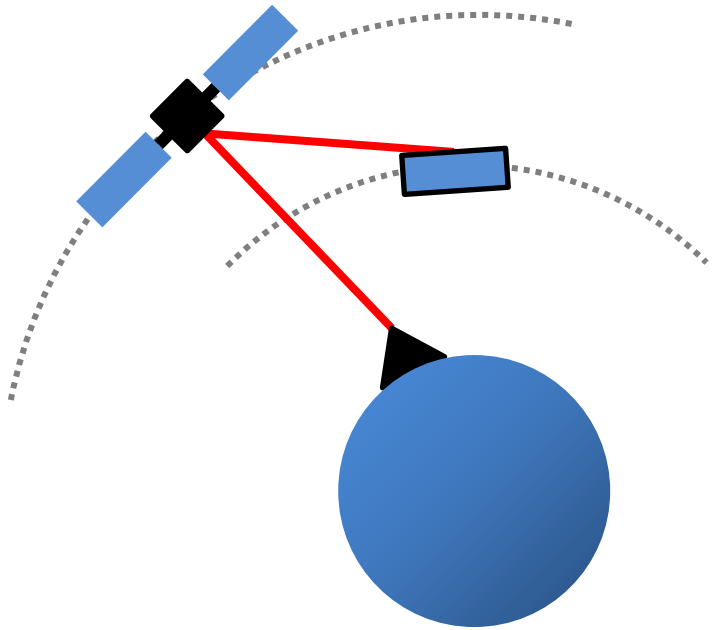
- Gravity field estimates derived from LEO satellite orbits
- Loading-induced station displacements

Issue: Inconsistencies in background models between

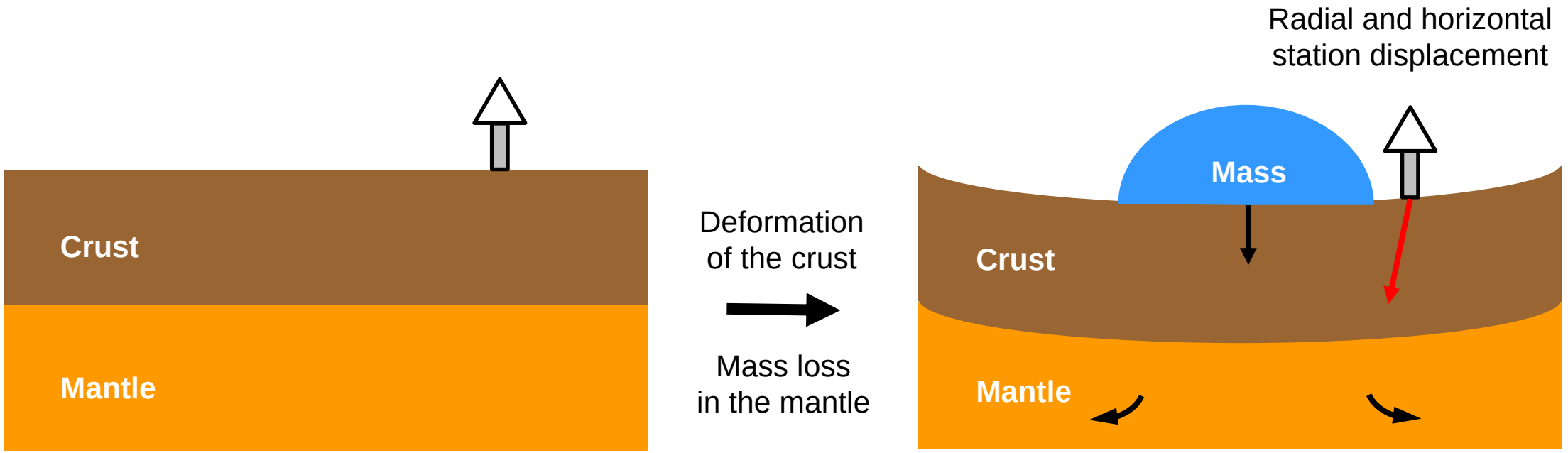
- Available GNSS products
- Gravity field processing

Solution: Consistent processing of

- Dynamic orbits of GNSS satellites
- Kinematic orbits of LEO satellites
- Station positions of a global GNSS station network



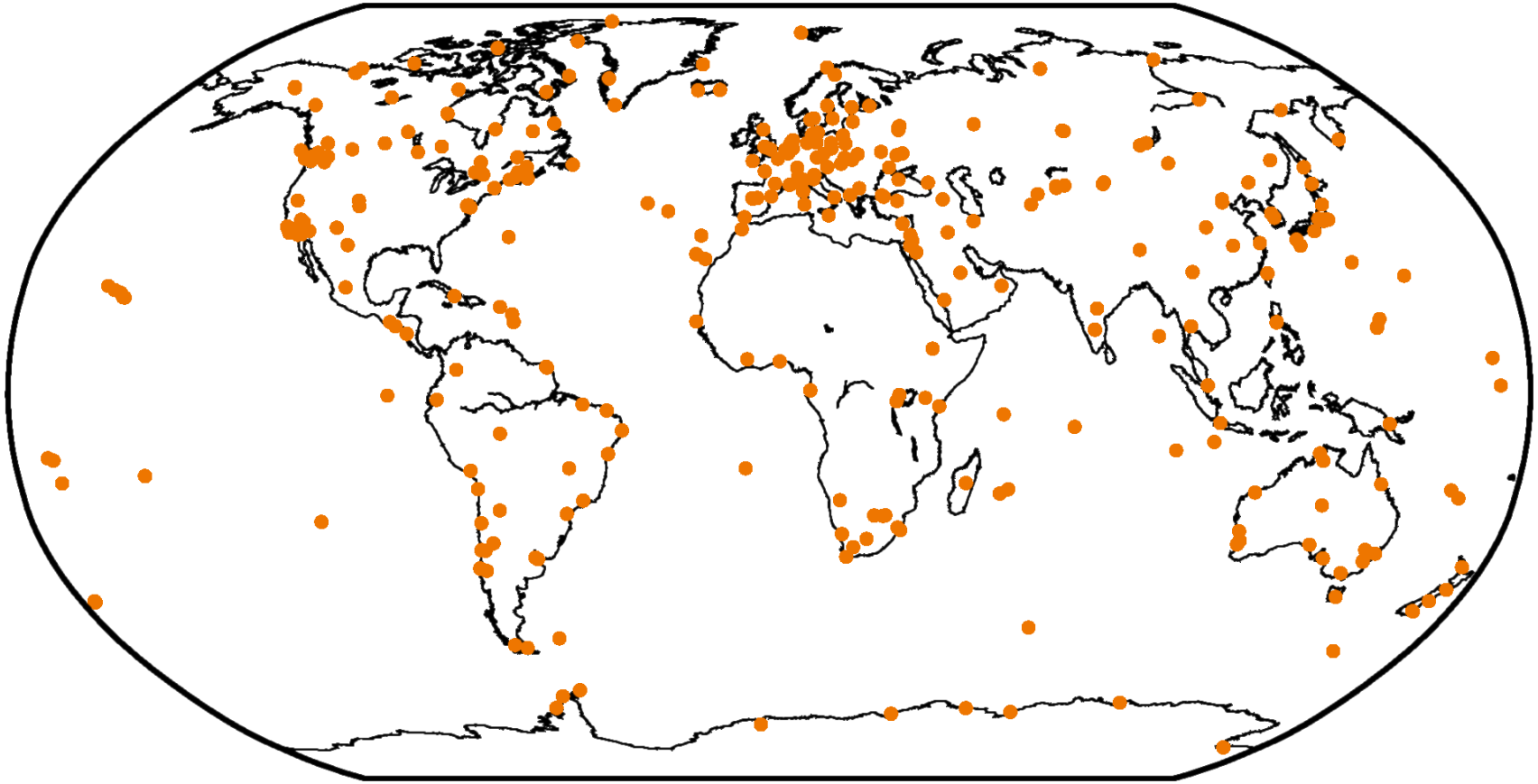
Loading theory



Combination test scenario

Two years of consistently processed data (2010-2011)

- GPS constellation
- 6 LEO satellites
- 382 IGS stations



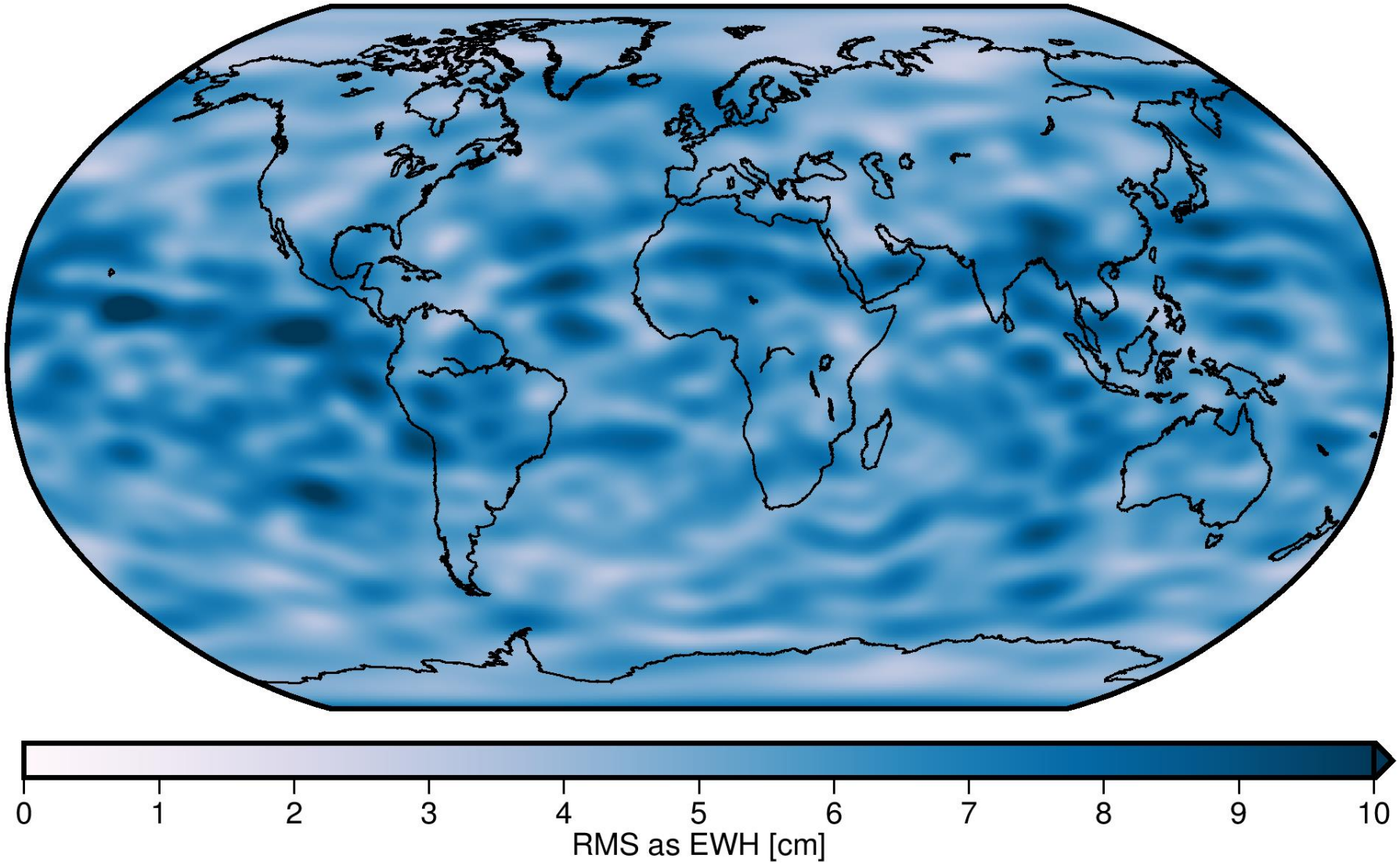
LEO satellites

- CHAMP
- GRACE A and B
- GOCE
- Jason 2
- TerraSAR-X

Gravity field

- Monthly solutions
- Up to degree and order 30
- 750 km Gaussian filter applied in visualizations

Agreement between hlSST and GRACE (2010-2011)



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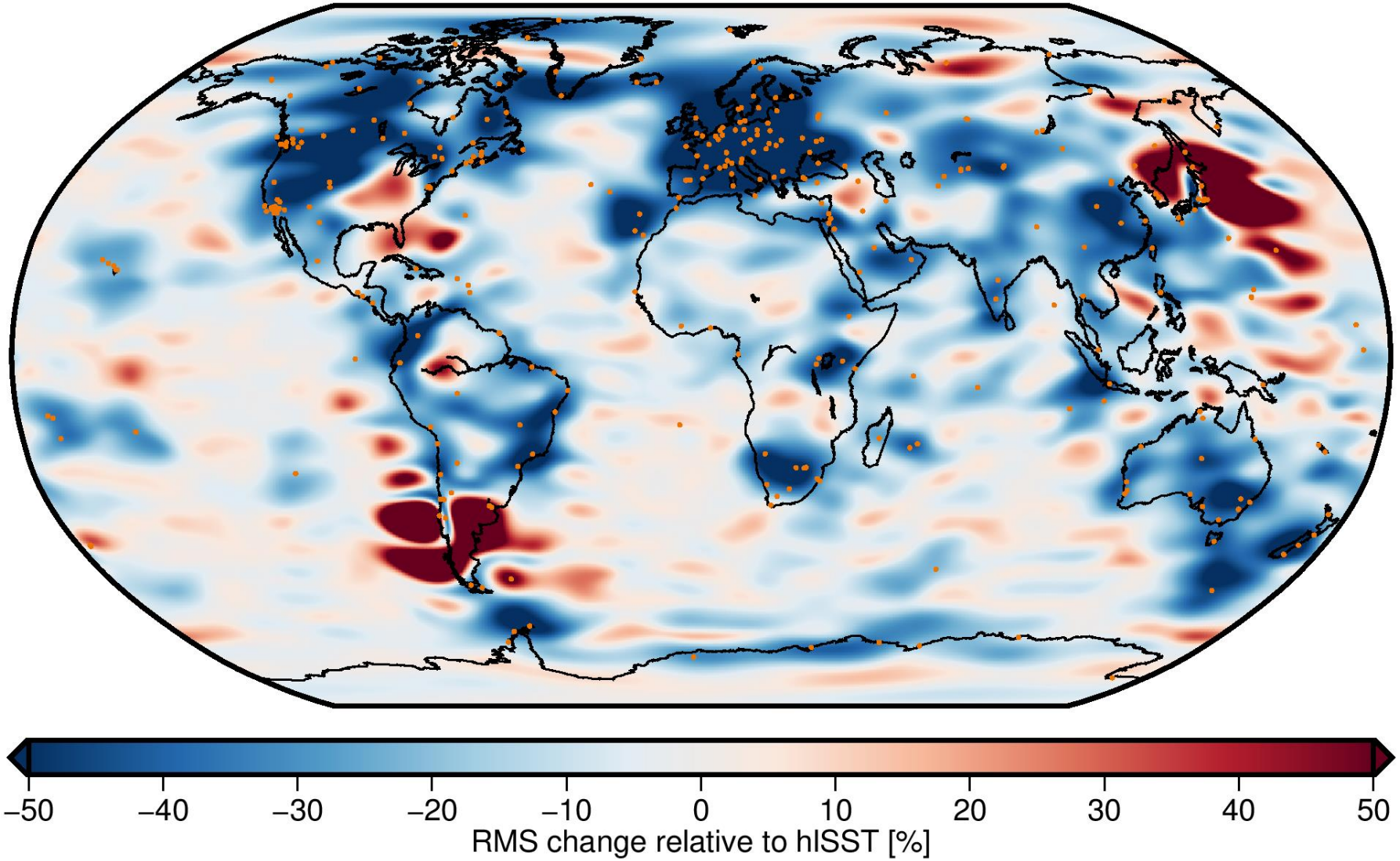
Impact of introducing GPS loading on agreement to GRACE



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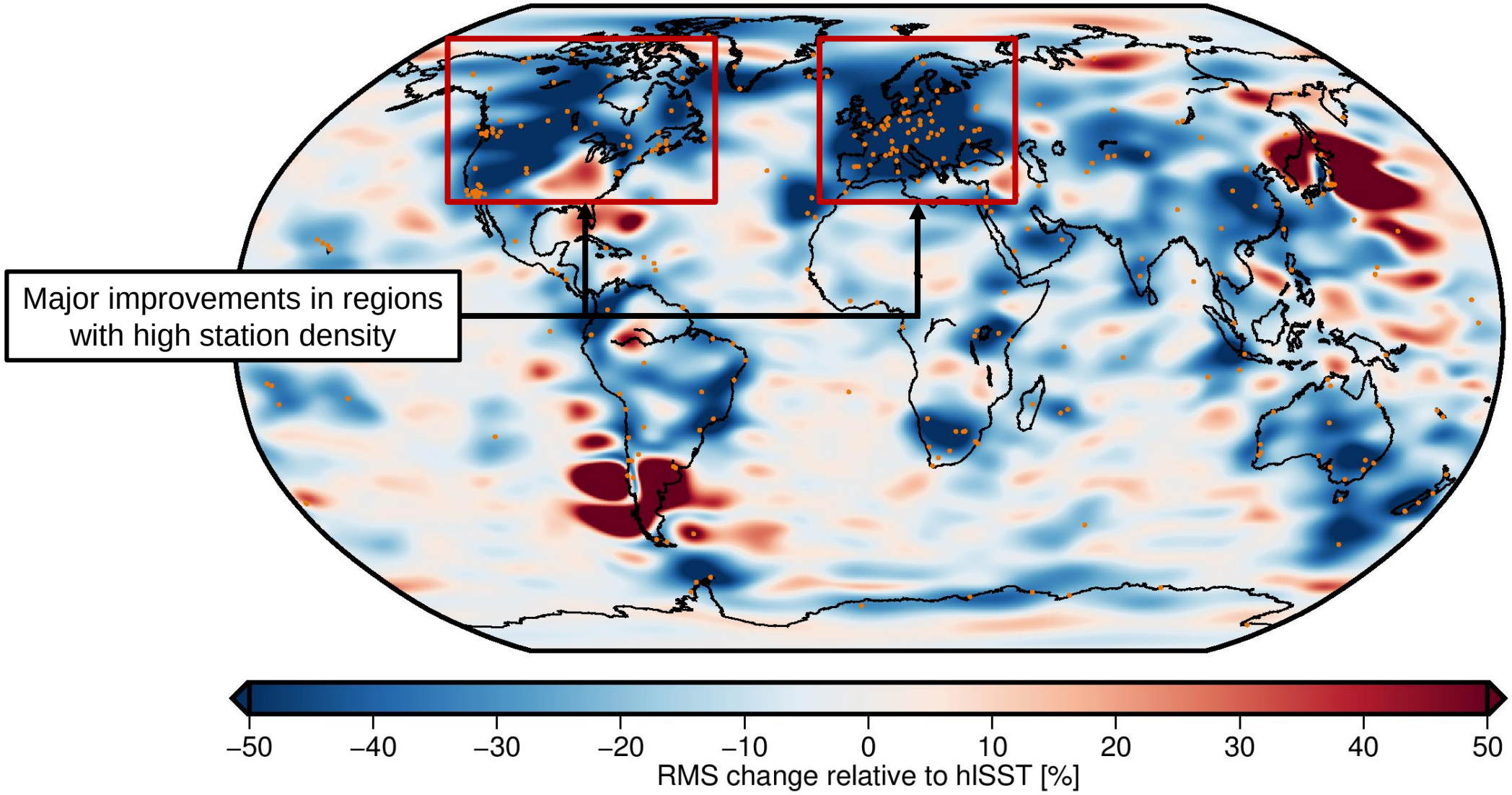

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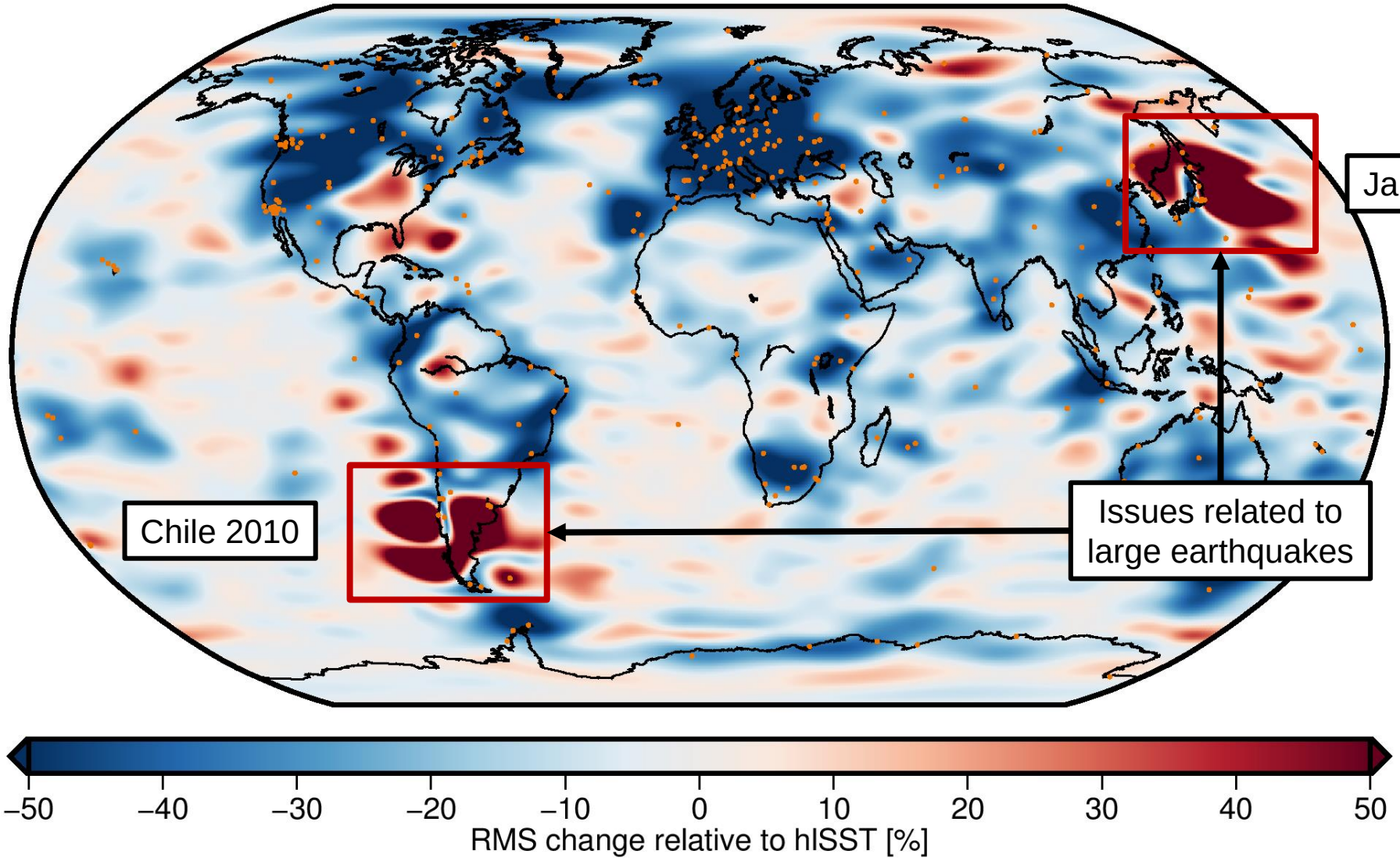

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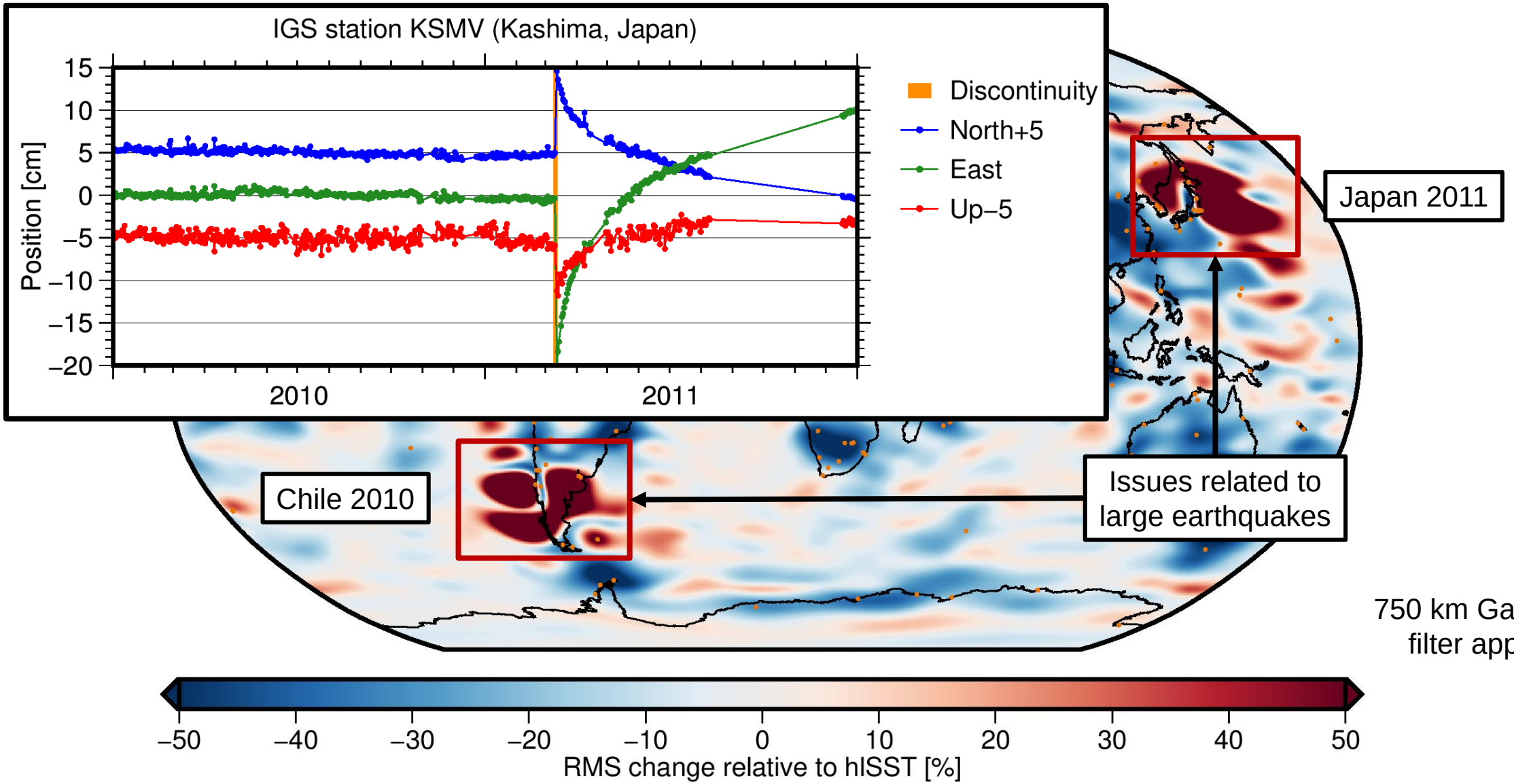
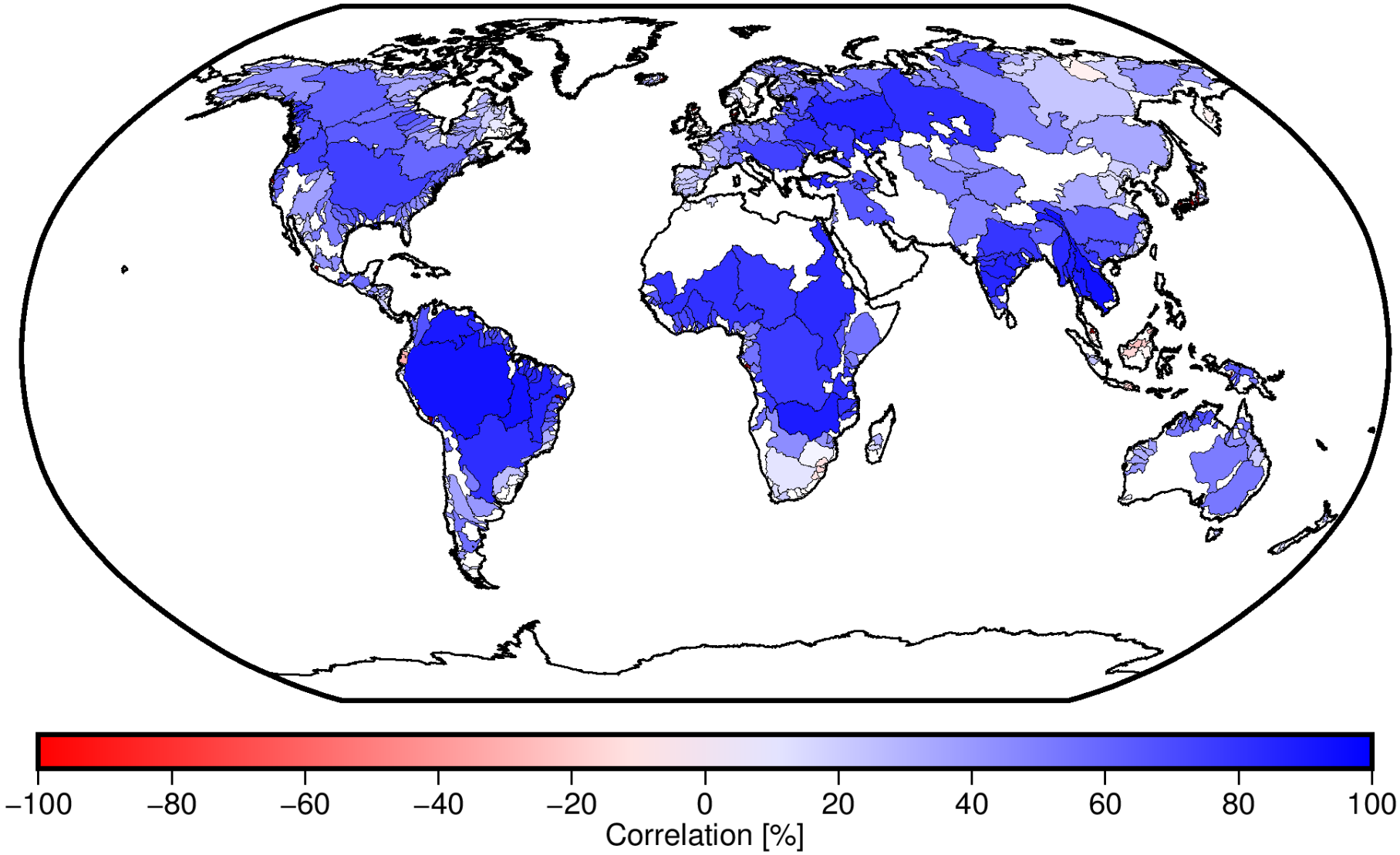


750 km Gaussian filter applied

Correlation between hlSST and GRACE for river catchments



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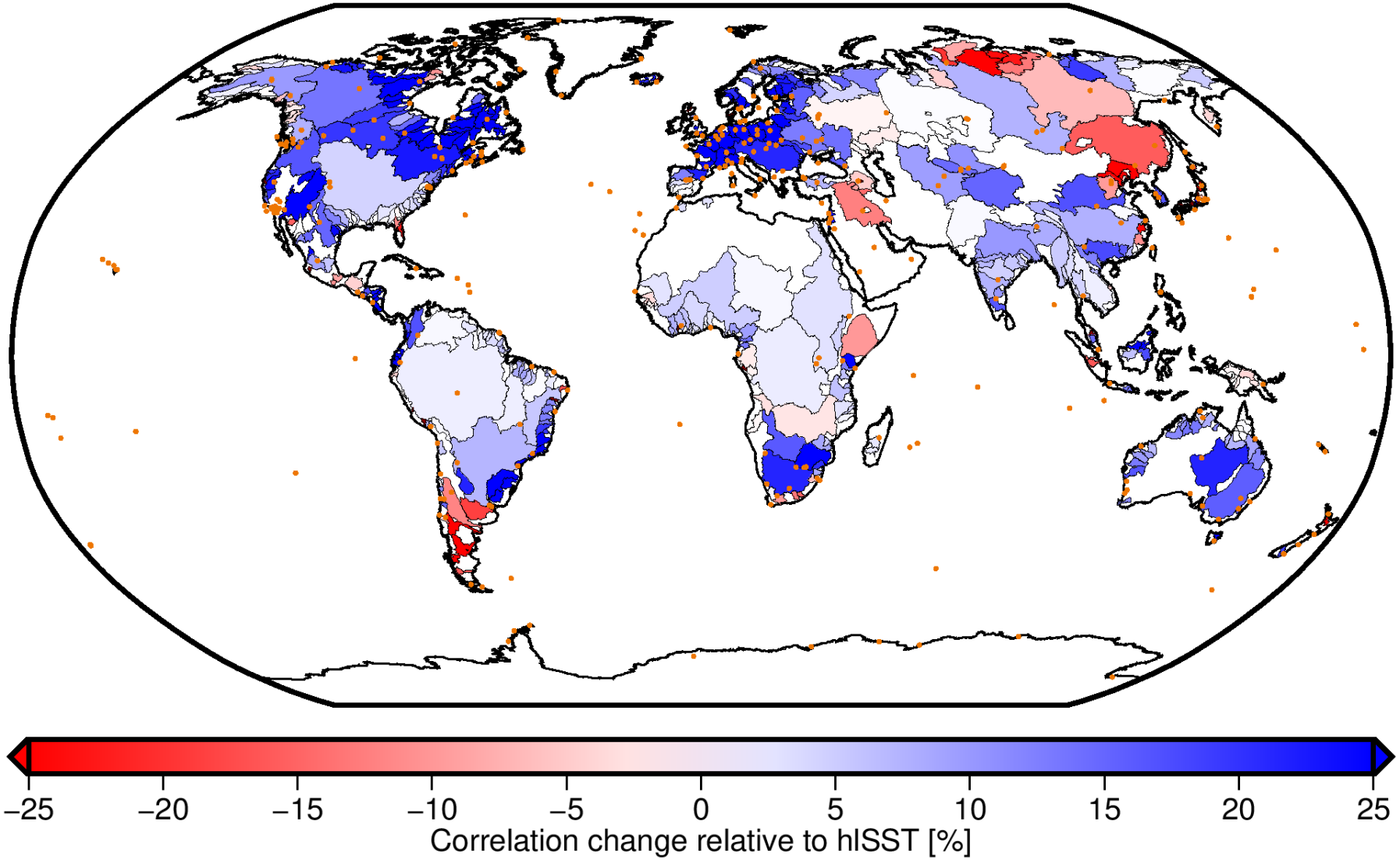

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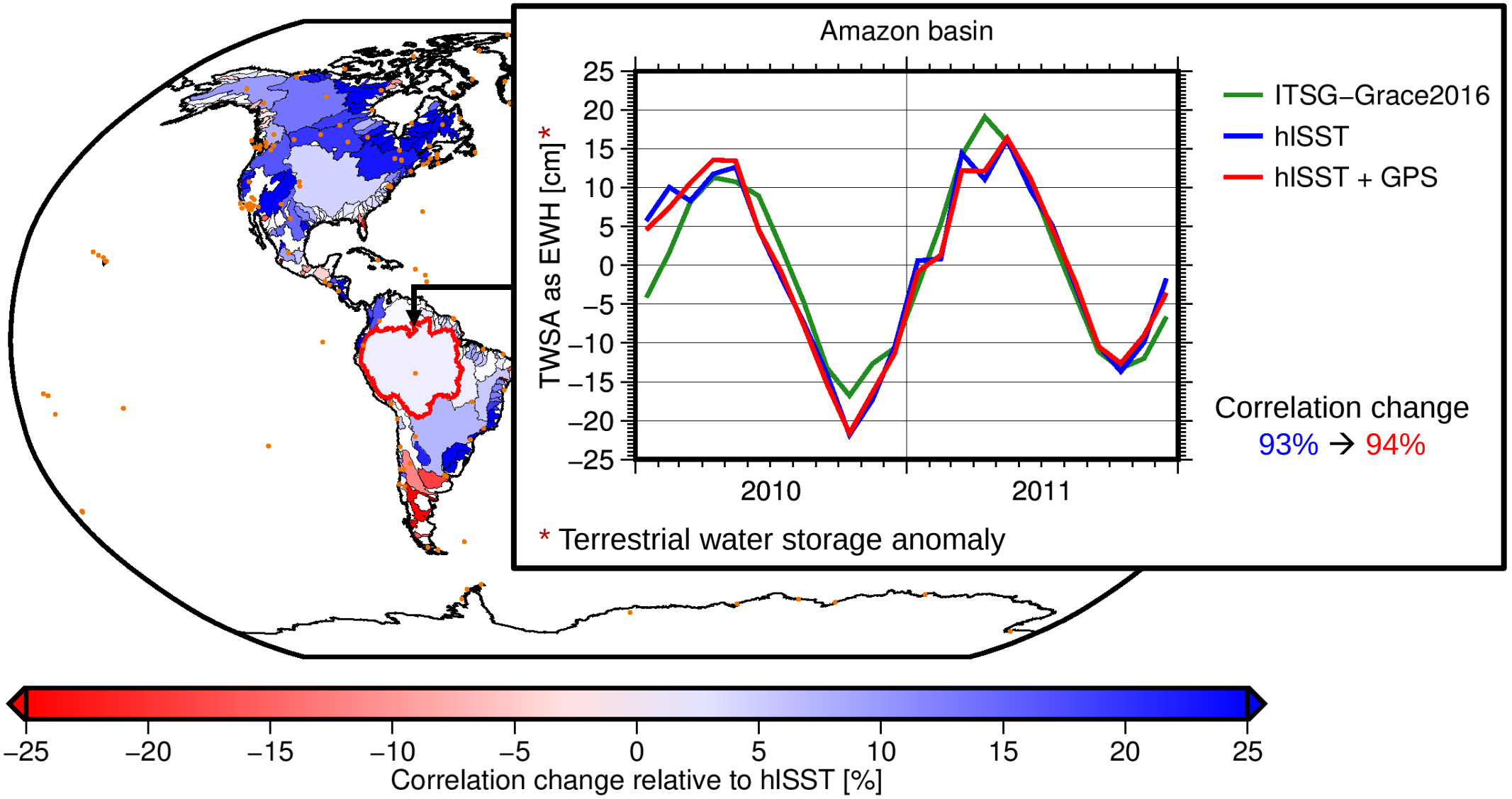

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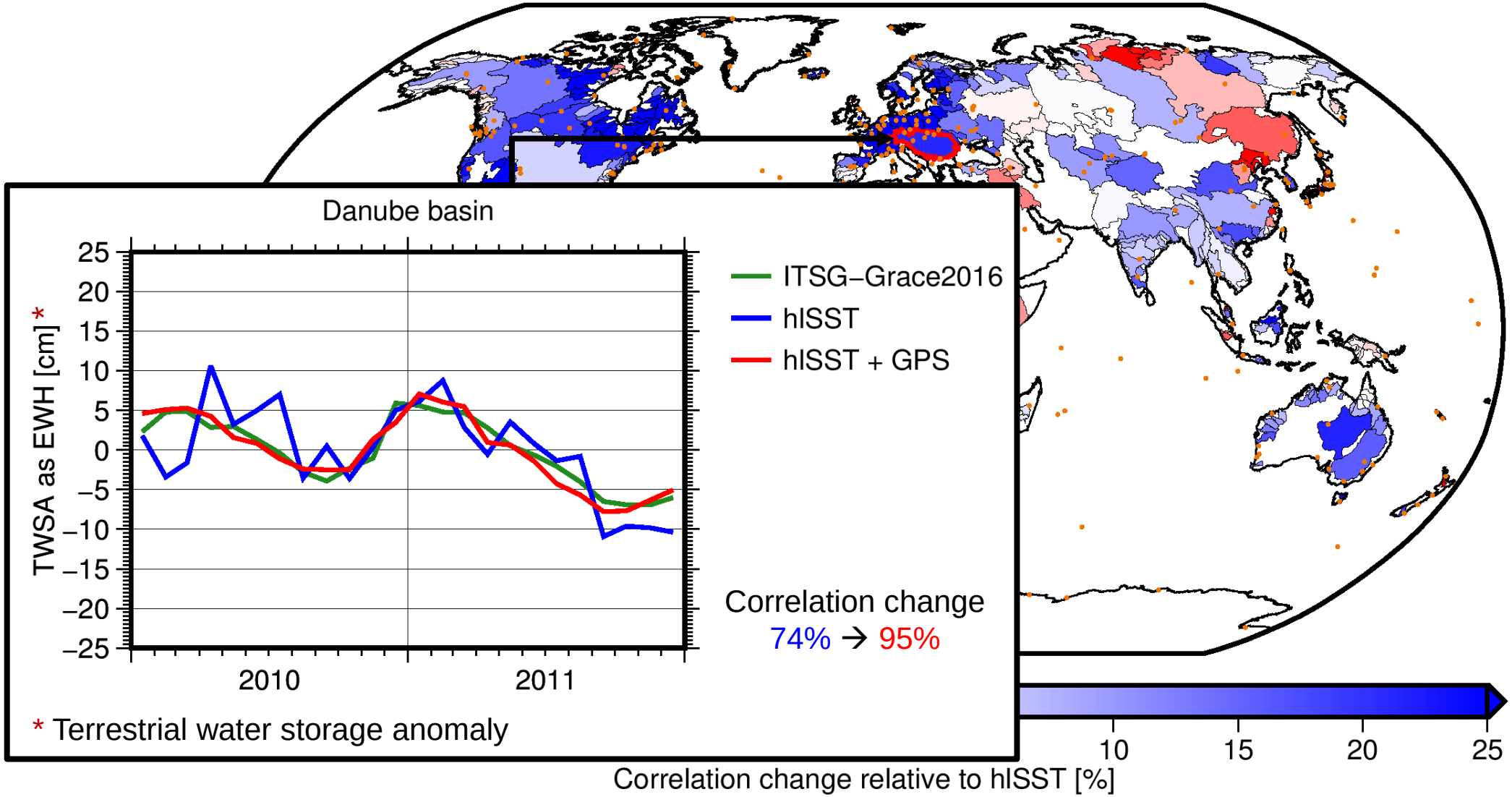


Conclusion and outlook

GNSS processing at Graz University of Technology

- Same level of quality as well-established GNSS processing approaches
- Consistent processing of GNSS orbits, stations positions, and LEO orbits

Combination of hlSST and GNSS loading

- Reduction of high-frequency noise improves detection of smaller signals
- Major improvements in regions with high station density
- Issues with signal separation in station position series (earthquakes, snow, multipath, …)

Main research focus in the future

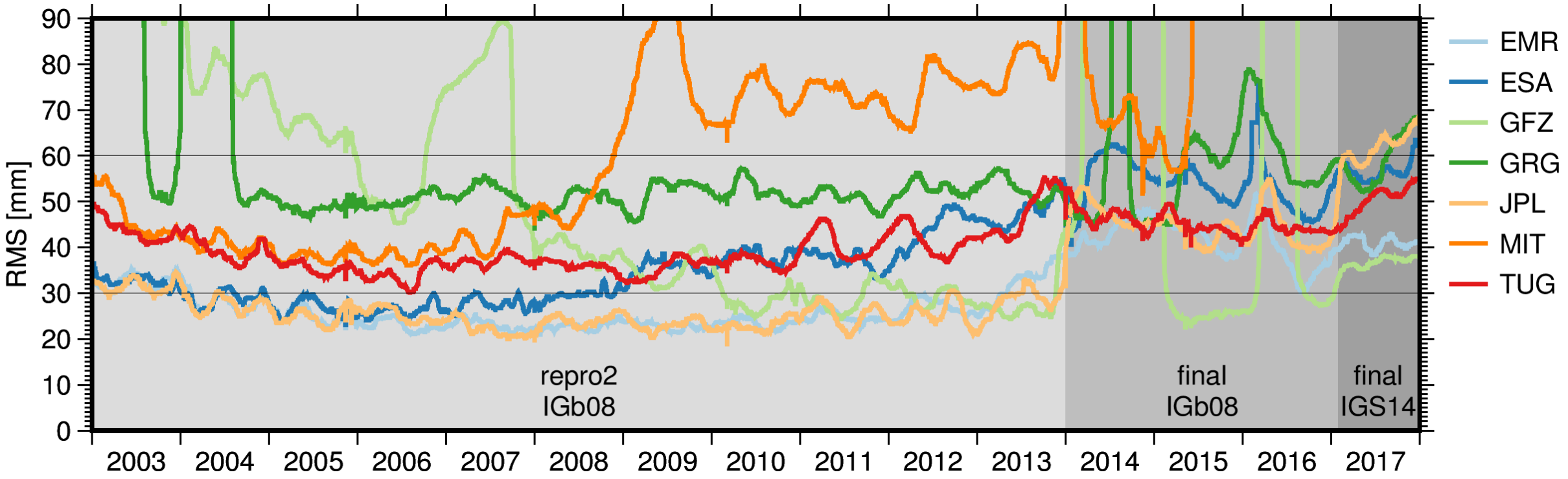
- Multi-GNSS and multi-frequency processing
- Parametrization improvements in GNSS processing

Thank you!

The project CAKAO has received funding from the Austrian Research Promotion Agency (FFG) within the Austrian Space Applications Programme (ASAP).

Backup slides

Daily GPS clock RMS relative to IGS combination



Clocks synchronized between all institutions
(system-wide absolute clock shifts corrected)

91-day median-filtered for clarity

Estimated parameters

Exemplary single day processing

- 32 satellites
- 180 stations
- Dual-frequency code and phase
- 30 second sampling

→

- ~18 million observations per day
- ~5.1 million parameters per day