

# How well can the combination of hISST and SLR replace GRACE?

A discussion from the point of view of applications

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RUES

RESEARCH UNIT  
IN ENGINEERING  
SCIENCES

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FACULTY OF SCIENCES, TECHNOLOGY AND COMMUNICATION



LANTMÄTERIET

  
UNIVERSITÉ DU  
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**AIUB**



# PROCESSING

A short overview

# HLSST + SLR

## High-low SST:

- 11 satellites with GPS

CHAMP	GRACE A	GRACE B
GOCE	MetOp A	MetOp B
TerraSAR X	TanDEM-X	
Swarm A	Swarm B	Swarm C

- accelerometer data used when available
- combination at the normal equation level

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Details in Zehentner et al:

*Non-dedicated satellite missions for time-variable gravity field recovery*

Today: 14:30

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## SLR:

- 9 satellites

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

- gravity parameters together with station coordinates, ERP, geocenter and range biases
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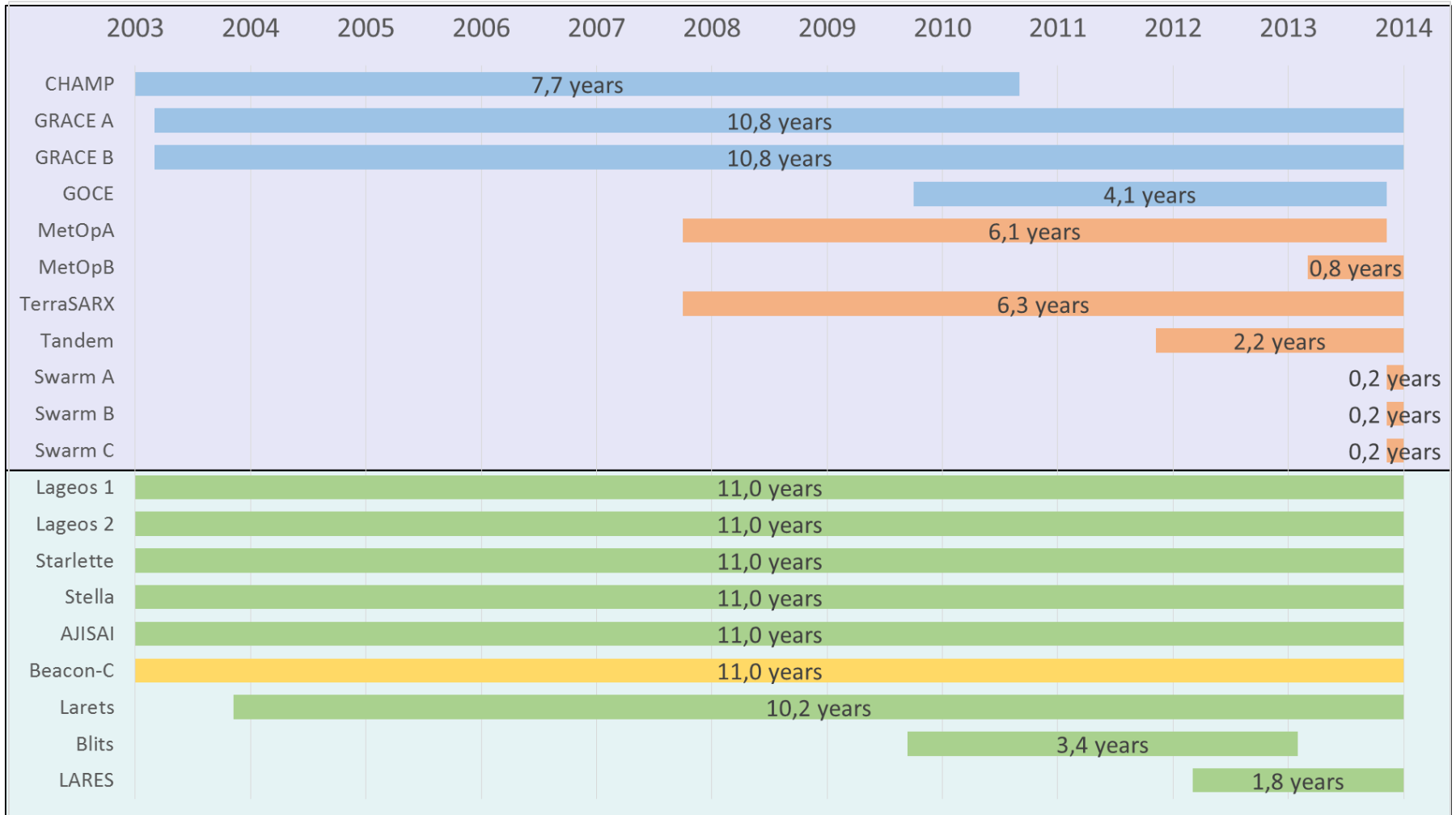
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Details in Sośnica et al:

*Time varying gravity from SLR, combined SLR and high-low satellite-to-satellite tracking data*

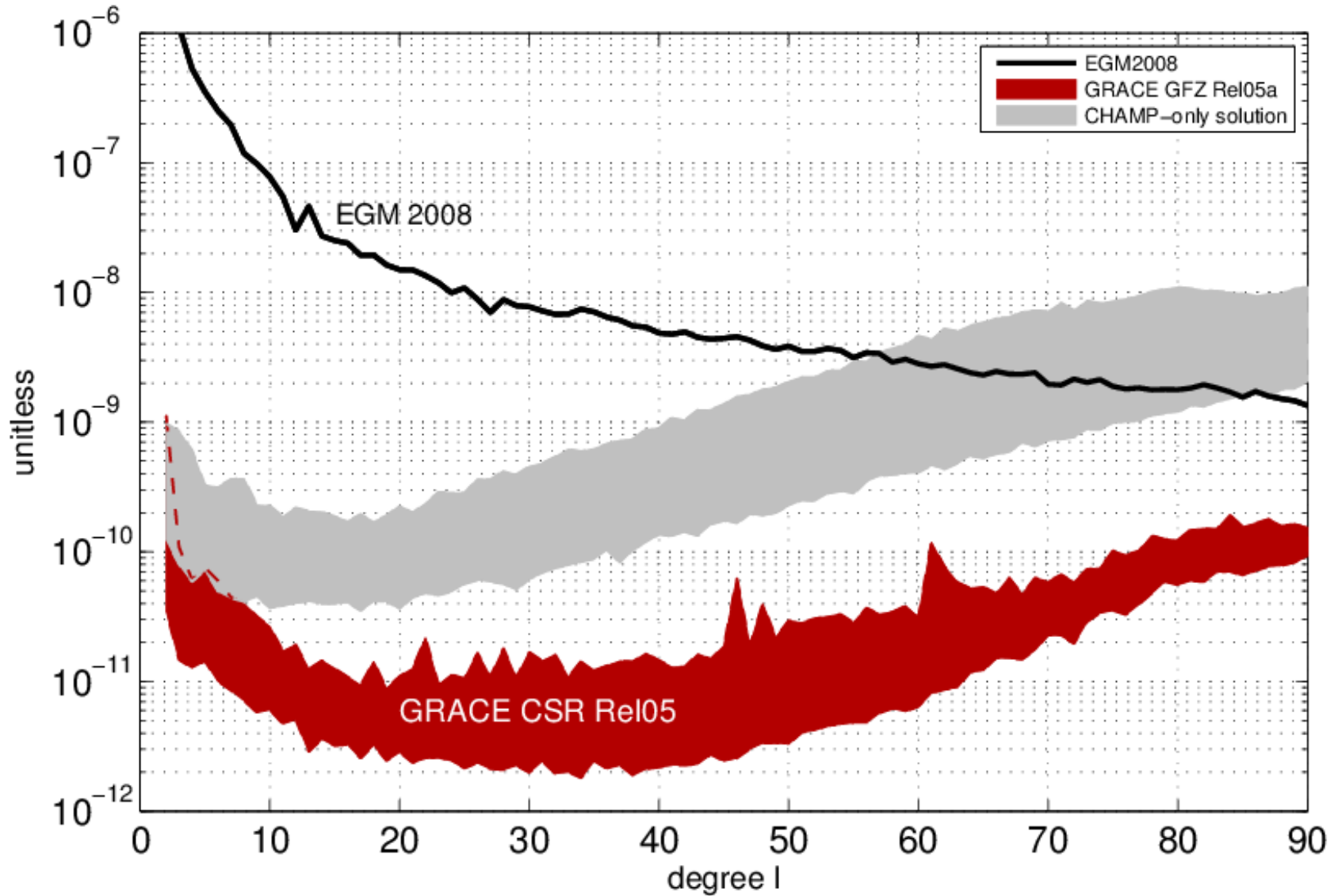
Today: 14:15

# Data availability



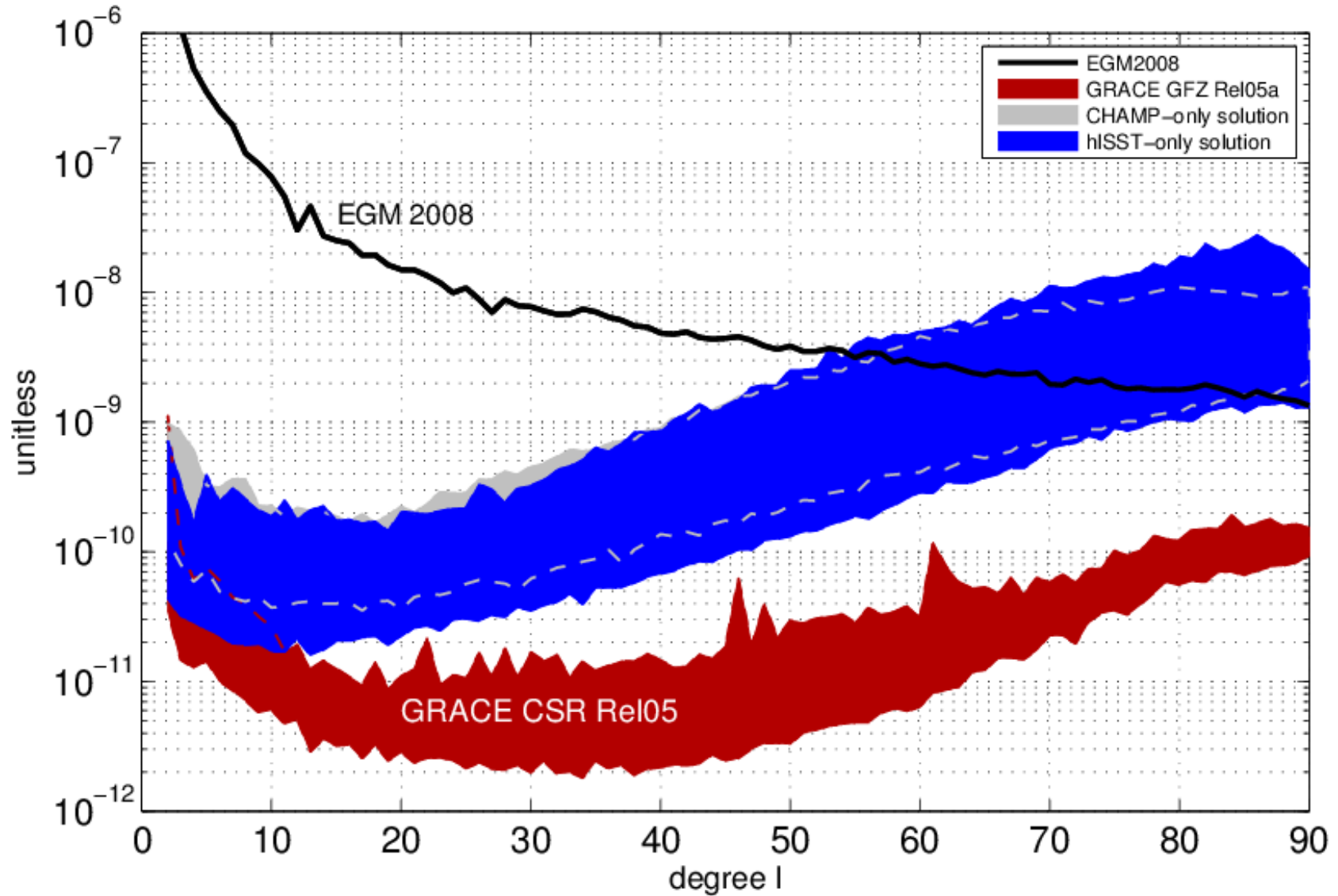
■ dedicated gravity field missions  
 ■ non-dedicated mission  
 ■ spherical SLR  
 ■ non-spherical SLR

# CHAMP-only

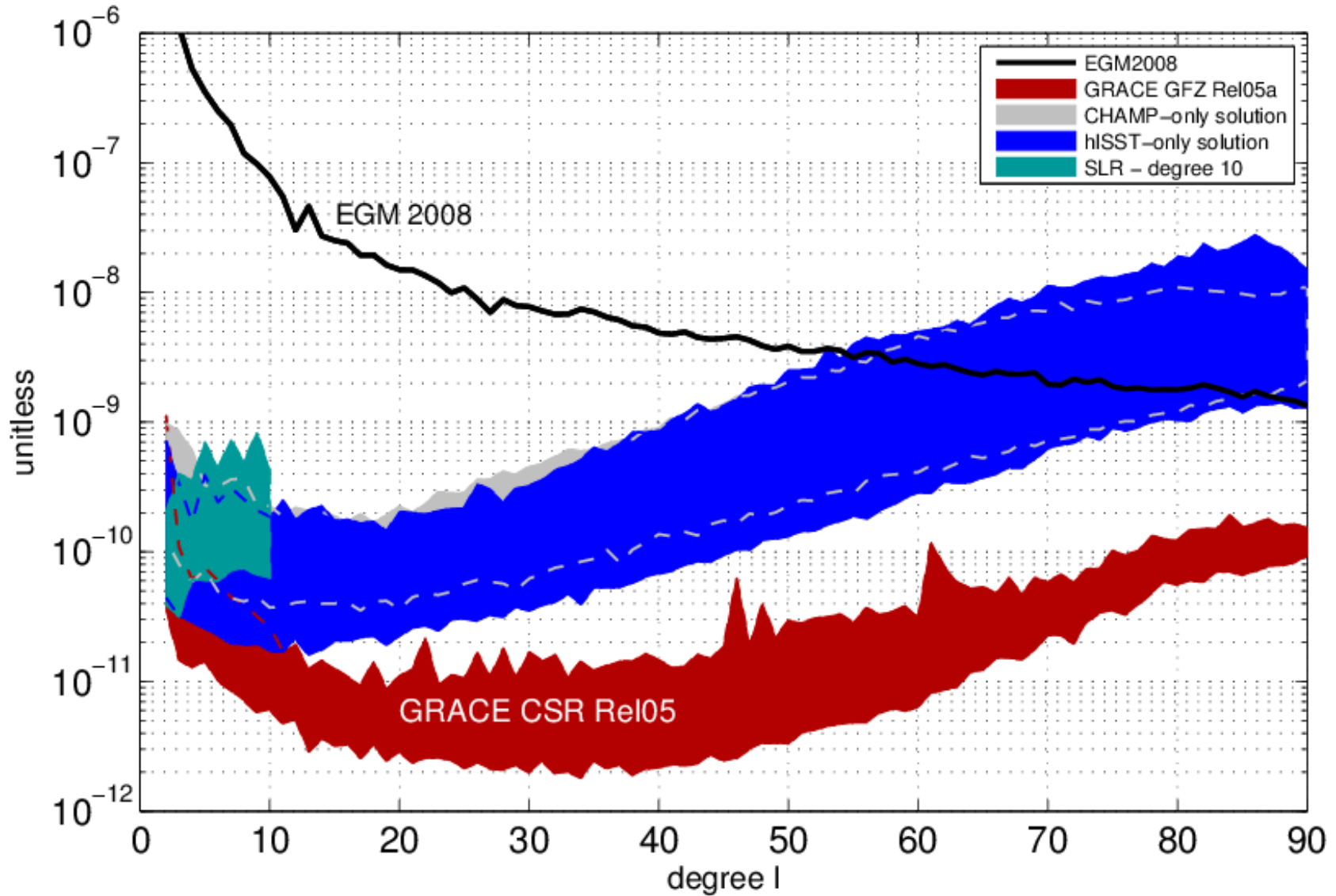




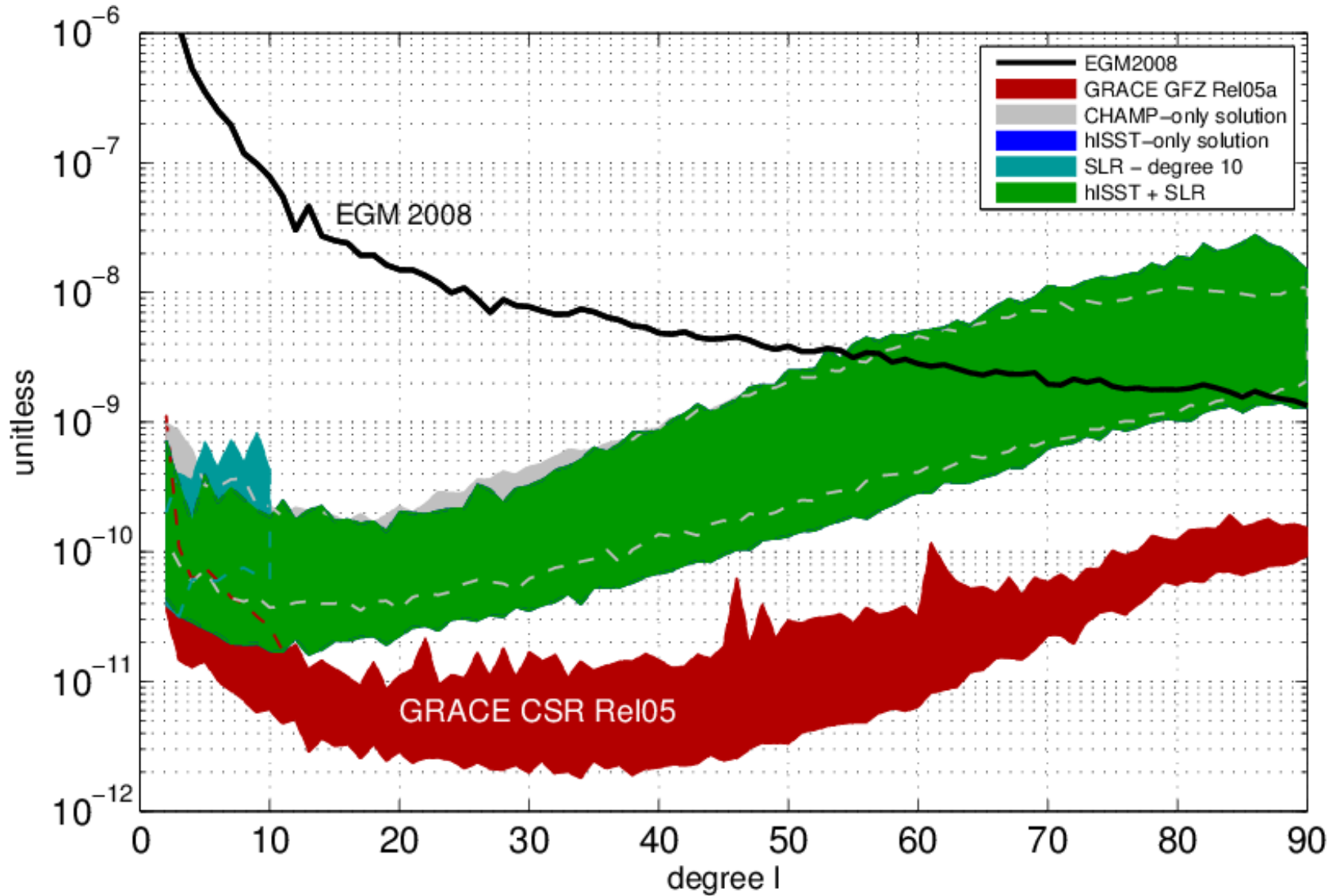
# Combined hISST



# Combined hISST vs SLR

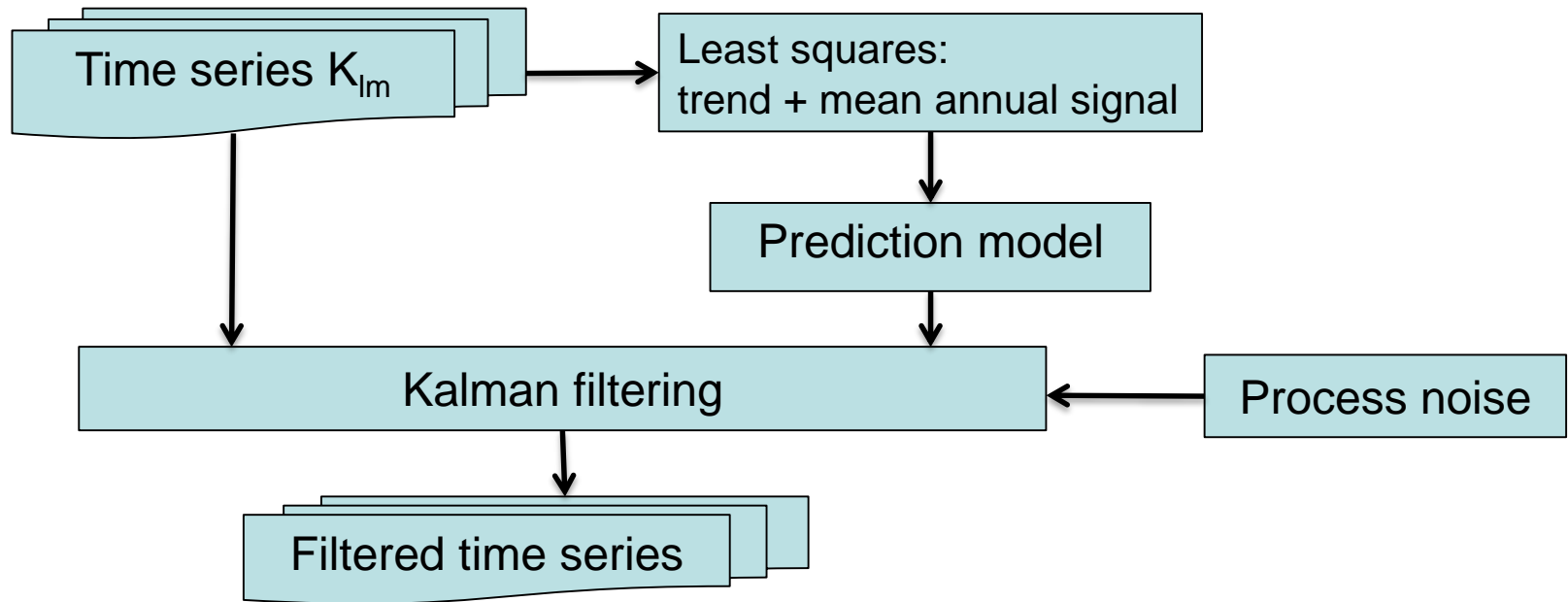


# hISST + SLR



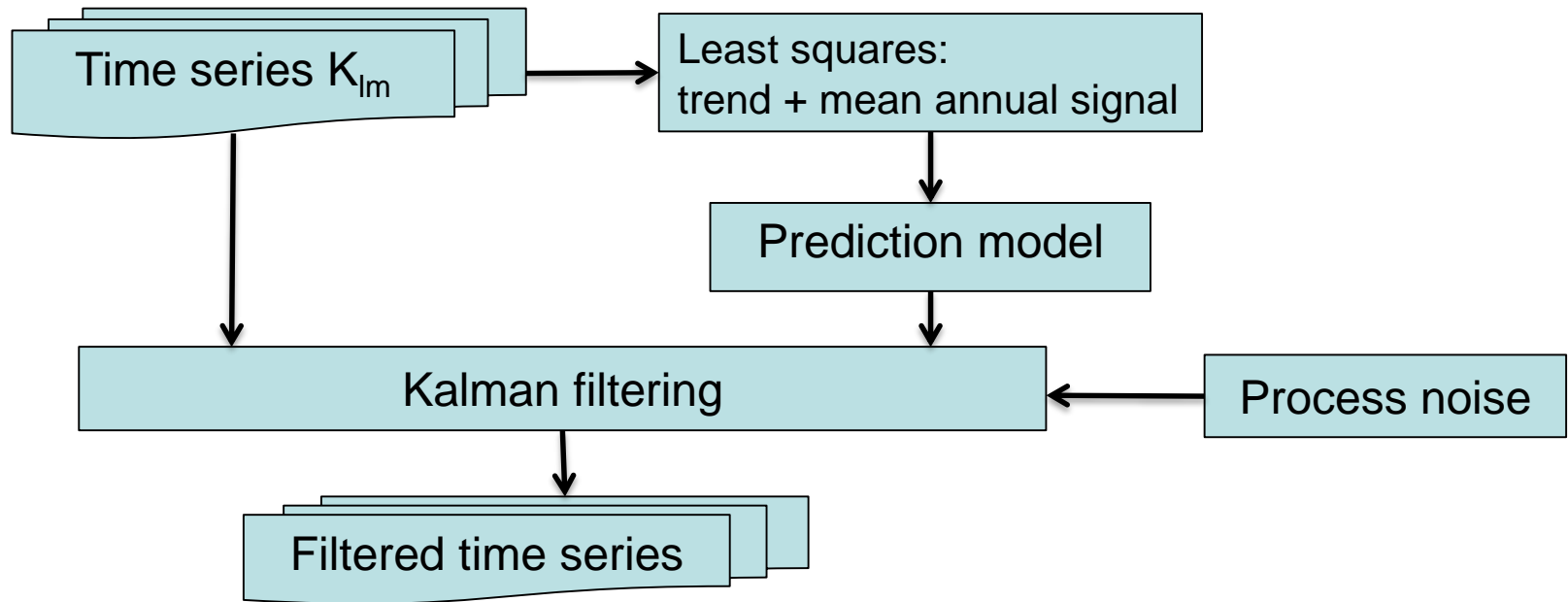
# Post-processing: old approach

- Kalman filtering
  - ... allows to handle small numbers of sample (filter warm-up issue).



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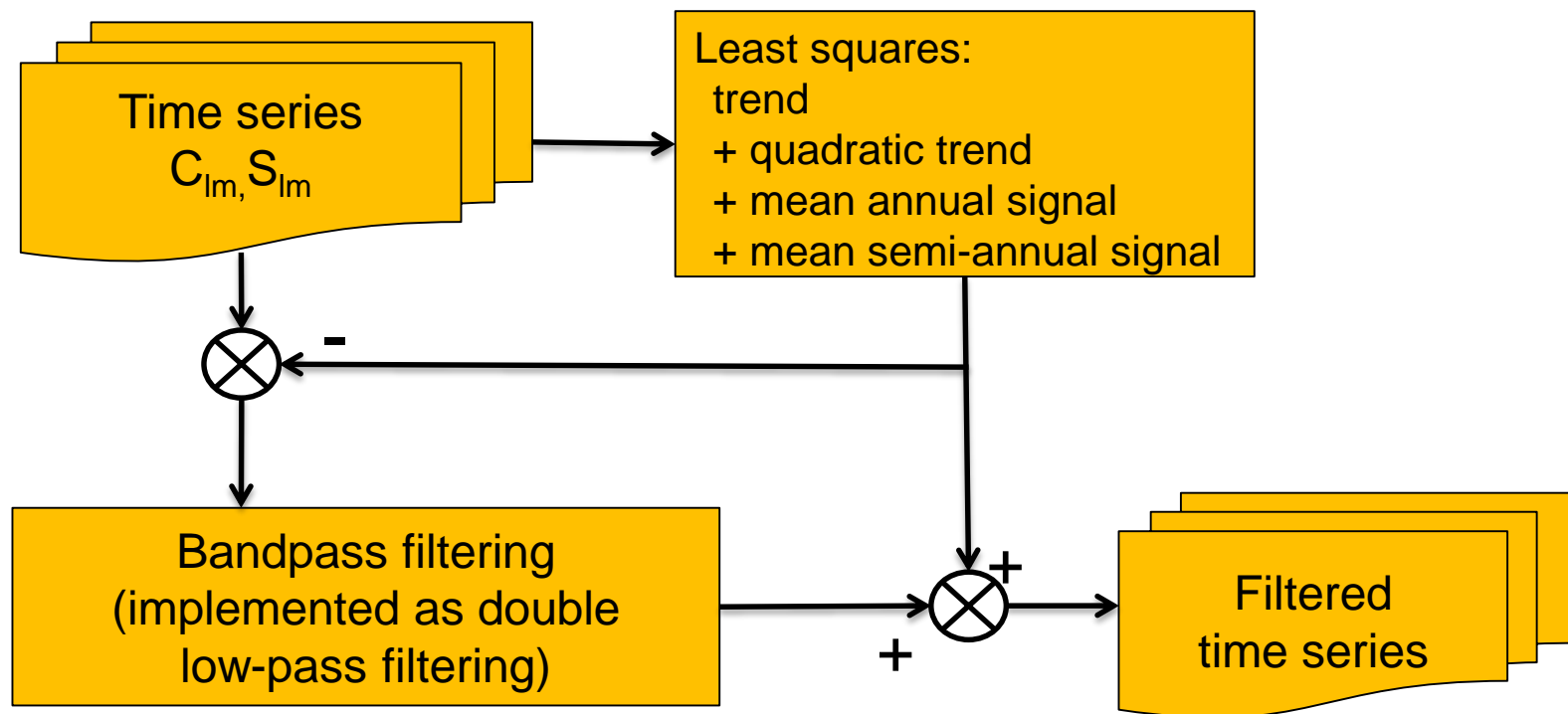
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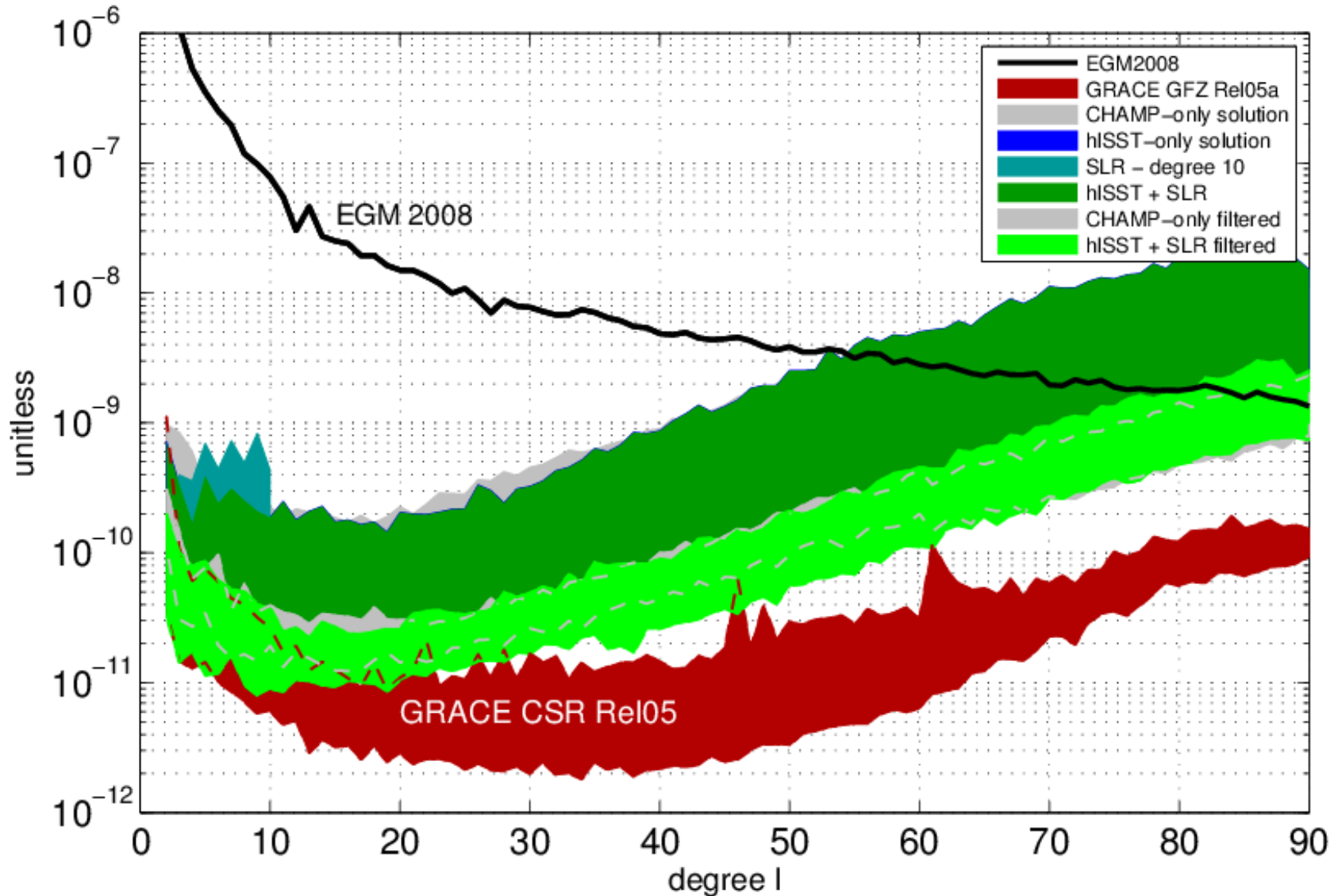
... is equivalent to an AR(2) process: filter design is limited.

# Post-processing: new approach

- Bandpass filtering  
... is possible due to the longer time series (11 years)



# hISST + SLR + post-processing



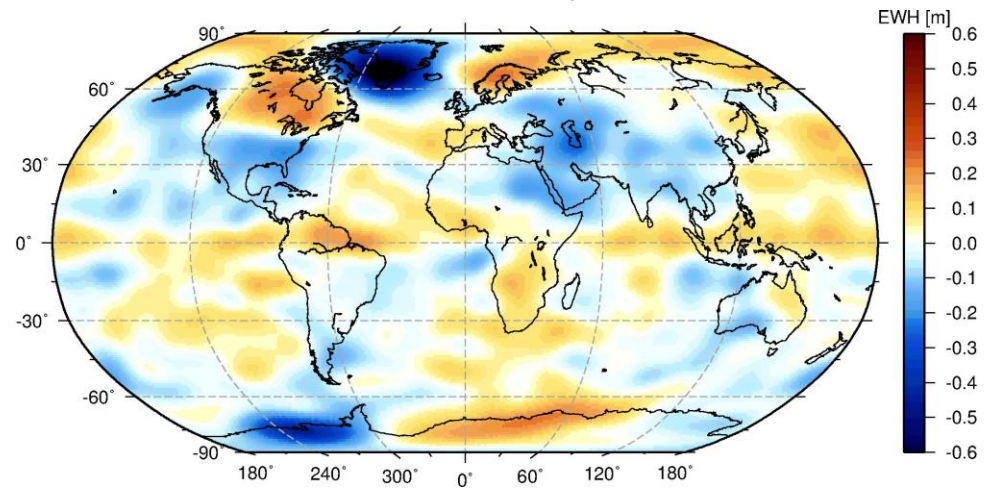
# MASS TRENDS AND ANNUAL SIGNALS



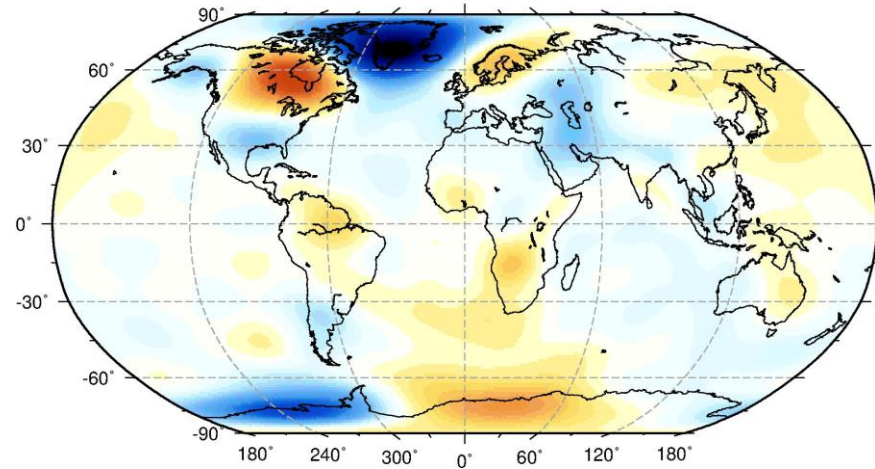
# Trends

- Total change in terms of EWH
- Gaussian filtering with 750 km

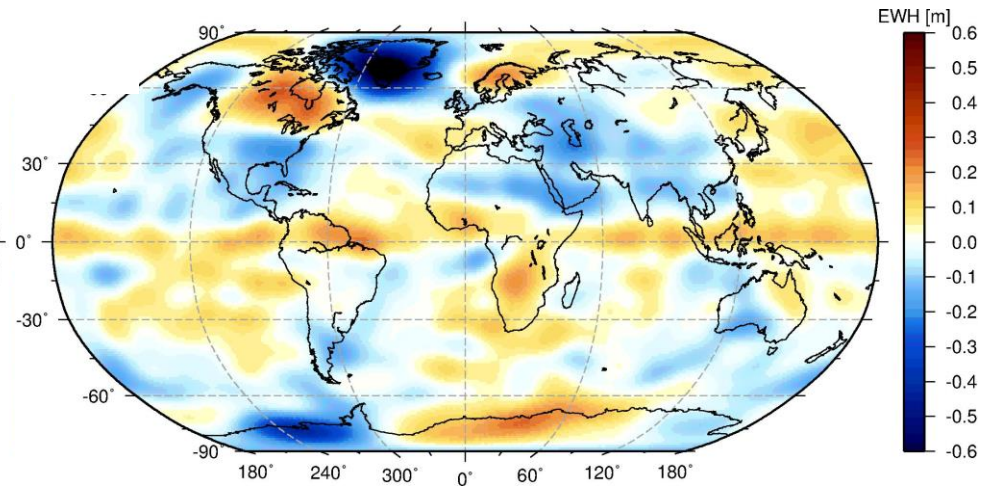
hISST-only



GRACE CSR



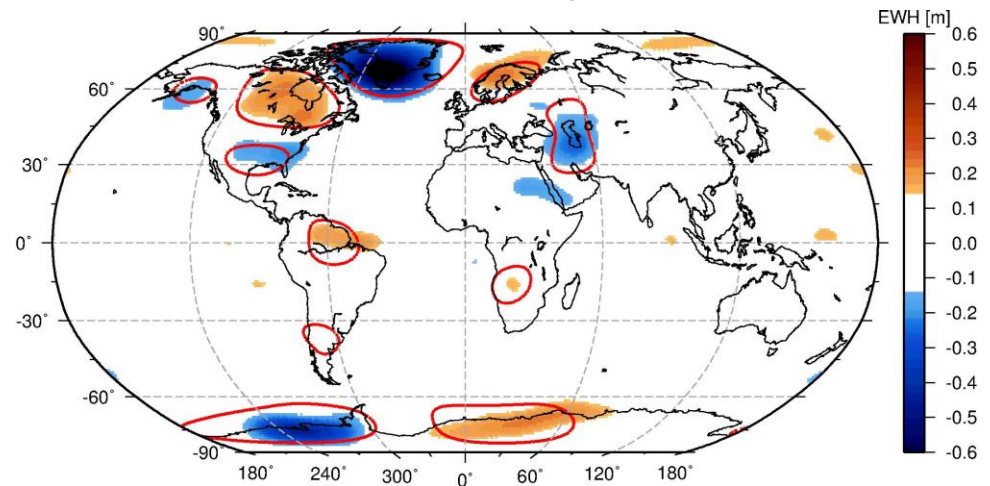
hISST & SLR



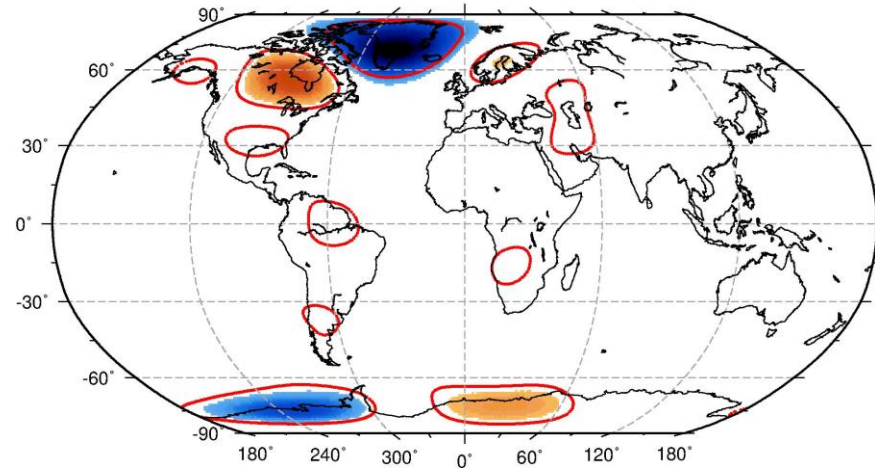
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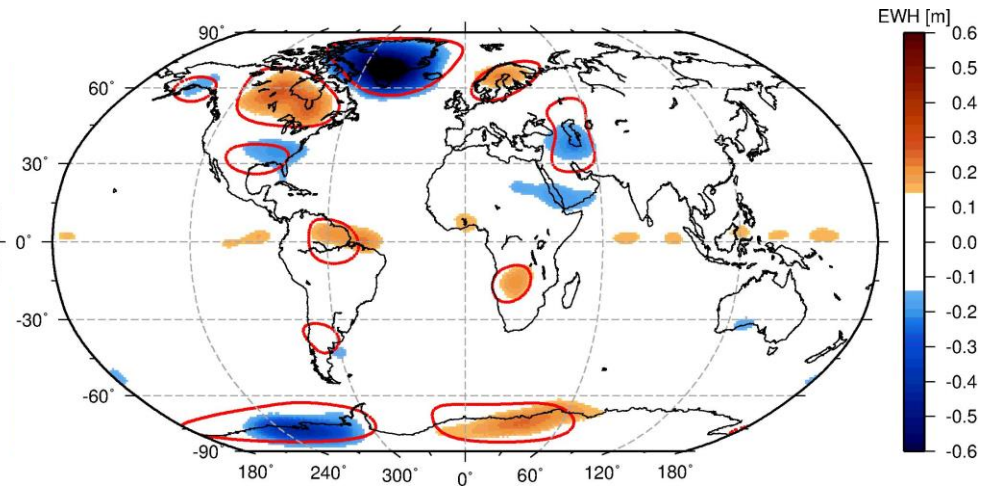
hISST-only



GRACE CSR



hISST & SLR



# Trends

Mass change rates in [Gt/yr] of areas with the strongest signals

Region	hISST-only <sup>a</sup>		hISST + SLR		GRACE CSR <sup>a</sup>
		$\Delta$ Grace		$\Delta$ Grace	
Greenland	$-252 \pm 10$	-12%	$-267 \pm 12$	-6%	$-285 \pm 10$
Greenland ext. <sup>b</sup>	$-275 \pm 12$	-13%	$-294 \pm 12$	-7%	$-316 \pm 10$
Canadian Shield	$152 \pm 10$	-12%	$158 \pm 6$	-8%	$172 \pm 6$
West Antarctica	$-127 \pm 10$	-10%	$-119 \pm 10$	-15%	$-140 \pm 10$
East Antarctica	$103 \pm 10$	0%	$104 \pm 10$	1%	$104 \pm 6$

<sup>a</sup>  $C_{20}$  replaced by values from SLR.

<sup>b</sup> including Iceland, Svalbard, and the Canadian Arctic archipelago

Uncertainties are give at the 95% ( $2\sigma$ ) confidence level.

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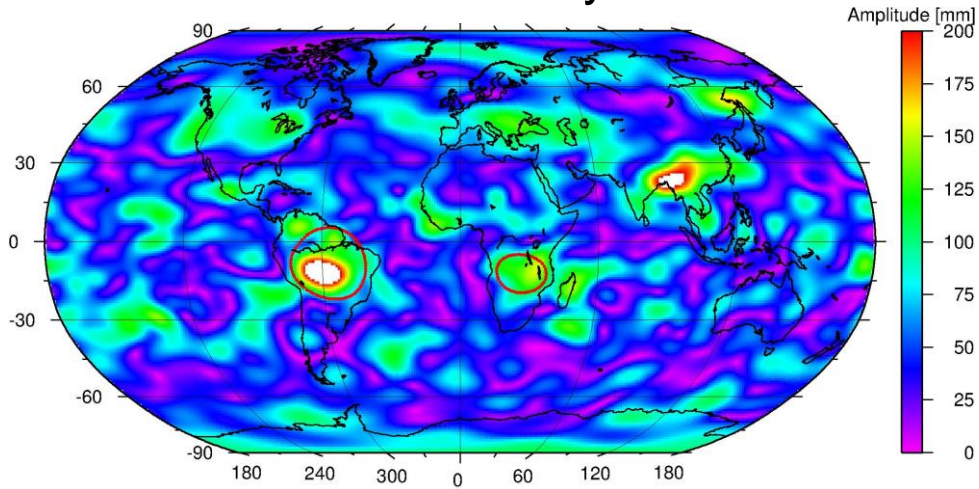
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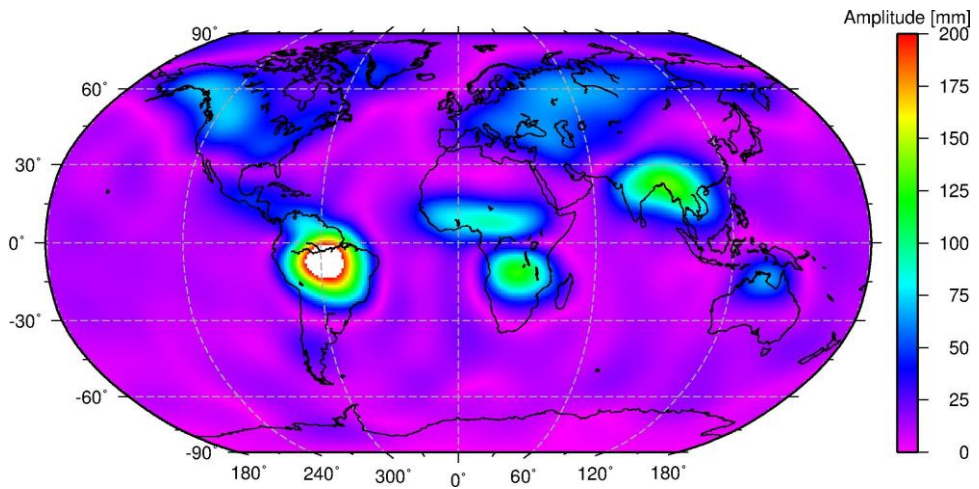
# Annual signal

Gaussian filtering with 750 km

## CHAMP-only



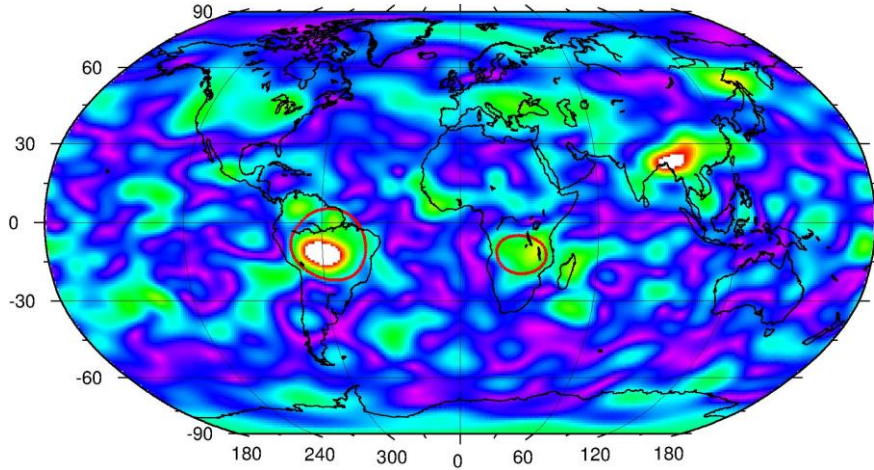
## GRACE CSR



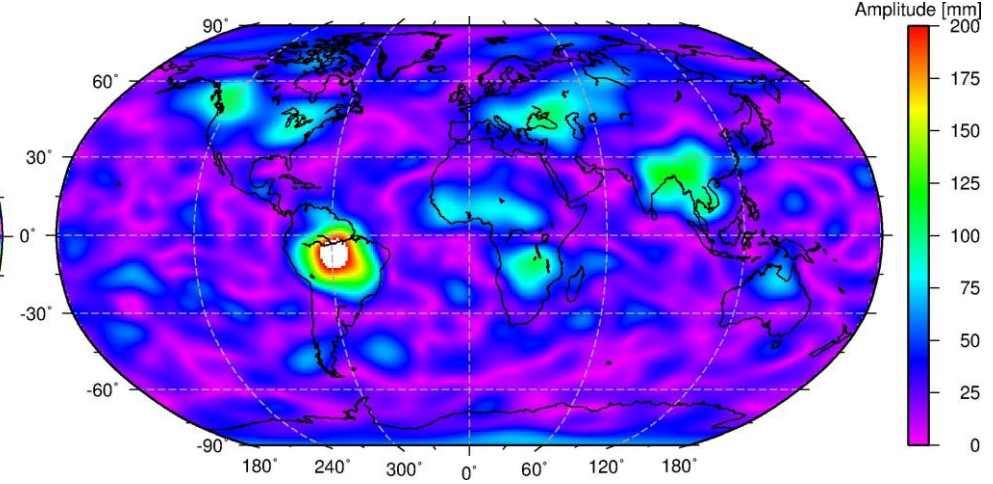
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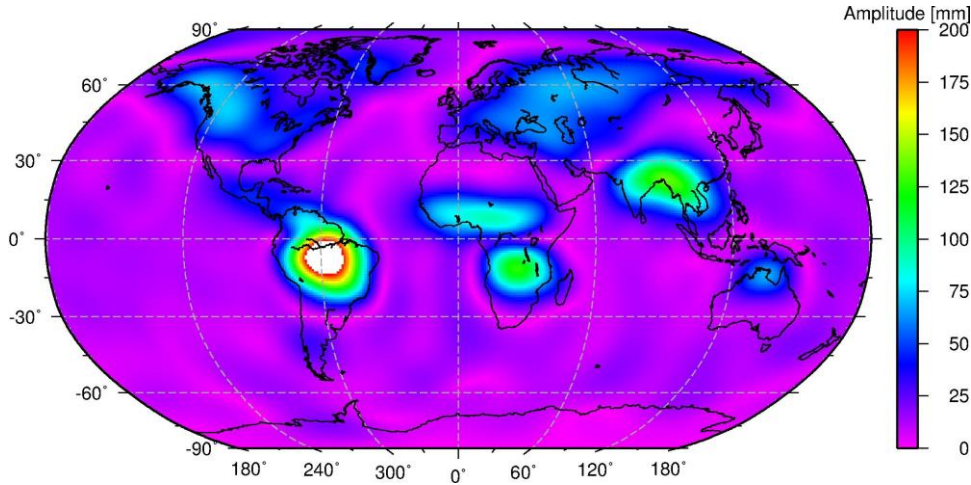
## CHAMP-only



## hISST-only



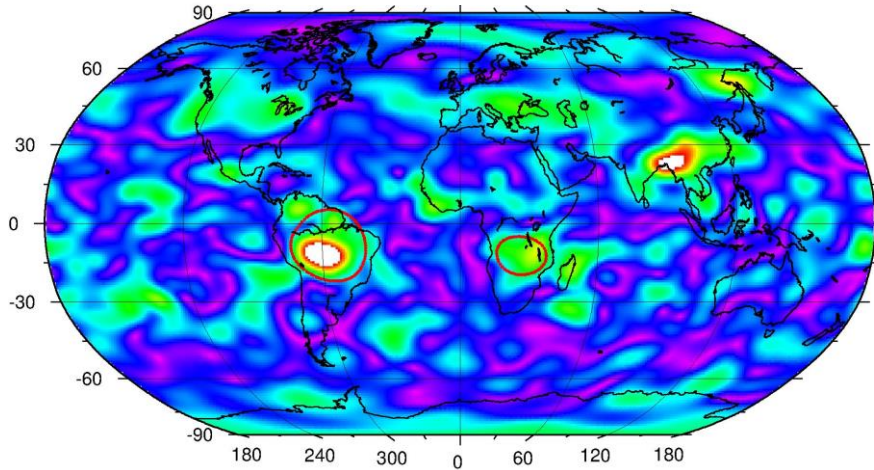
## GRACE CSR



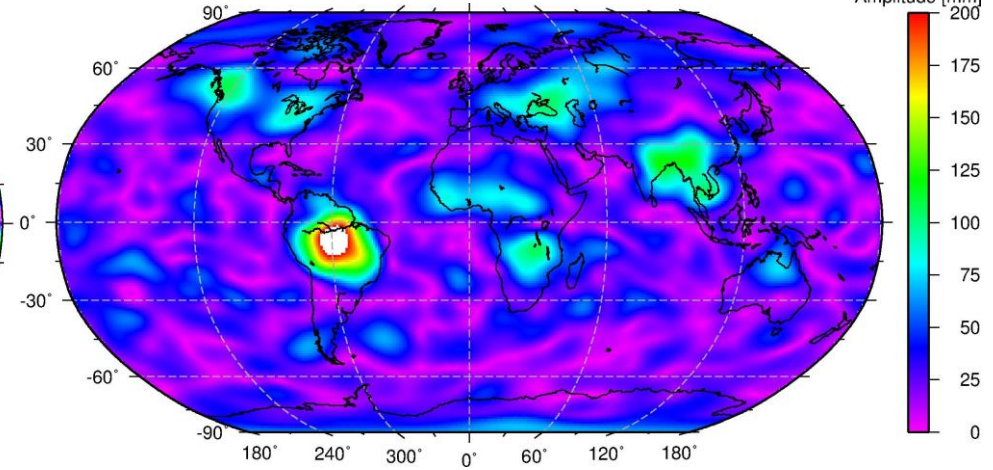
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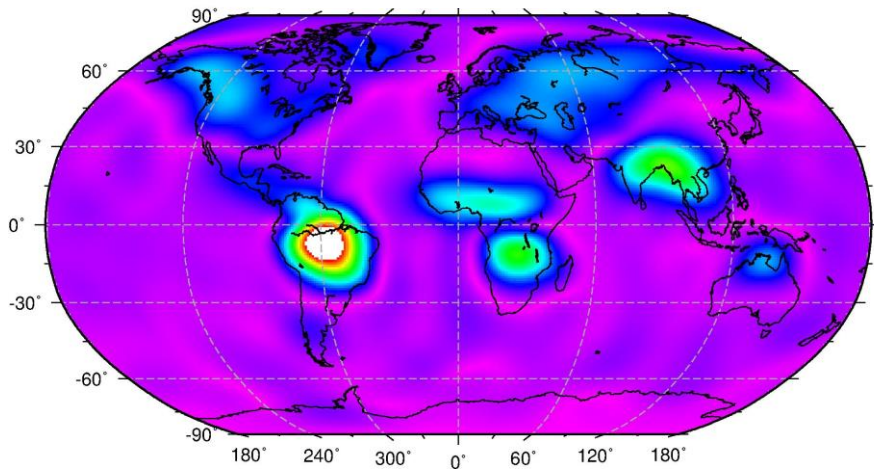
## CHAMP-only



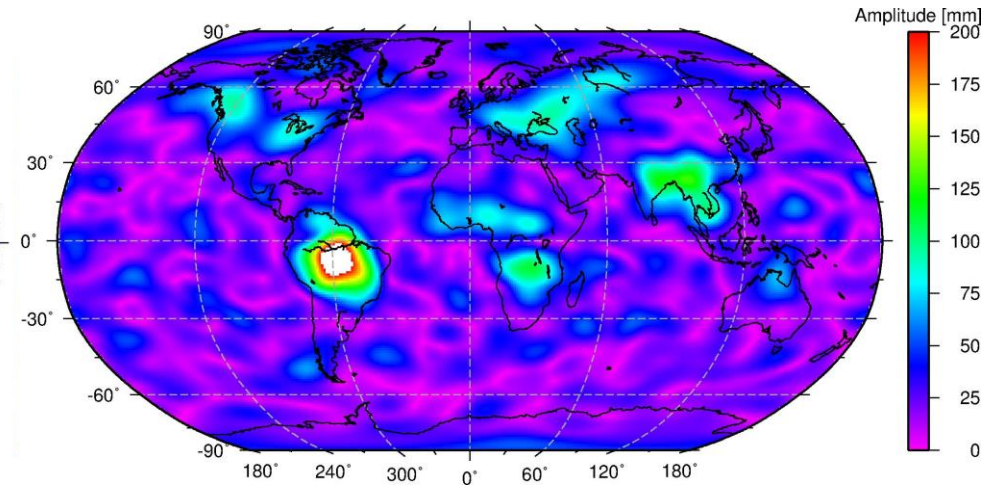
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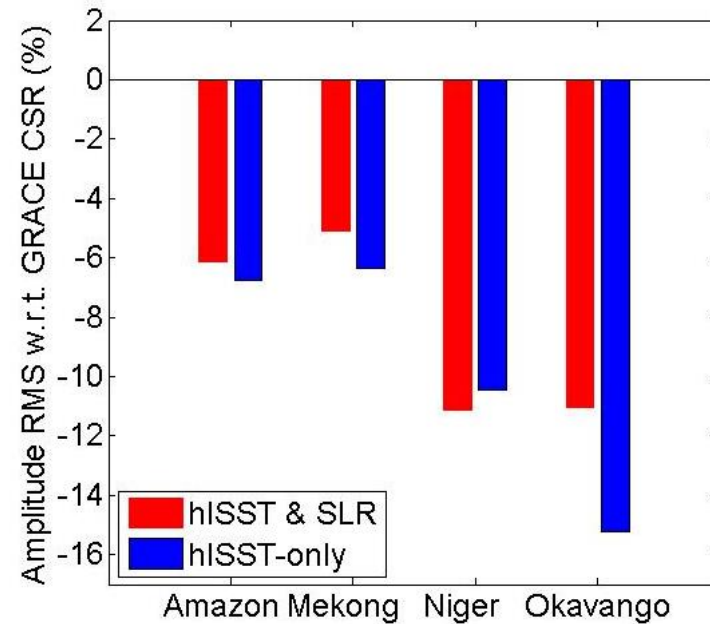
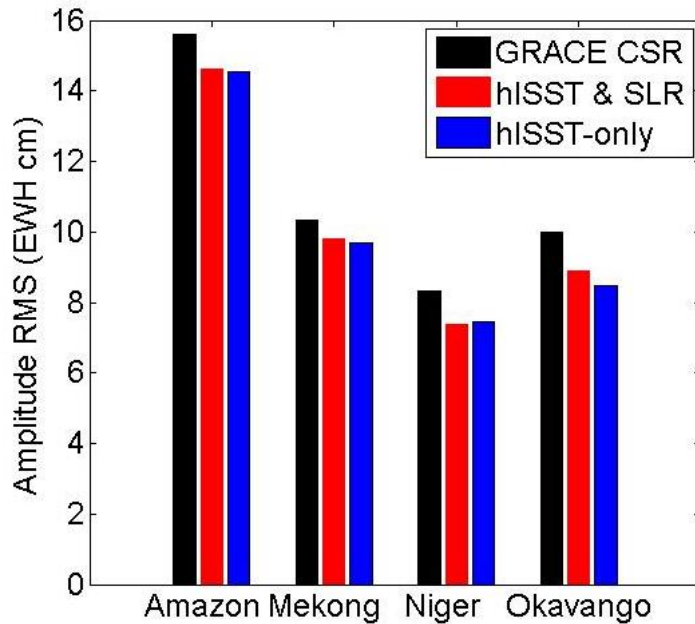
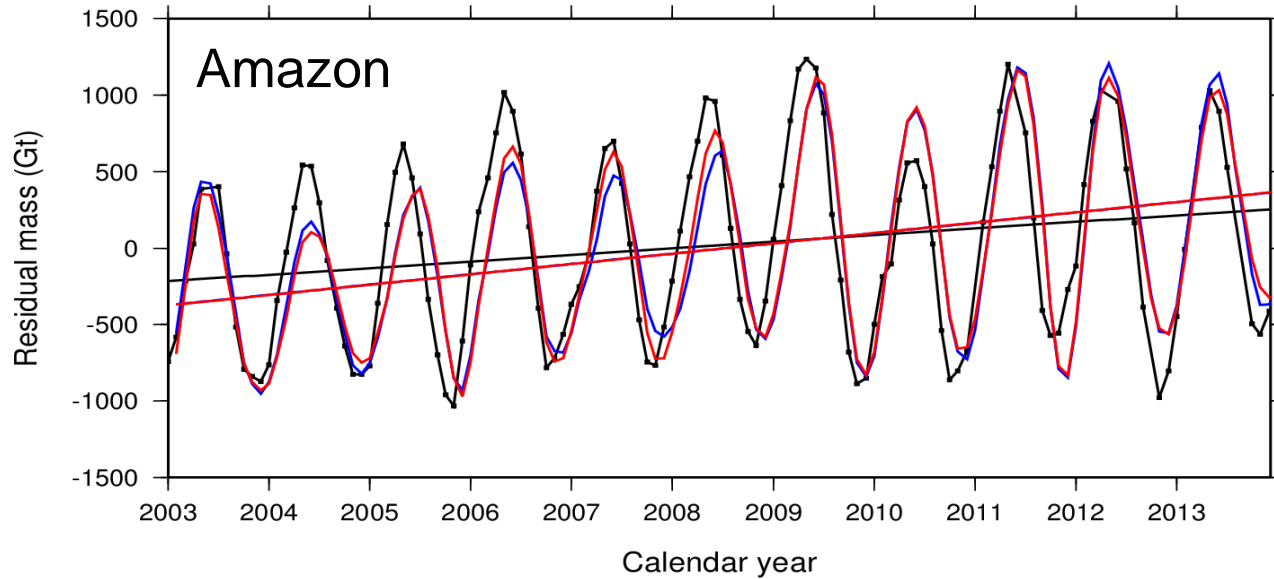
## GRACE CSR



## hISST & SLR



# Annual signal





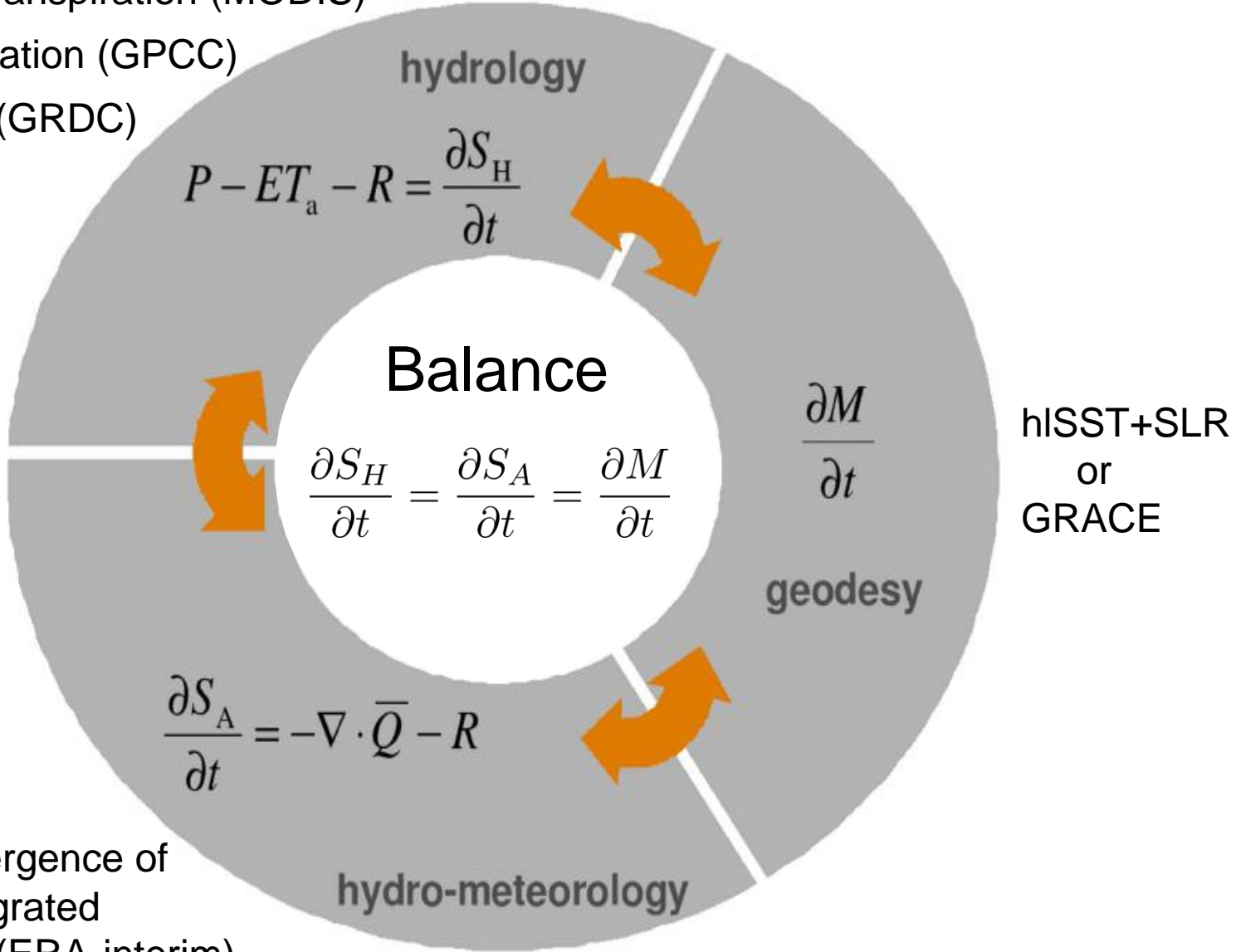
# HYDROLOGY AND HYDRO-METEOROLOGY

# Mass change as a hydrological observable

$ET_a$  = Evapotranspiration (MODIS)

$P$  = Precipitation (GPCC)

$R$  = Runoff (GRDC)



$\nabla \cdot \bar{Q}$  = divergence of vertically integrated moisture flux (ERA-interim)

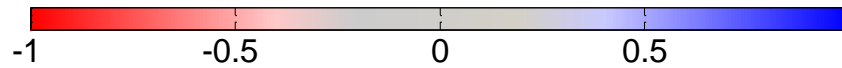
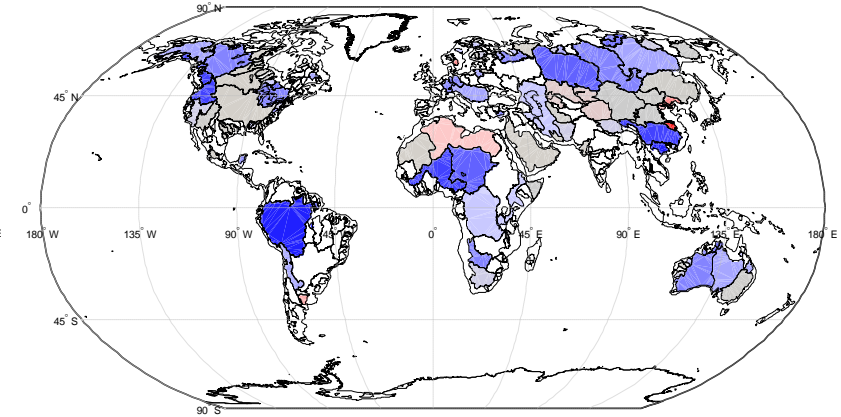
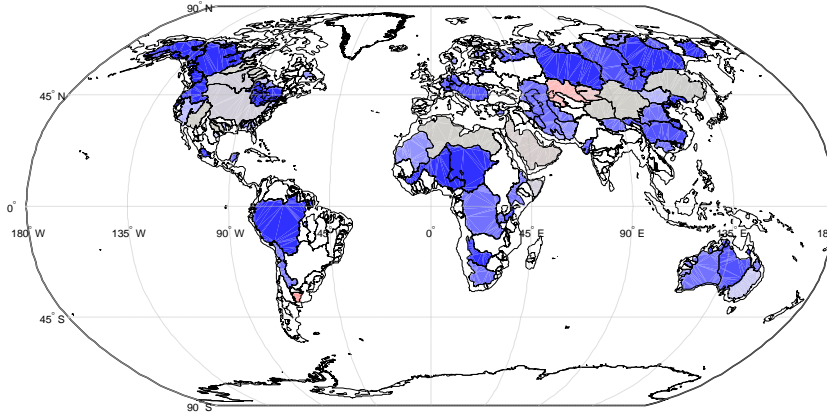
# Hydrological validation: $P-ET_a-R$

Gaussian  
filtering with  
750km

Correlation:

GRACE

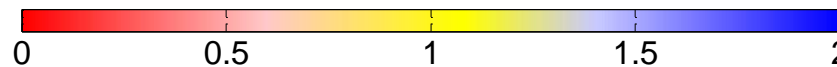
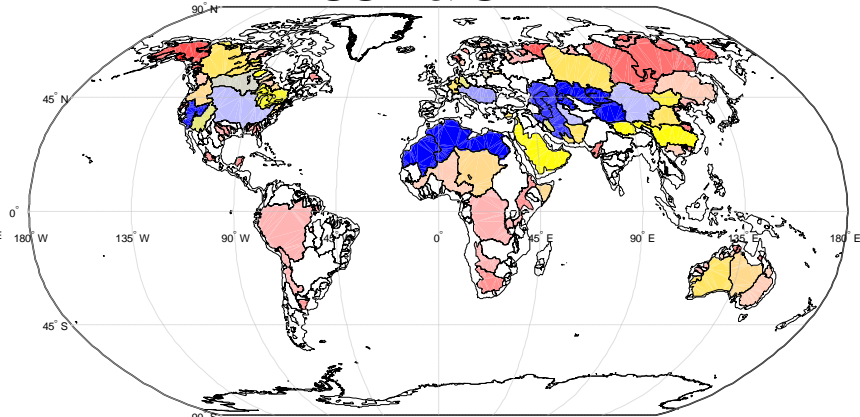
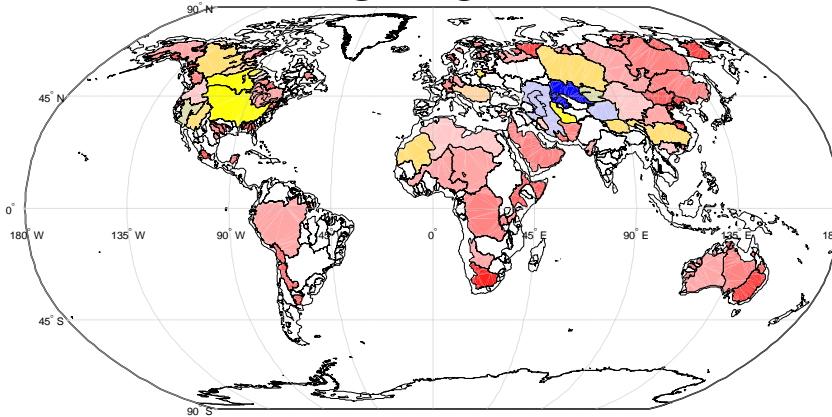
hISST & SLR



RMS ratio:

GRACE

hISST & SLR



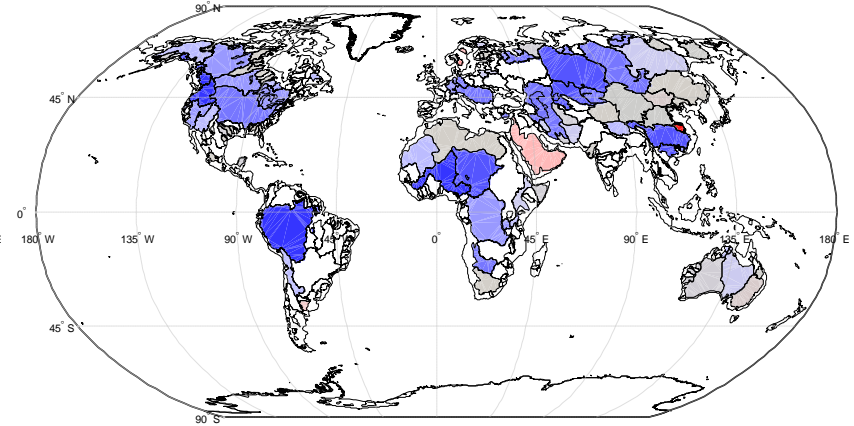
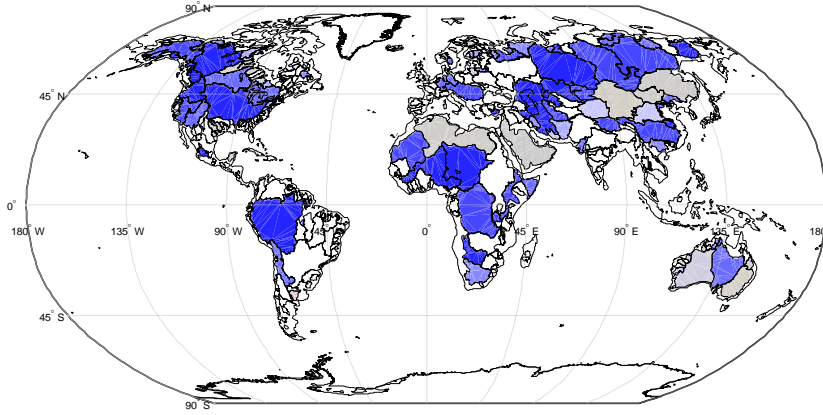
# Hydro-meteorological validation: $\nabla \cdot Q - R$

Gaussian filtering with 750km

Correlation:

GRACE

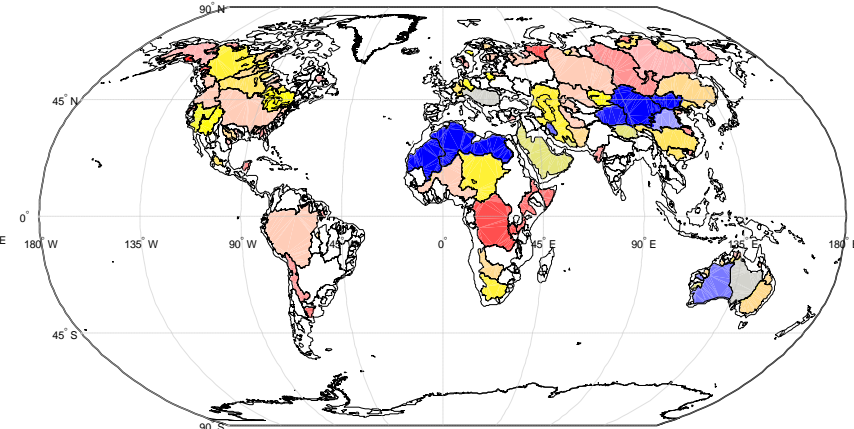
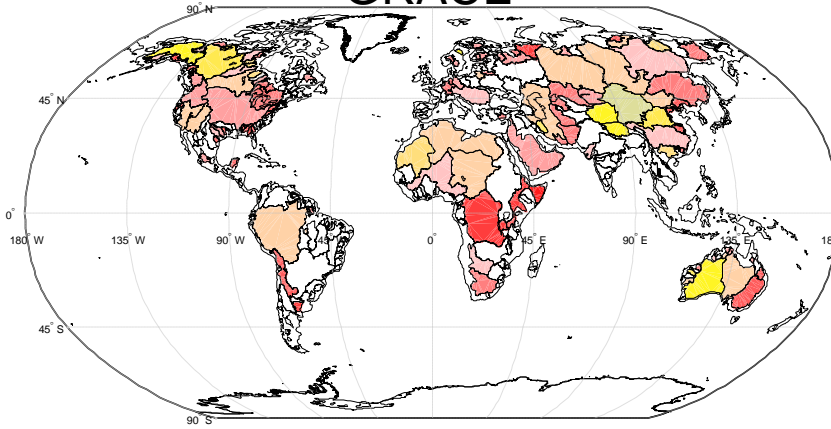
hISST & SLR



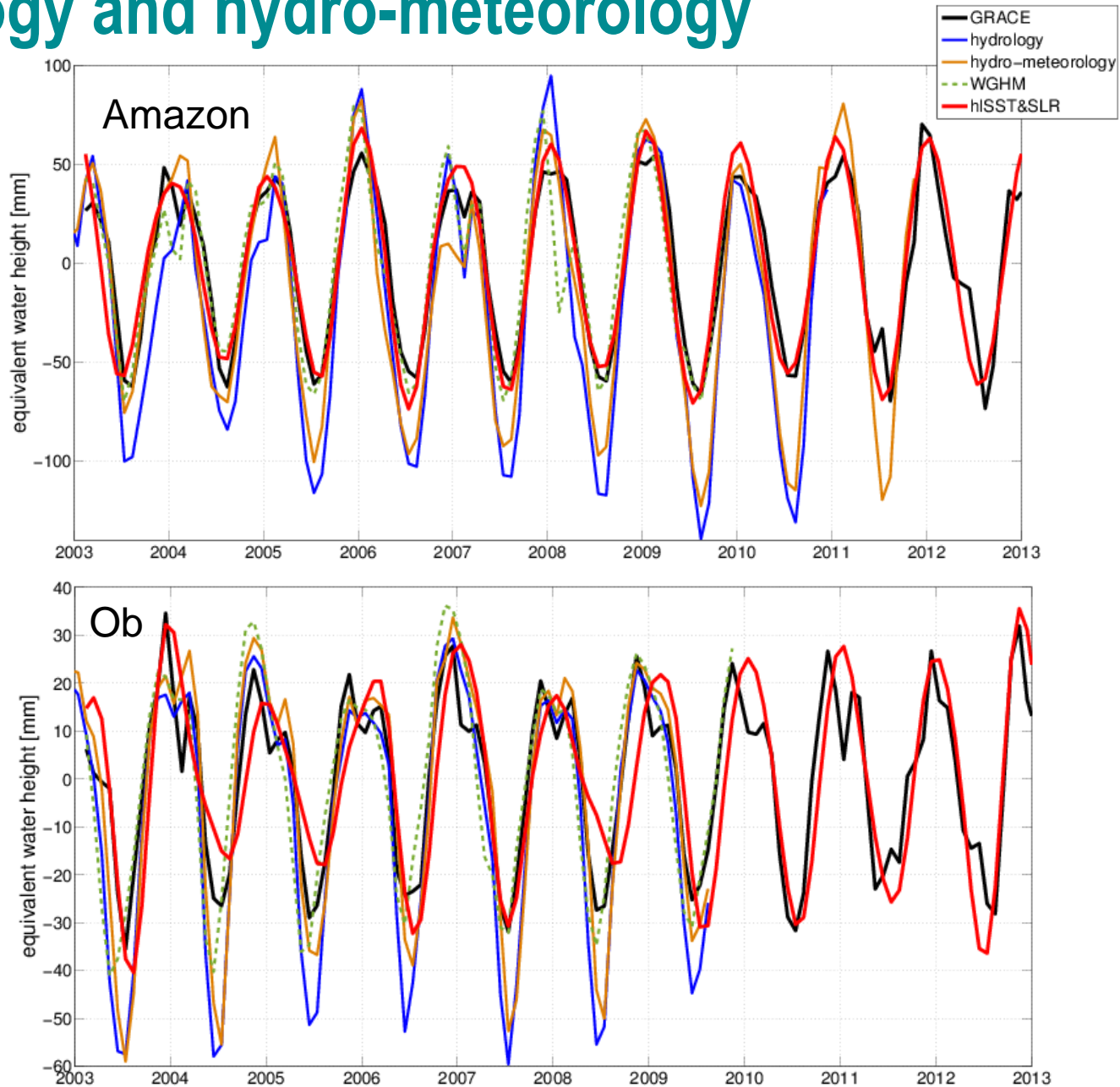
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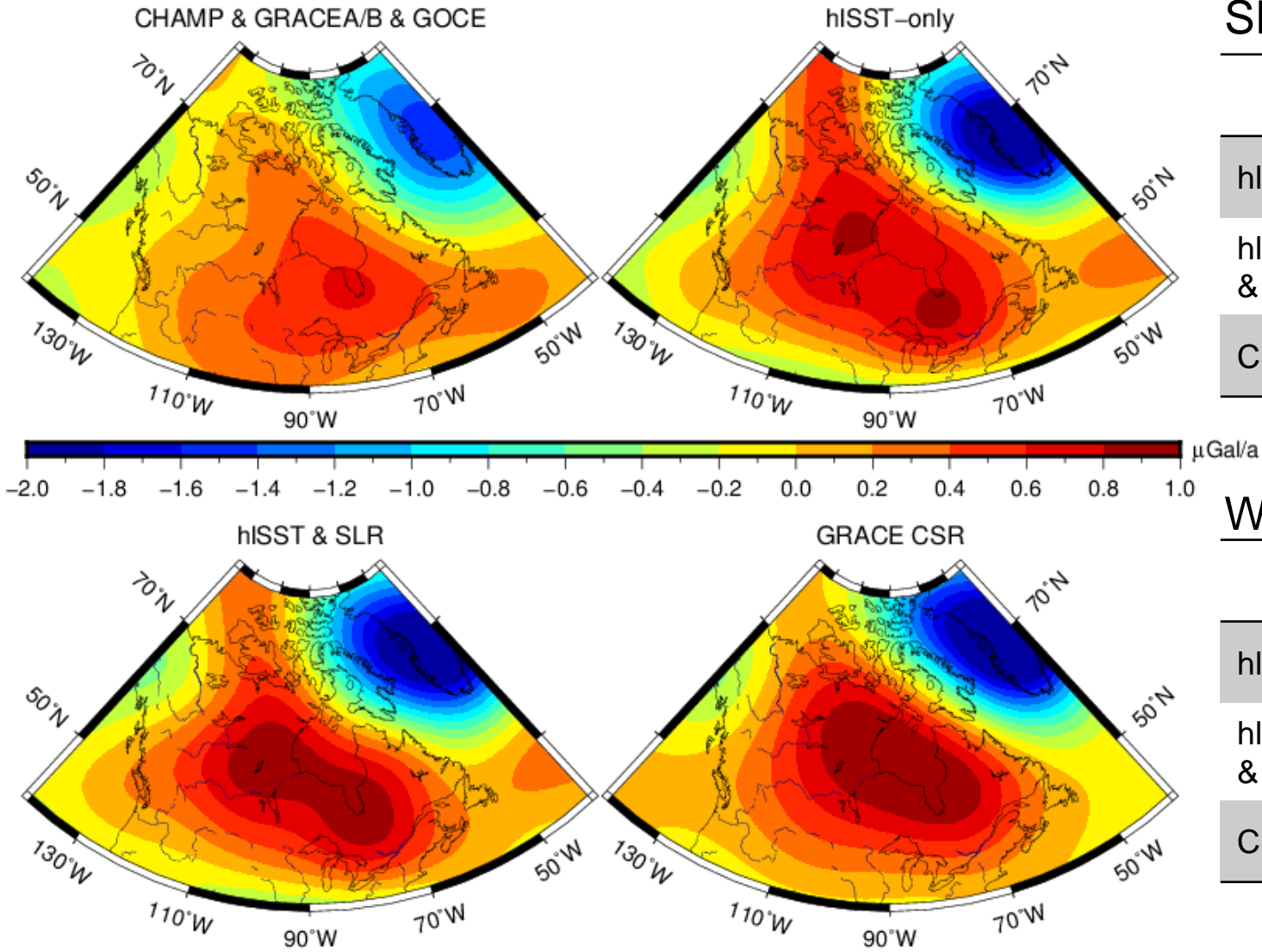
# Hydrology and hydro-meteorology



# GLACIAL ISOSTATIC ADJUSTMENT

# North America

## Gaussian filtering with 750km



SE maximum:

	$\varphi$	$\lambda$
hISST	49°N	80°W
hISST & SLR	52°N	80°W
CSR	54°N	75°W

W maximum:

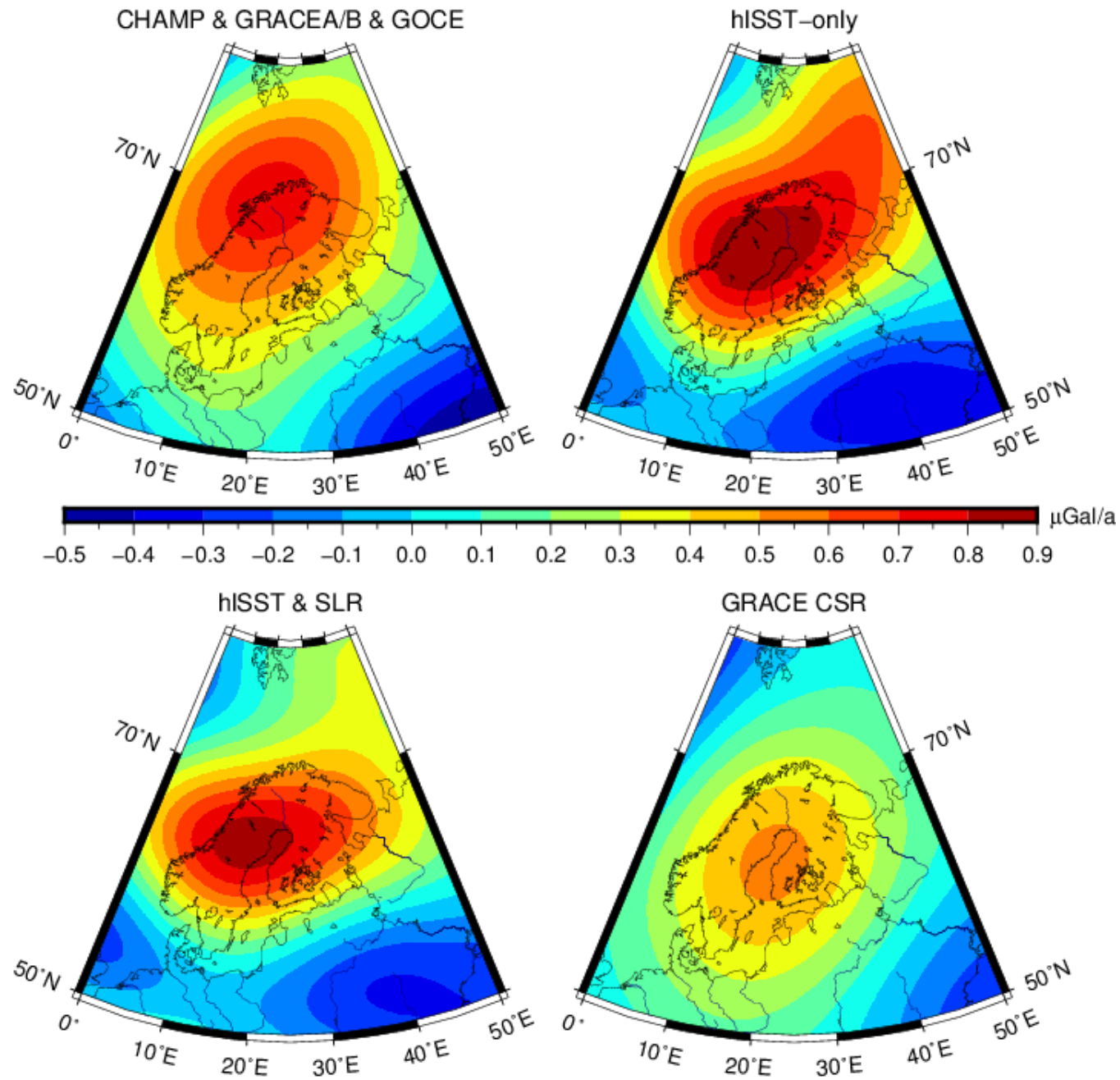
	$\varphi$	$\lambda$
hISST	60°N	99°W
hISST & SLR	58°N	100°W
CSR	63°N	99°W

# Fennoscandia

Gaussian filtering with 750km

Maximum:

	$\varphi$	$\lambda$
hiSST	65°N	18°W
hiSST & SLR	65°N	18°W
CSR	63°N	20°W





# HOW GOOD ARE WE THEN?

# What can be done:

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  - ... can be improved by spatial filtering – e.g. Gaussian 750km

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- Mass trend and annual signals are approximately 5-15% underestimated.
- Hydrological signal is similarly underestimated in wet areas. In arid areas the signal is overestimated (SNR!)
- HISST-only and hISST+SLR are able to resolve the double peak of the GIA signal in North America. The smaller Fennoscandia is still overestimated.

# WHAT ARE THE LIMITATIONS?

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- Filtering process smears out episodic events.
- Approach depends 1:1 on the precision of GNSS and SLR observations → spatial resolution remains limited

# Limitations:

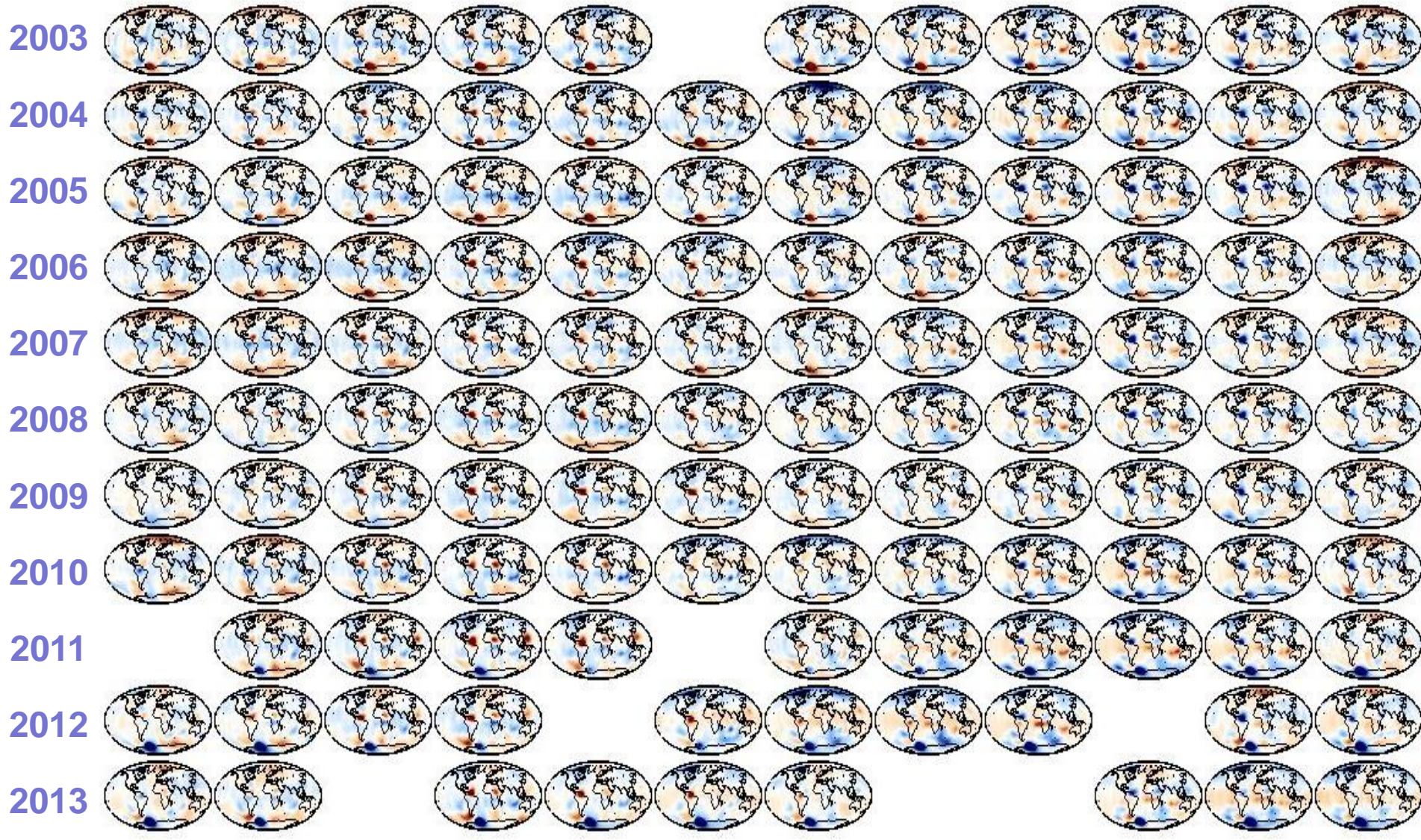
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... but the time series can be continued as satellite data will be available throughout the time to GRACE Follow-On

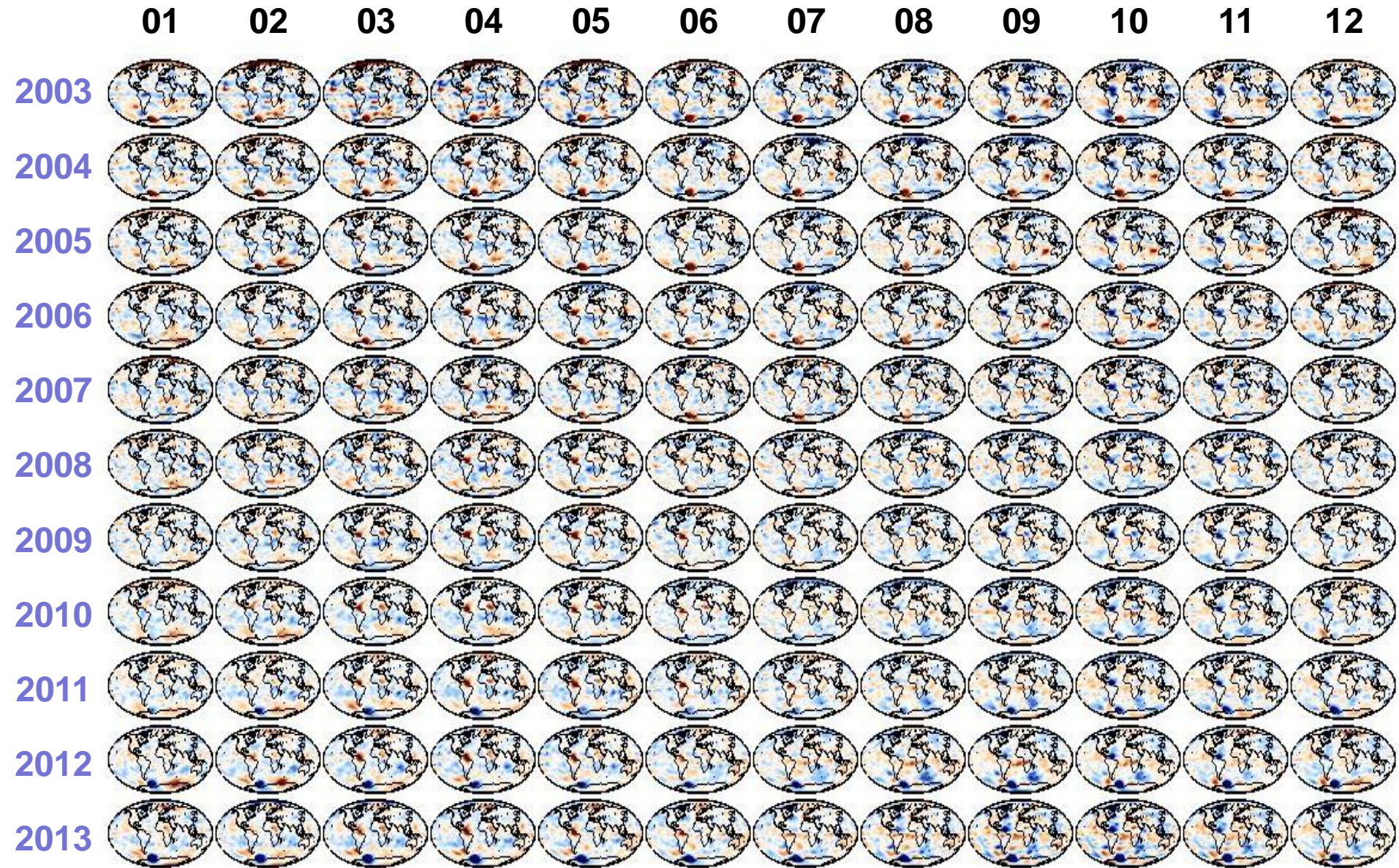
and SLR observations → spatial resolution remains limited

# GRACE data availability

01 02 03 04 05 06 07 08 09 10 11 12



# hISST + SLR data availability





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Publications

# http://geosat.uni.lu

Generally, data that has been published is freely available. Access to other data may be limited and at times special conditions apply. In order to access these data, please send an email to [matthias.weigelt@uni.lu](mailto:matthias.weigelt@uni.lu) in order to get access to the protected area. The [login](#) to the protected area is on the top right.

### About us:

The LGP focuses on four main topics: climate variability, geodynamics, resource management and regional processes. The main objectives are the development of reliable measurement of environmental changes at all spatial and temporal scales, the assessment of the relative impact of human and natural factors in these changes, a better understanding of the relation of the various environmental changes and the evaluation of the risk they induce for mankind. The research relies mainly on the modeling and the interpretation of satellite data.

The LGP is located within the [Research Unit in Engineering Science \(RUES\)](#) at the [Faculté des Sciences, de la Technologie et de la Communication](#), University of Luxembourg. The LGP also hosts the [Global Geophysical Fluid Center \(GGFC\)](#).



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