

Using New Data to Construct the Bayesian Statistics for GIA with Applications to GRACE

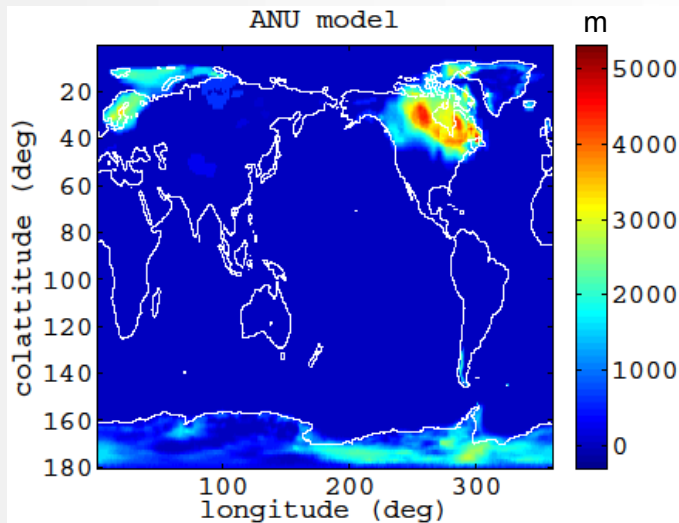
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Main questions

- What are the unknown parameters in GIA and how do they make it an unresolved, evolving field of work?
- How do you calculate formal GIA uncertainties?
- What kind of product does the GRACE community want to use?

What are we talking about?

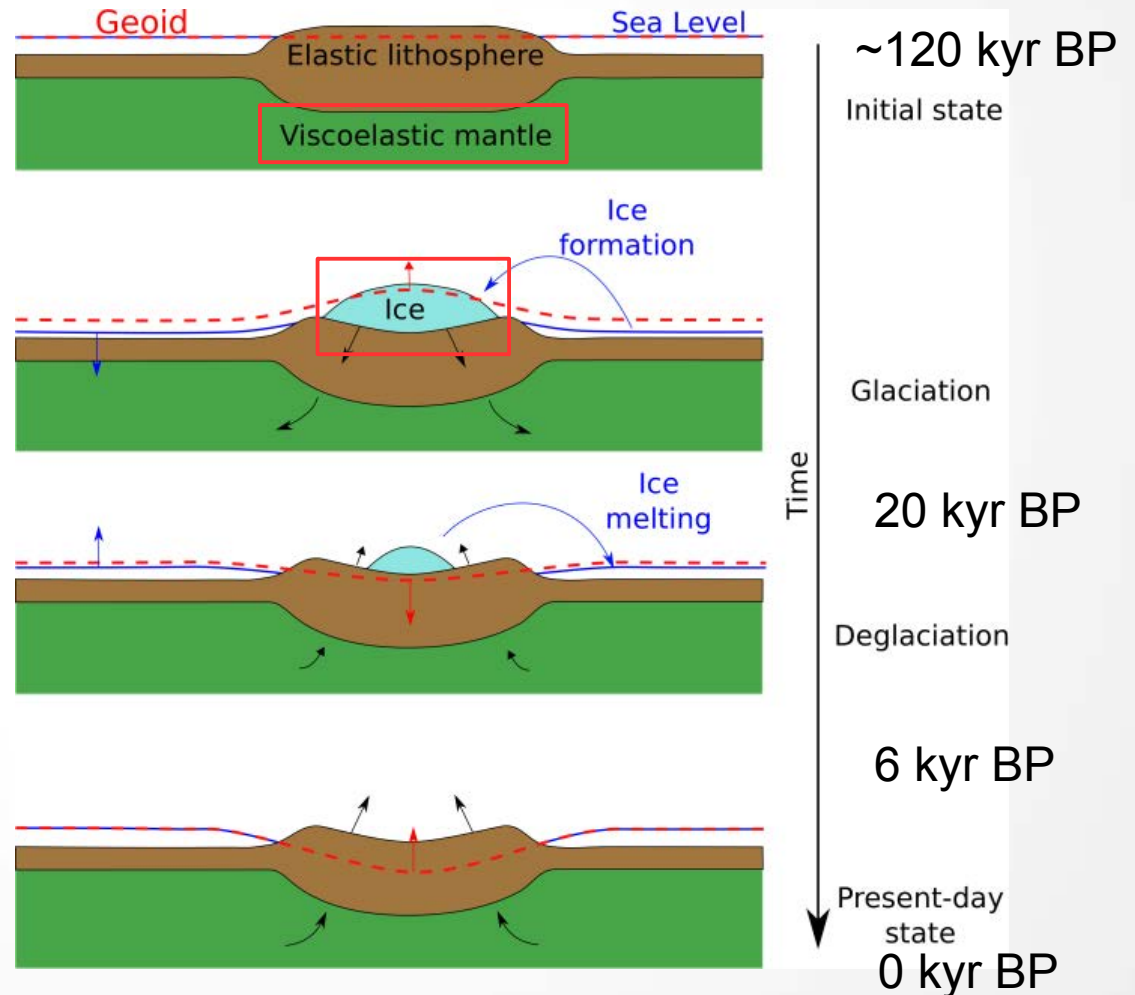
GIA = Solid Earth response to surface load changes associated with glacial cycles



Ice thickness at the Last Glacial Maximum (20kyr BP): kms of ice!

Sea level was ~130m below present-day

Present-day:
Vertical land motion: up to ~20 mm/yr
Gravity rate: up to ~60 mm/yr EWH



Relative sea level data?

Coral deposit from Tetiaroa Island,
French Polynesia



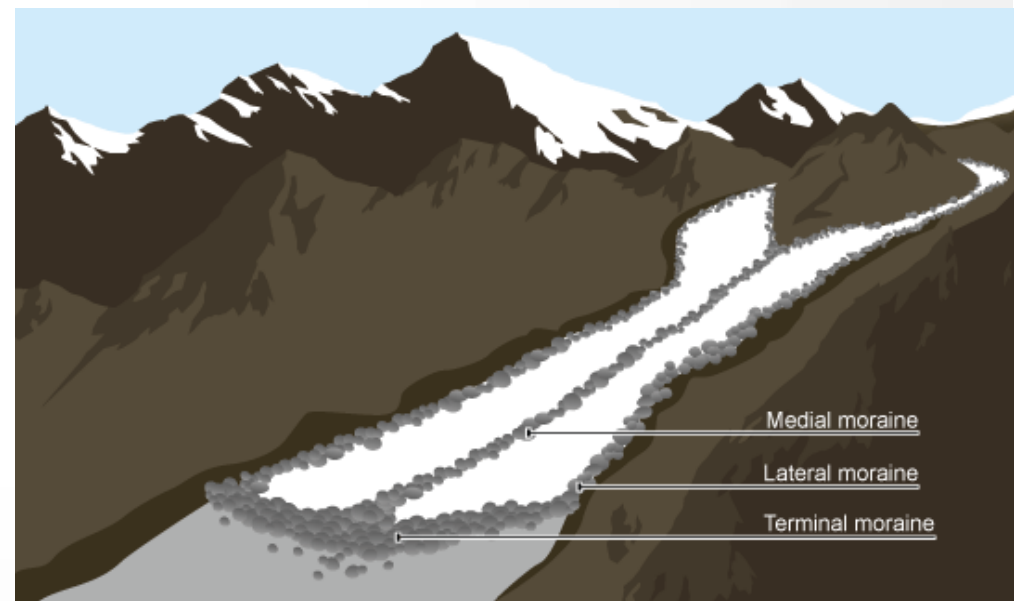
Raised beaches in Nunavut, Canada

Evolving constraints

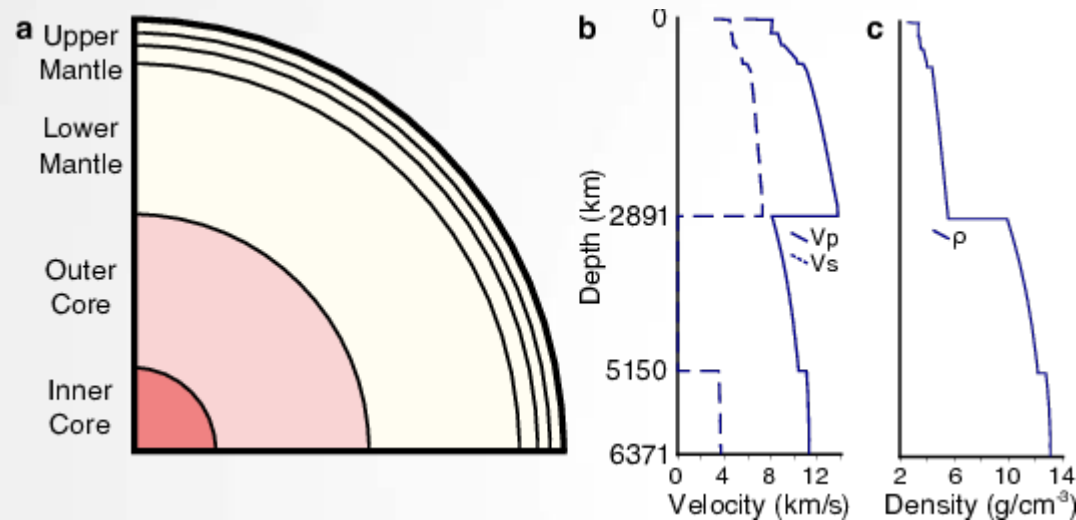
- State of the RSL data sets:
- Peltier and Andrews, [1976]: 19 RSL records
- Tushingham and Peltier, [1991]: 1,020 RSL records
- Our work, 2017: 11,451 RSL records
- +uncounted number of moraines (geological markers of ice sheet extension)
-

Geodetic data:

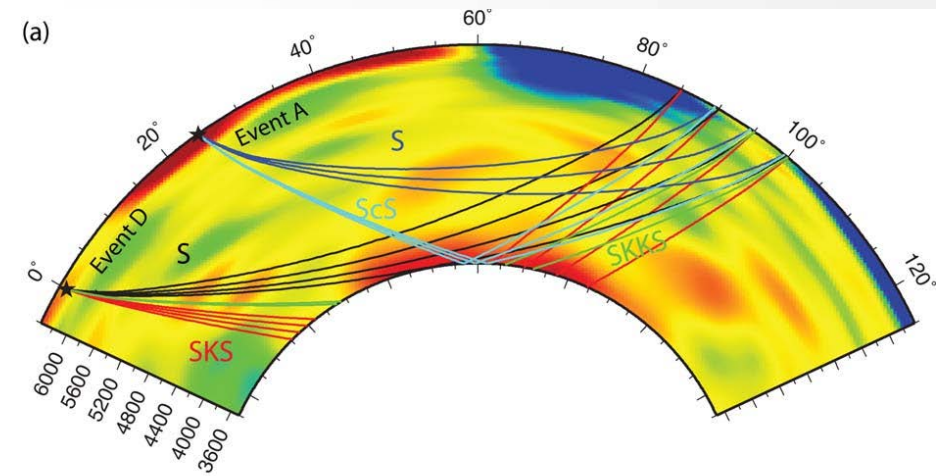
- First use in Peltier et al, [1994]
- GNSS, gravimetry, tide gauges data sets are growing
- But: these data only capture a snapshot of GIA in time, and we need time dependent information



Evolving priors & computational power



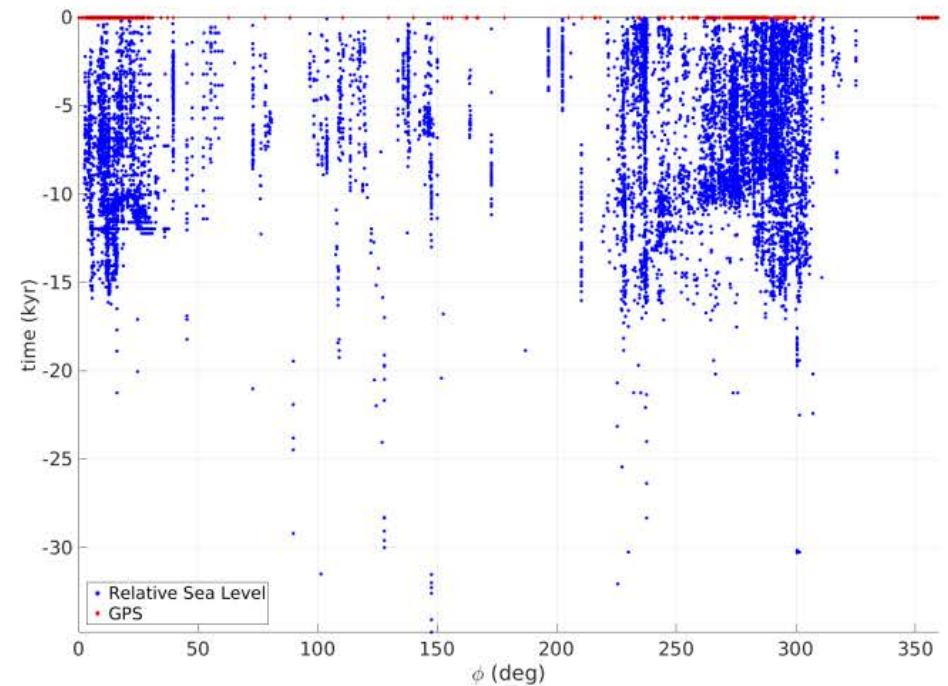
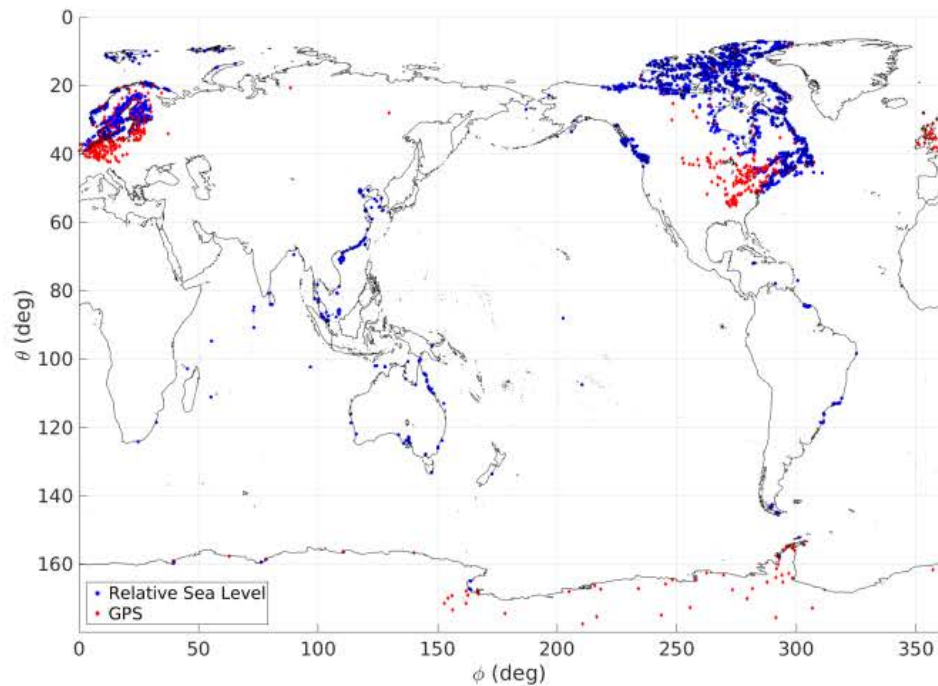
PREM [Dziewonski. & Anderson, 1981]



S40RTS [Ritsema et al., 2011]

- FEM GIA model with lateral variations: Wu et al. [2006]
- Use of heuristic methods for large sampling of the parameters space: Forte & Mitrovica [1996]

Constraining data set for GIA



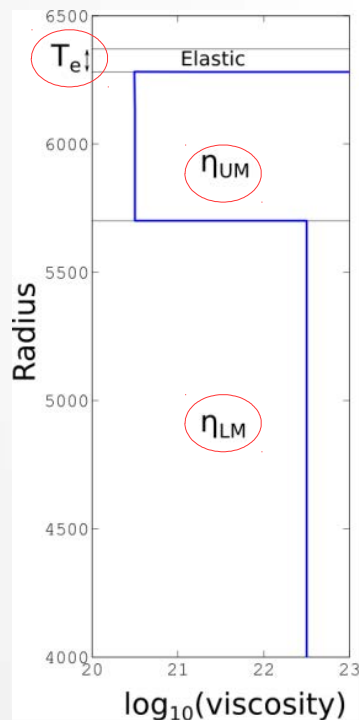
Distribution of constraining data set for GIA in space and time.

Sources of uncertainties are downplayed

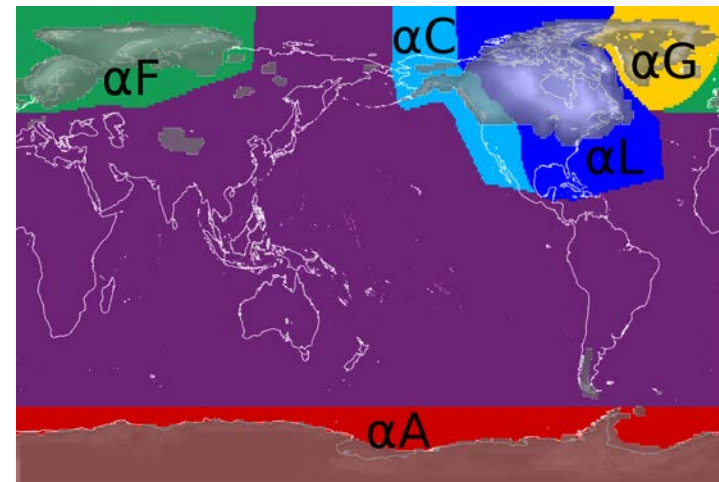
Bayesian inversion with 96,000 models varying jointly ice history and viscosity

$$p = \exp \left(-\frac{1}{2N_{data}} \sum_{i=1}^{N_{data}} \left(\frac{(y_{data,i} - y_{model,i}) w_i w_j}{\sigma_i} \right)^2 \right)$$

- Parameters we invert for:



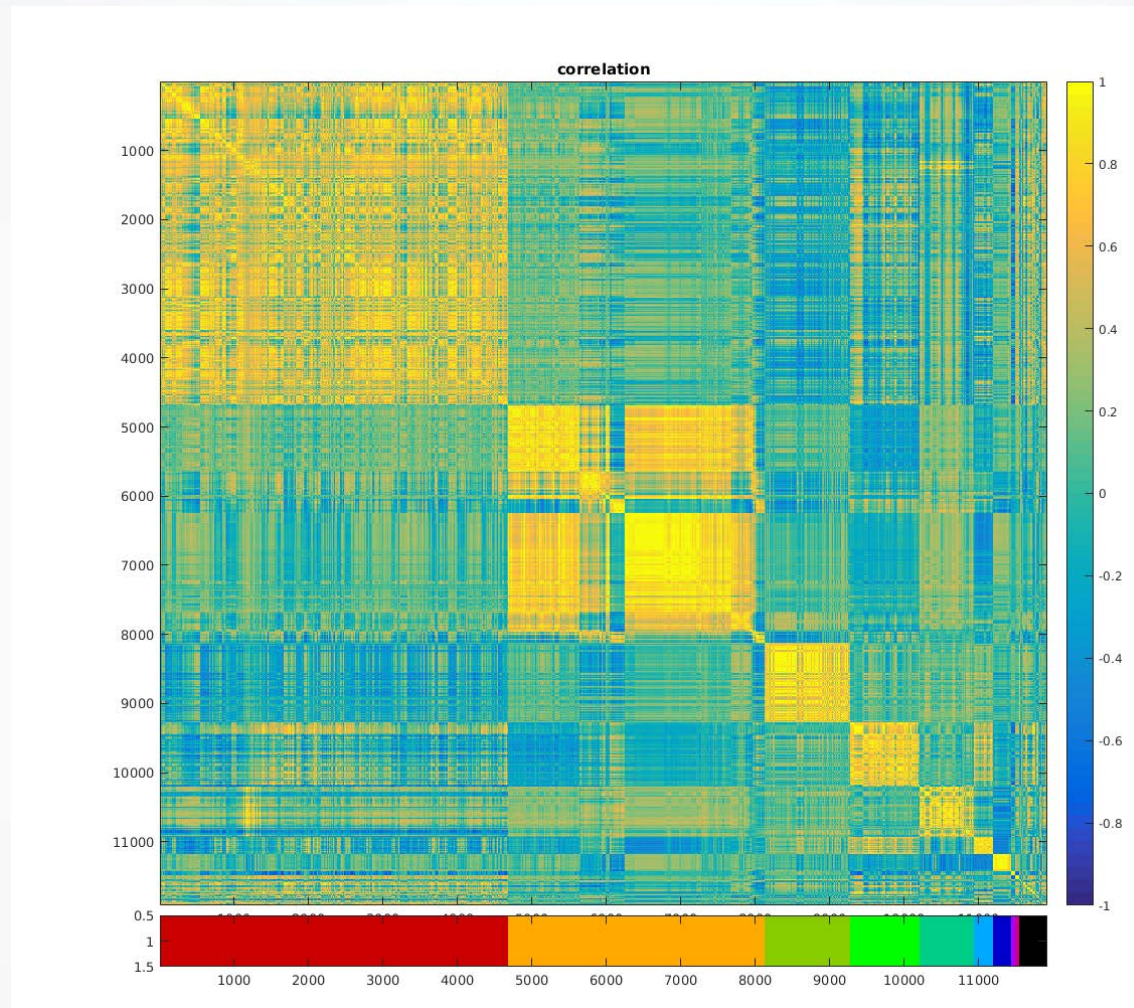
Viscosity profile versus depth



Ice history, region by region.

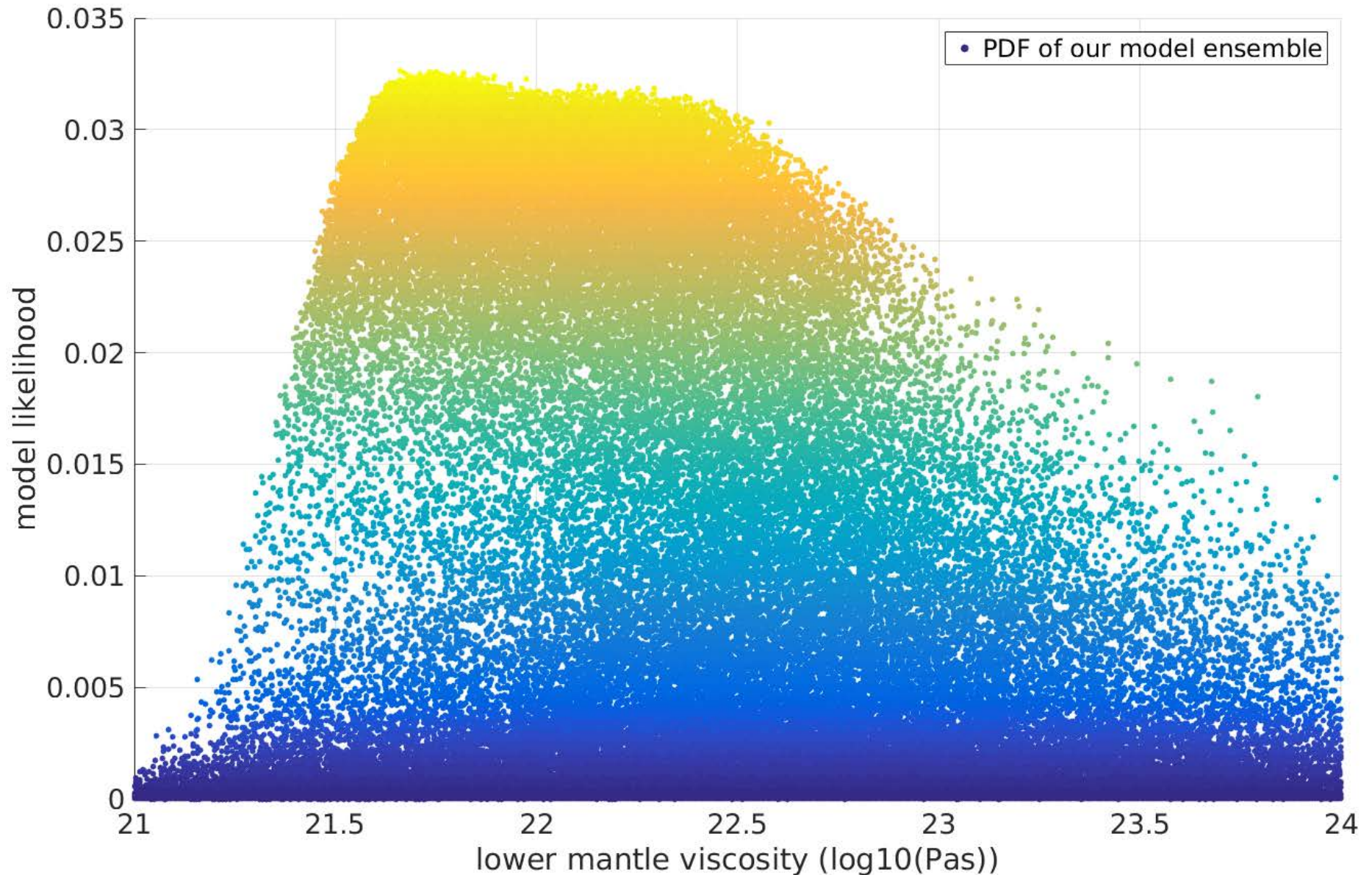
Each colored region contains a nominal ice history model which then gets scaled by a factor in the inversion.

The data distribution is bad...

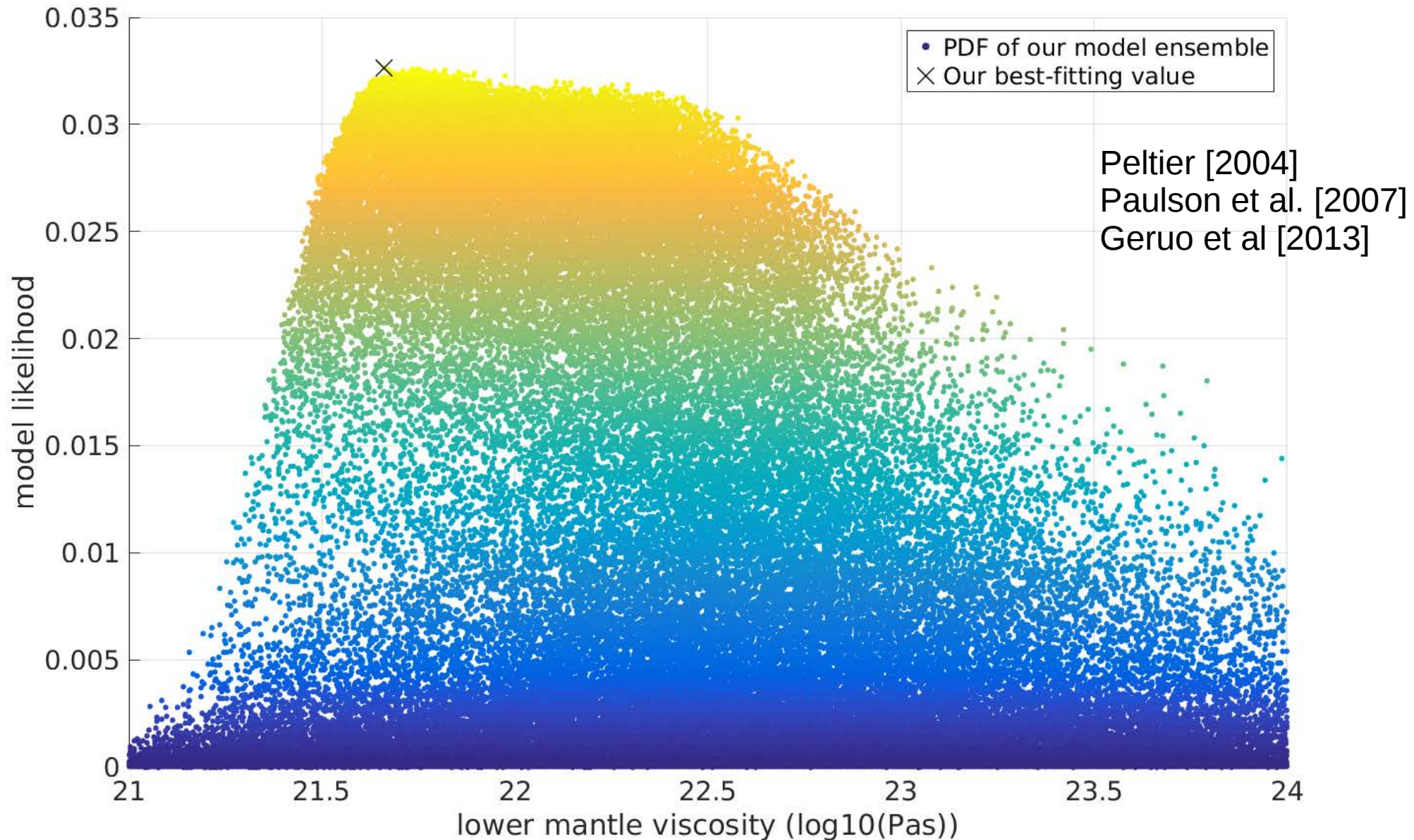


Use intrinsic correlations of the predictions to remove redundancy of information!

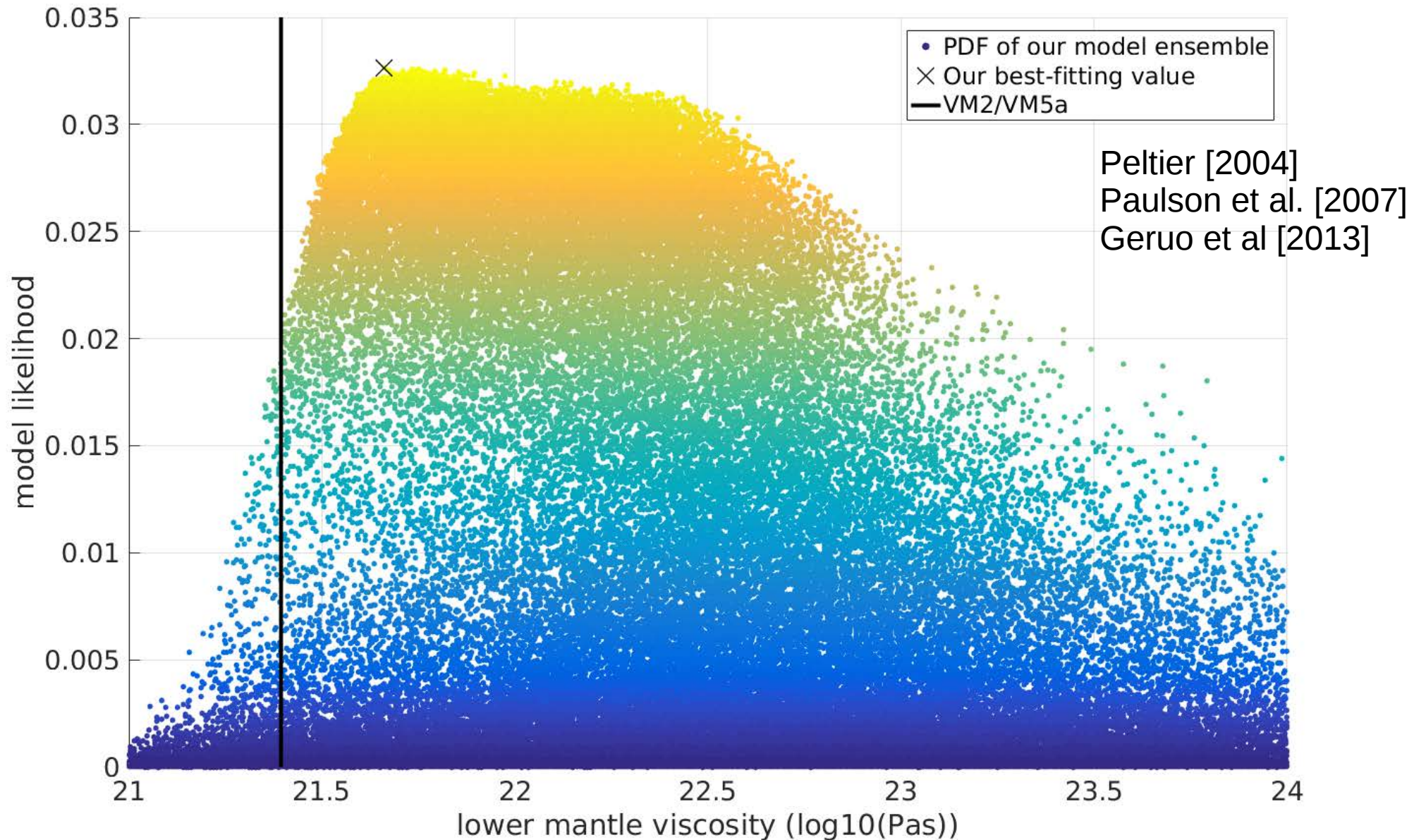
“single best model mentality”



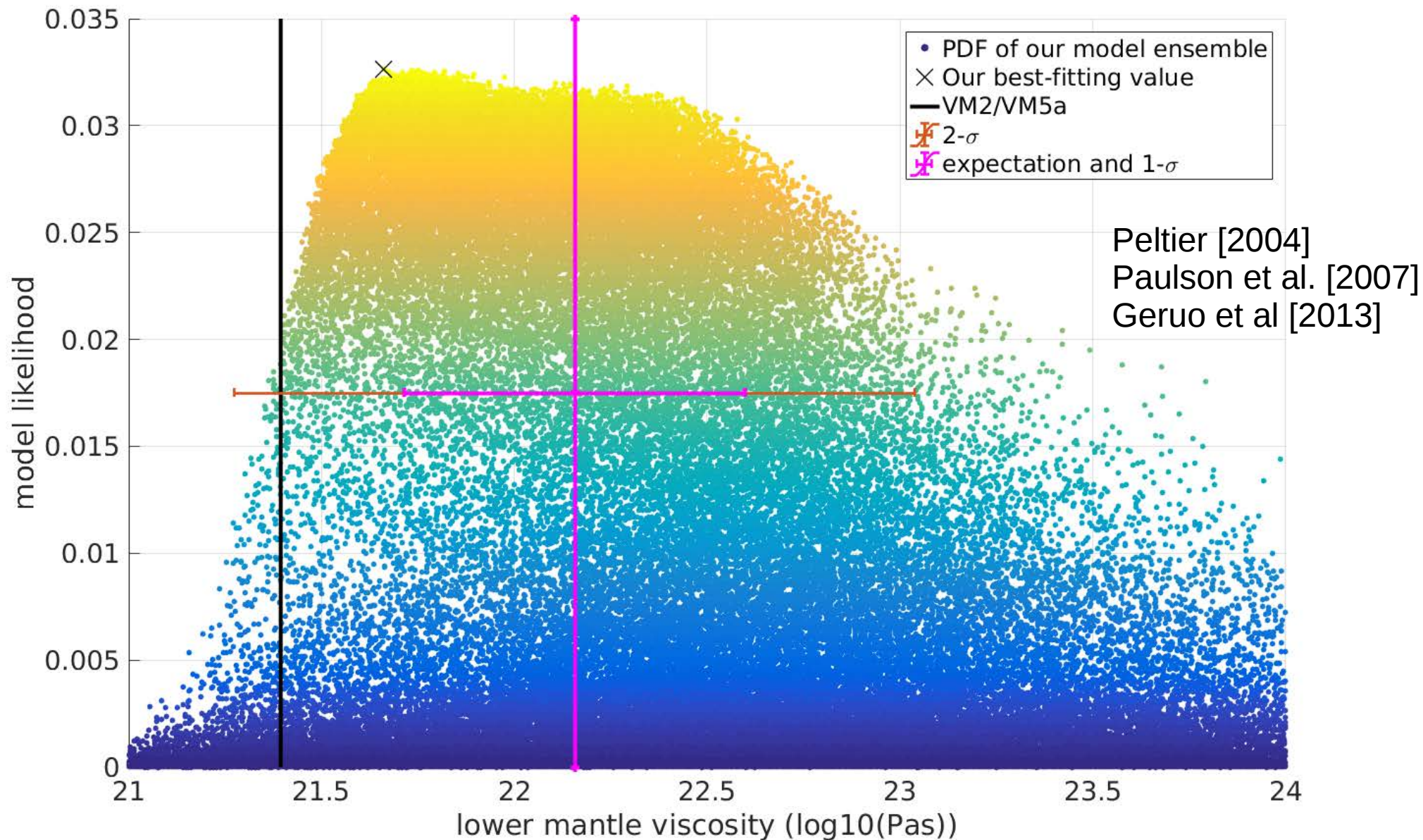
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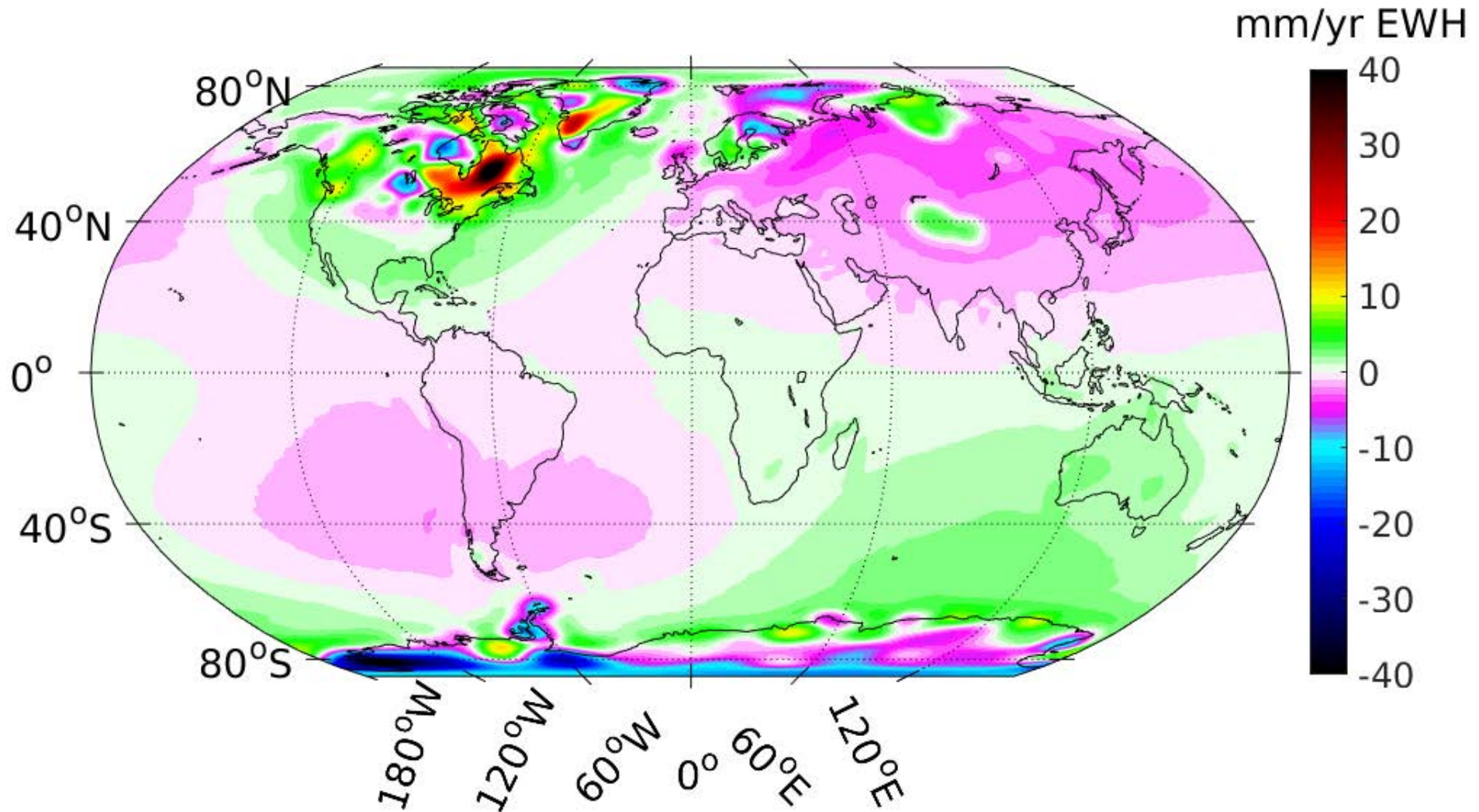


“single best model mentality”



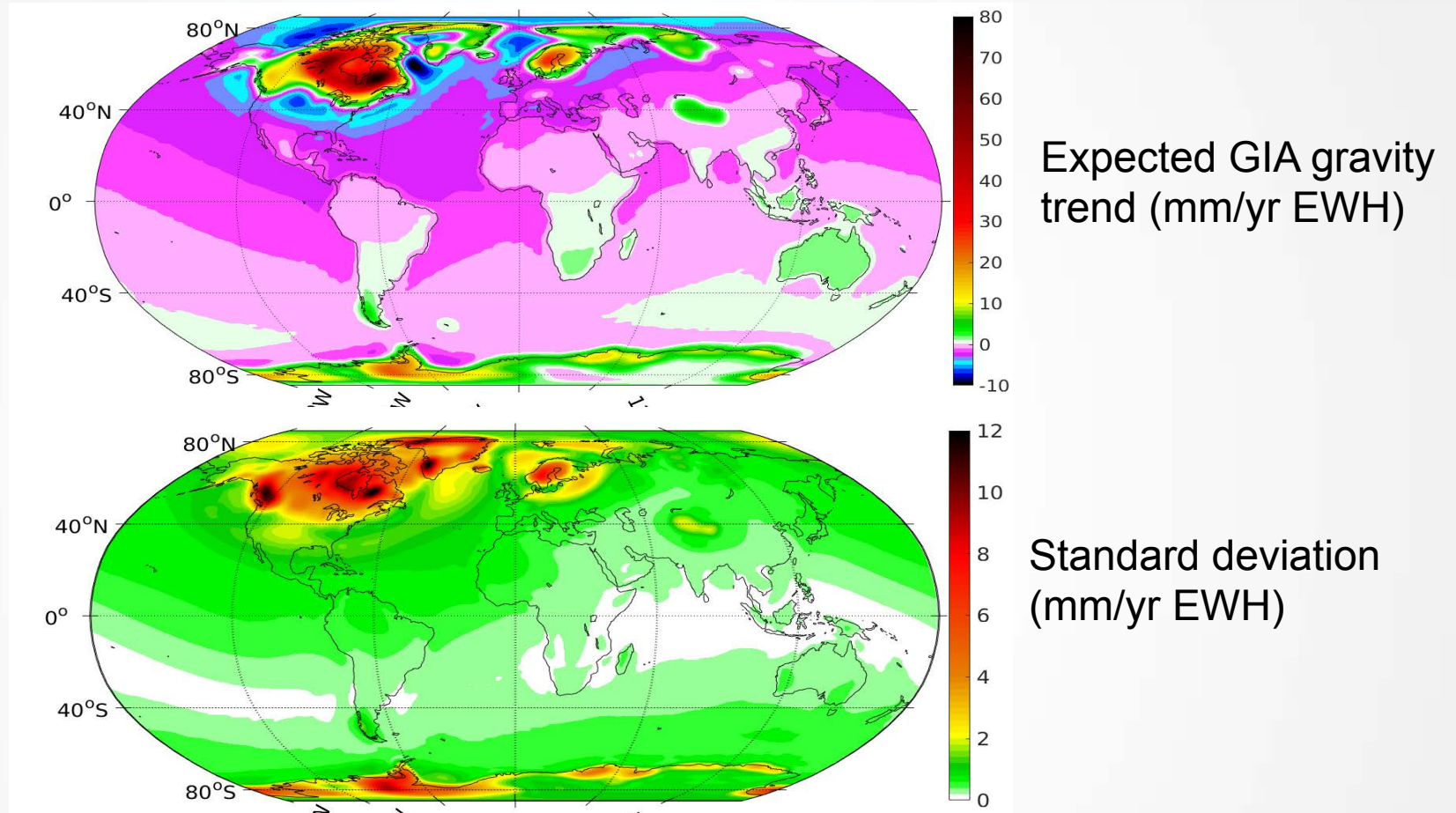
Does it make any actual difference?

Difference of gravity trend with Geruo et al. (2013)



Results

Statistical properties of the GIA model ensemble.



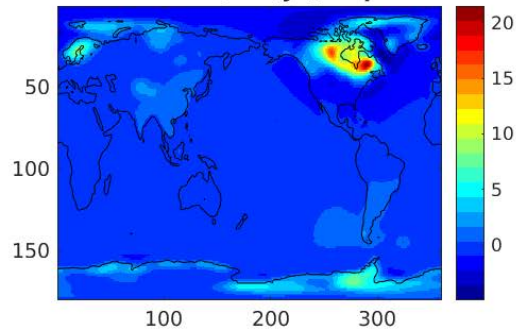
GRL publication in prep.

These results will be freely available online!

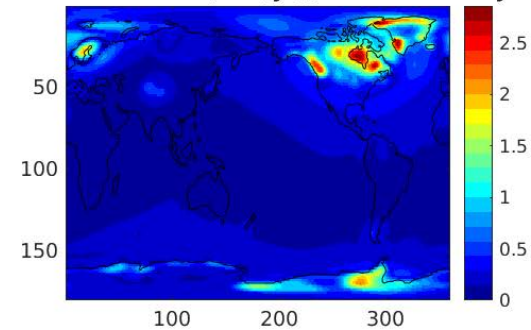
Thank you for your attention!

Present day predictions

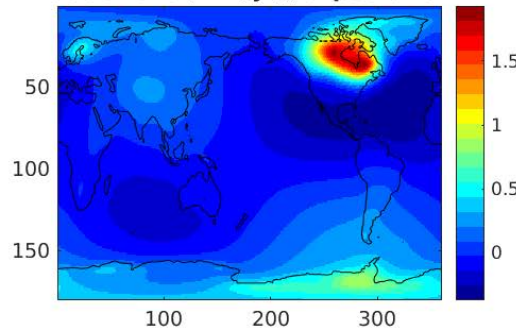
Vertical motion (mm/yr), expectation



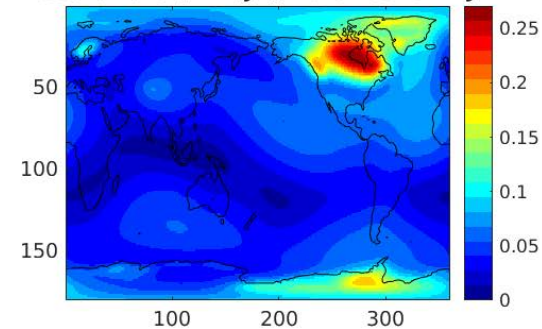
Vertical motion (mm/yr), 1σ uncertainty



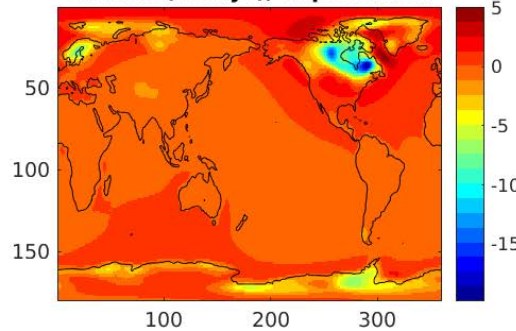
Geoid rate (mm/yr), expectation



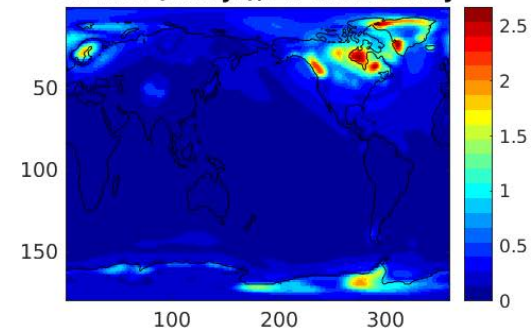
Geoid rate (mm/yr), 1σ uncertainty

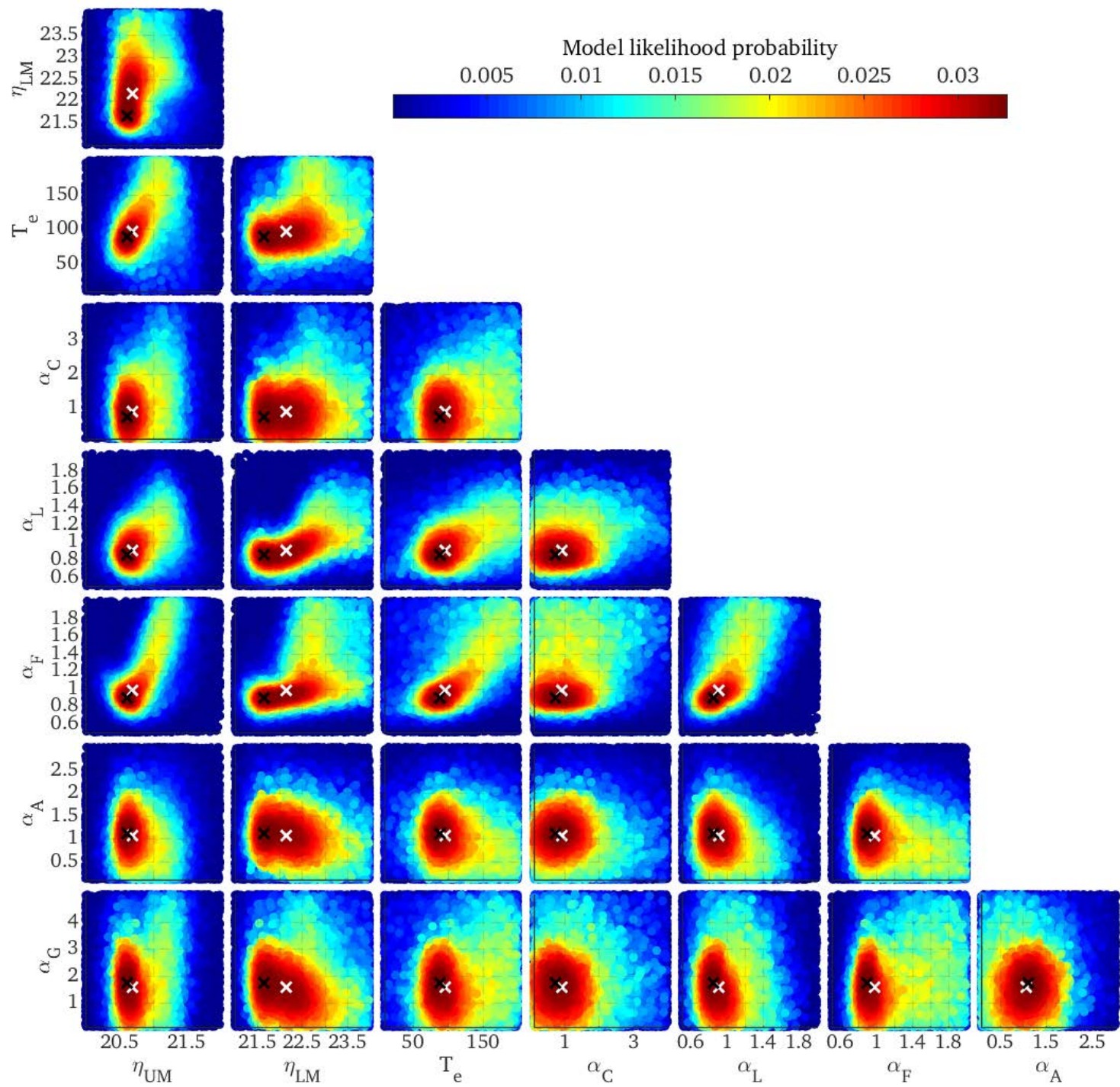


SL rate (mm/yr), expectation

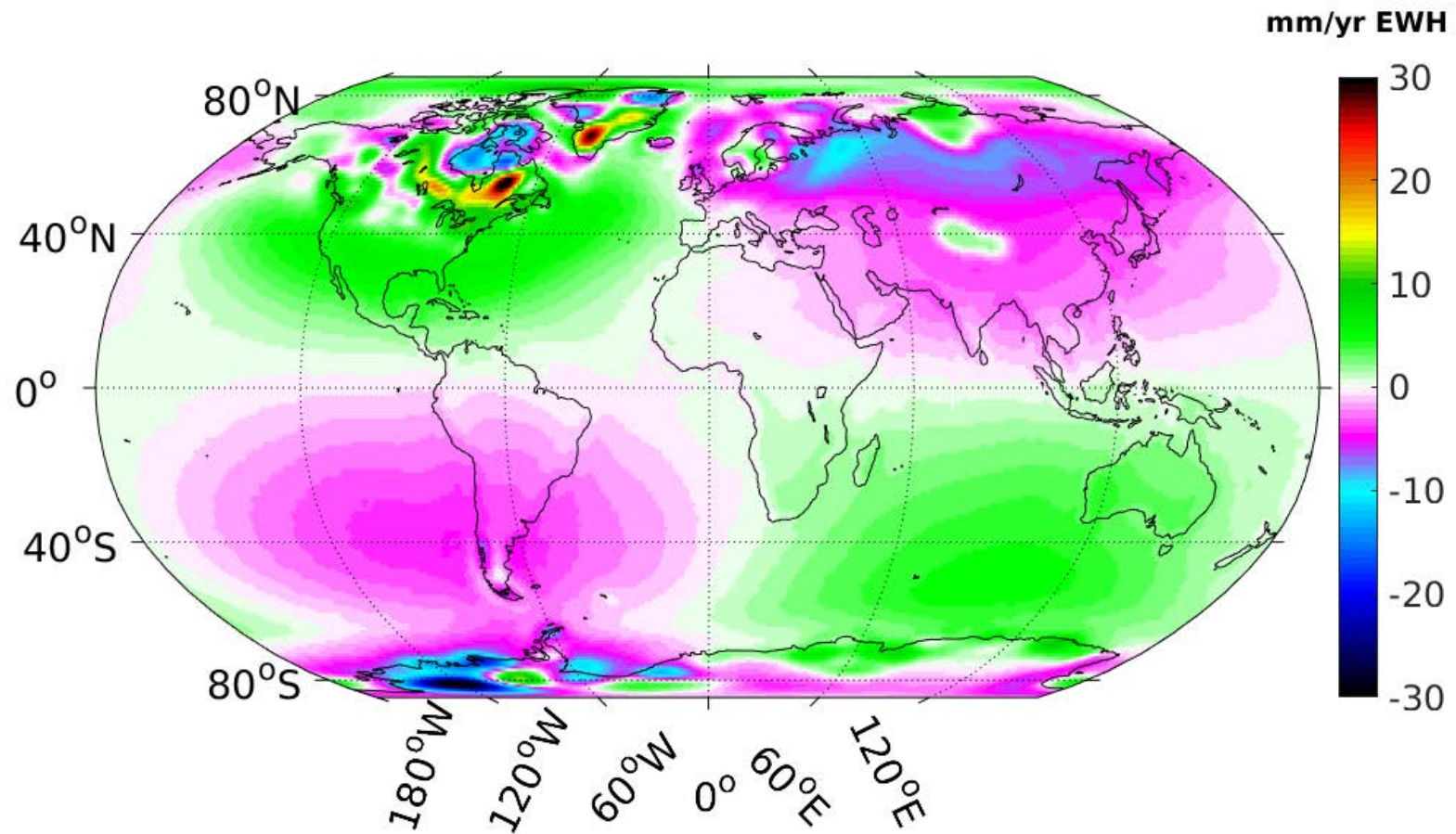


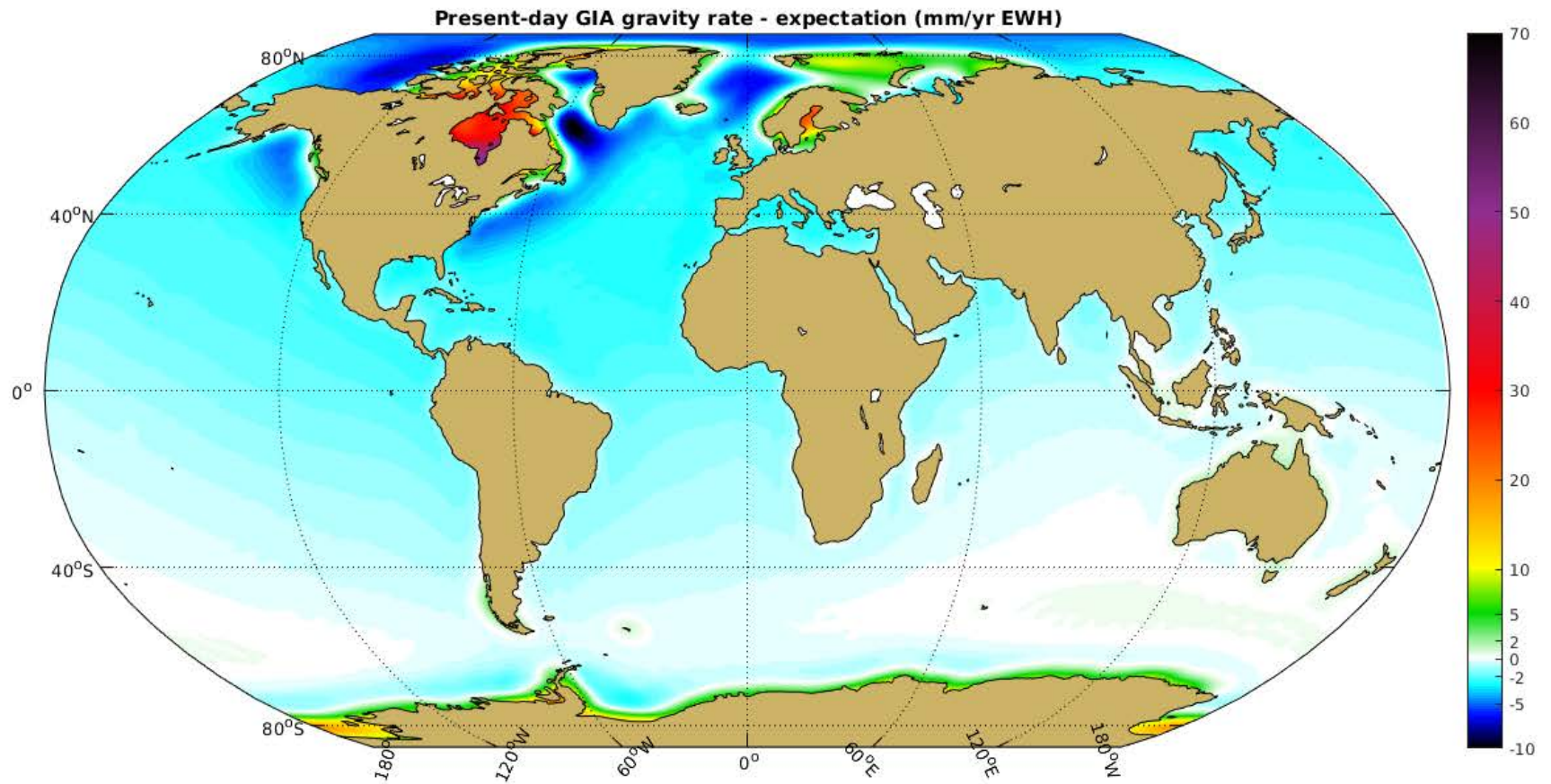
SL rate (mm/yr), 1σ uncertainty



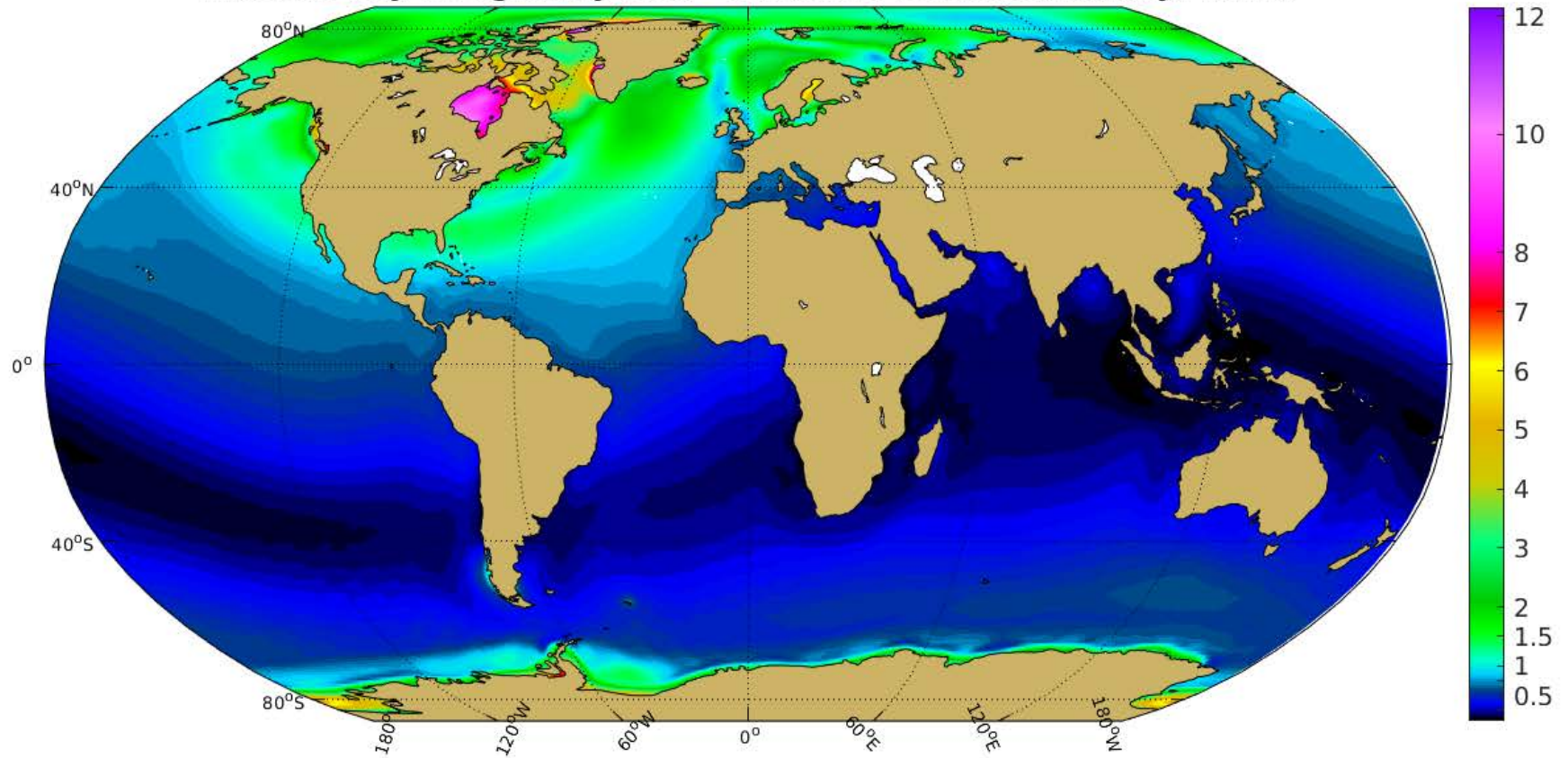


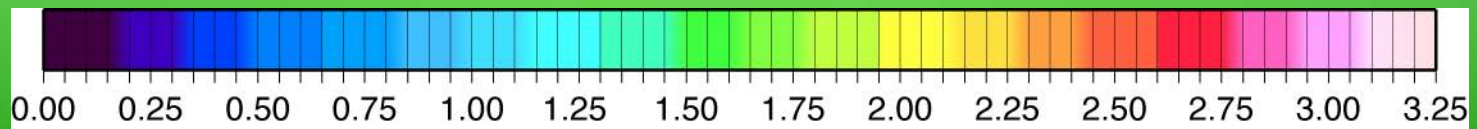
Difference with ICE-6G/VM5a





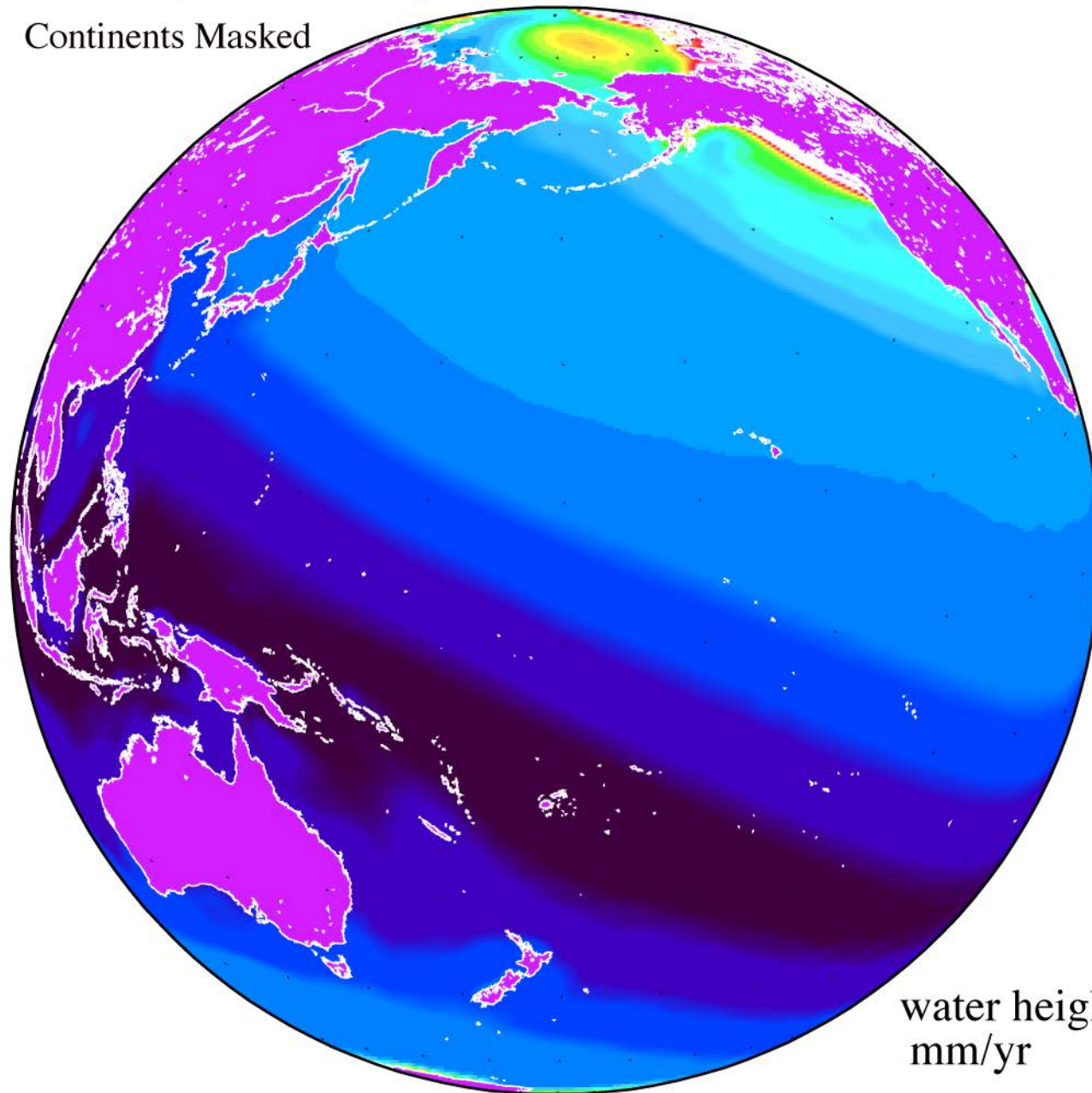
Present-day GIA gravity rate - Standard Deviation (mm/yr EWH)



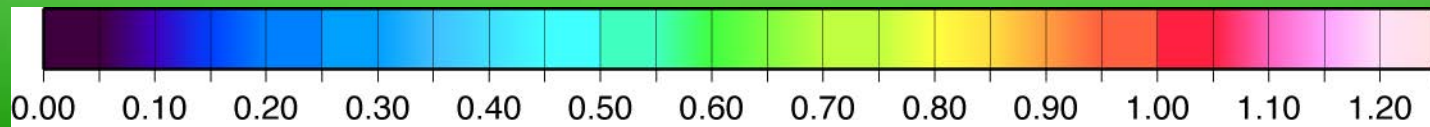


94,000 Bayesian GIA samplings in WHE (1- σ error)

Continents Masked

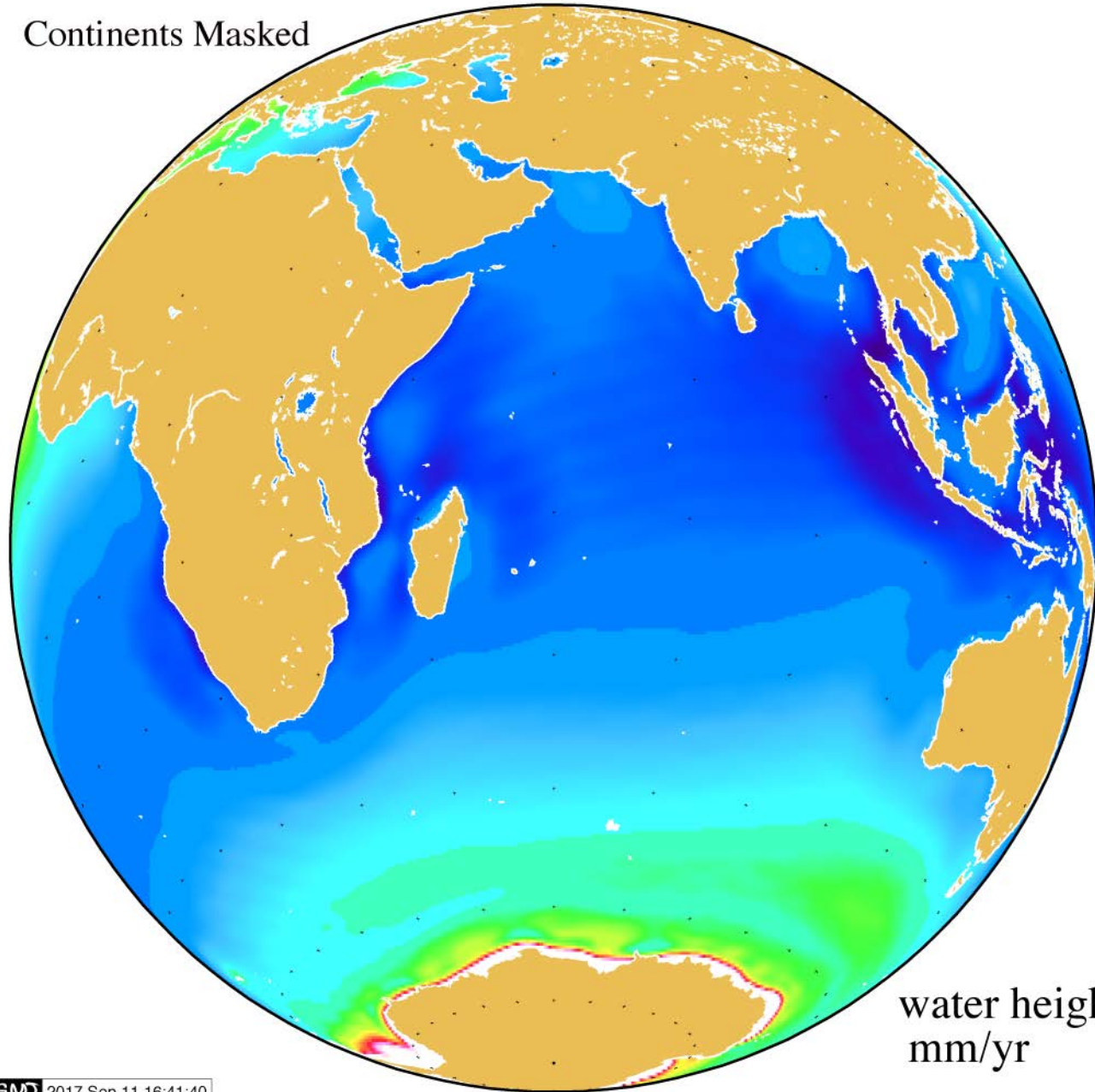


water height eq.
mm/yr

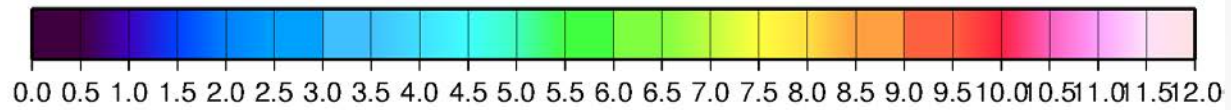


94,000 Bayesian GIA samplings in WHE (1- σ error)

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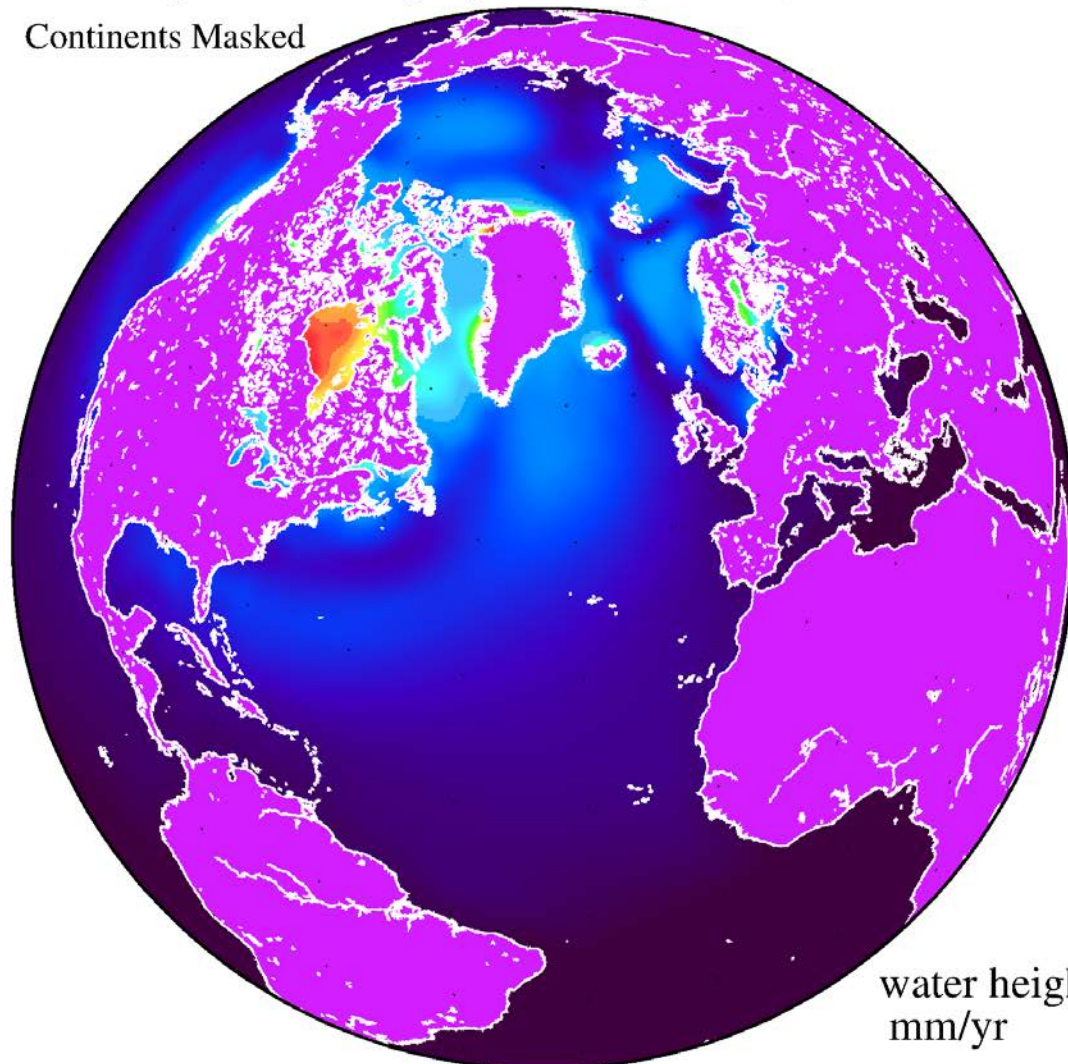


water height eq.
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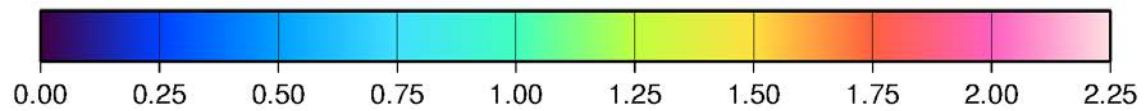


94,000 Bayesian GIA samplings in WHE (1- σ error)

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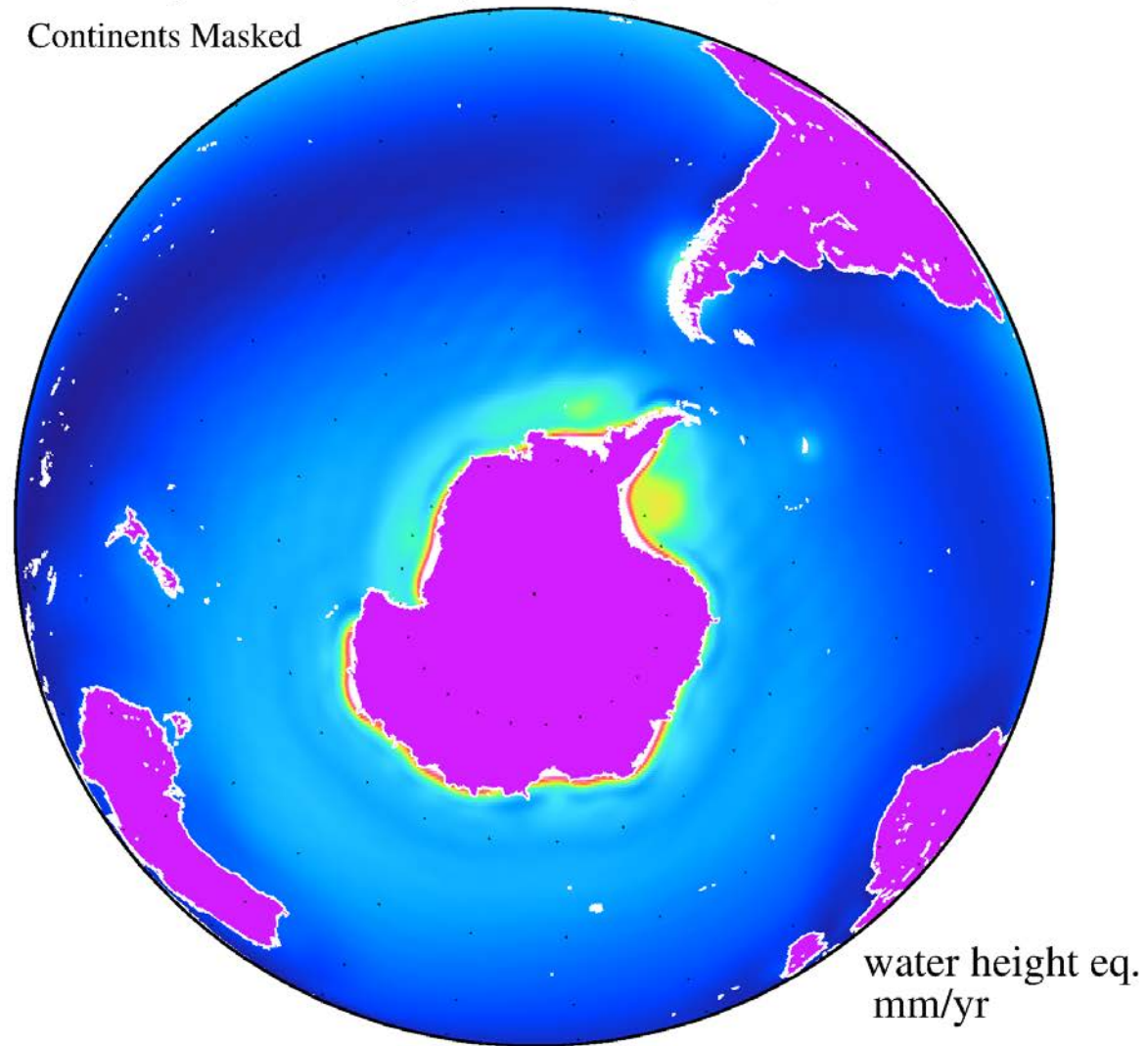


water height eq.
mm/yr

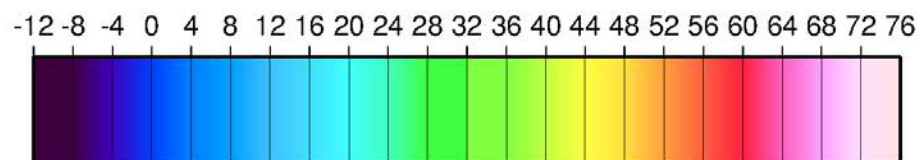


94,000 Bayesian GIA samplings in WHE (1- σ error)

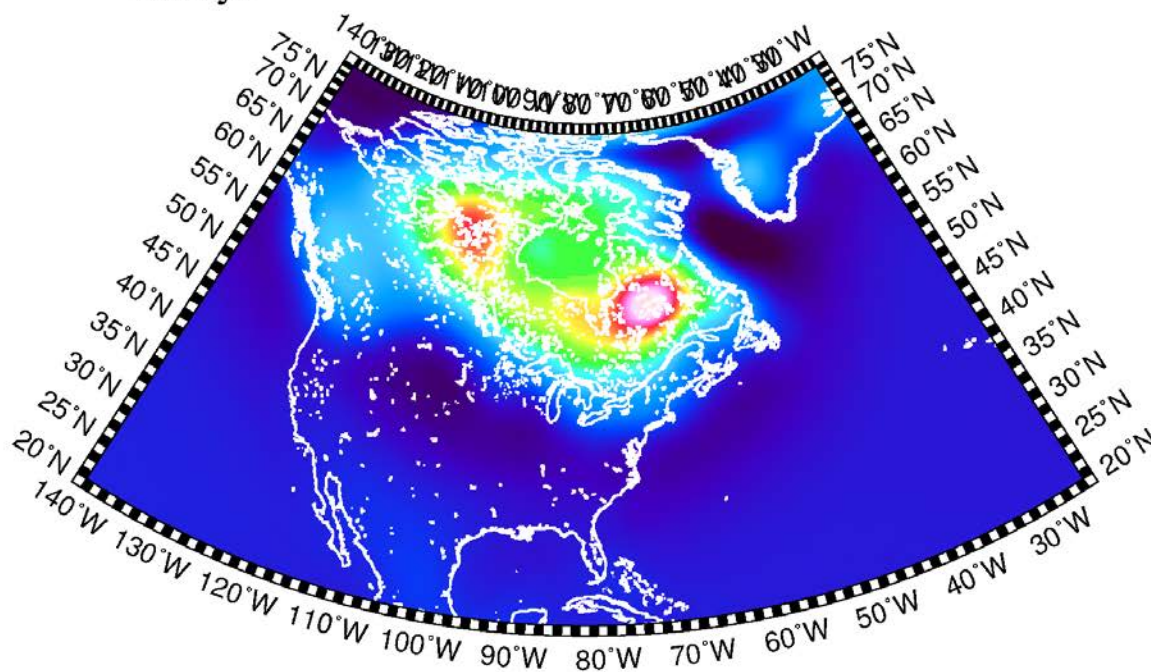
Continents Masked



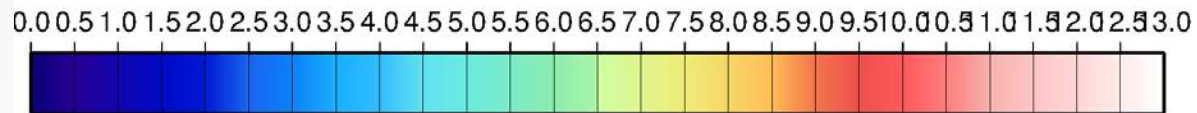
94,000 Bayesian GIA samplings in WHE



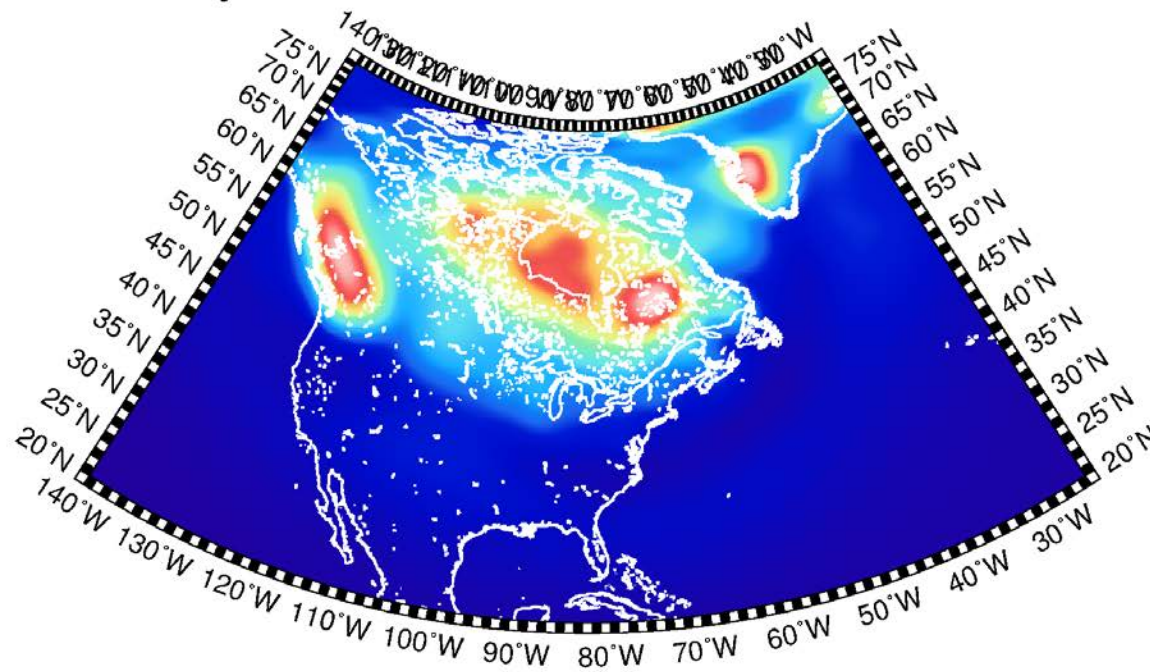
water height eq.
mm/yr



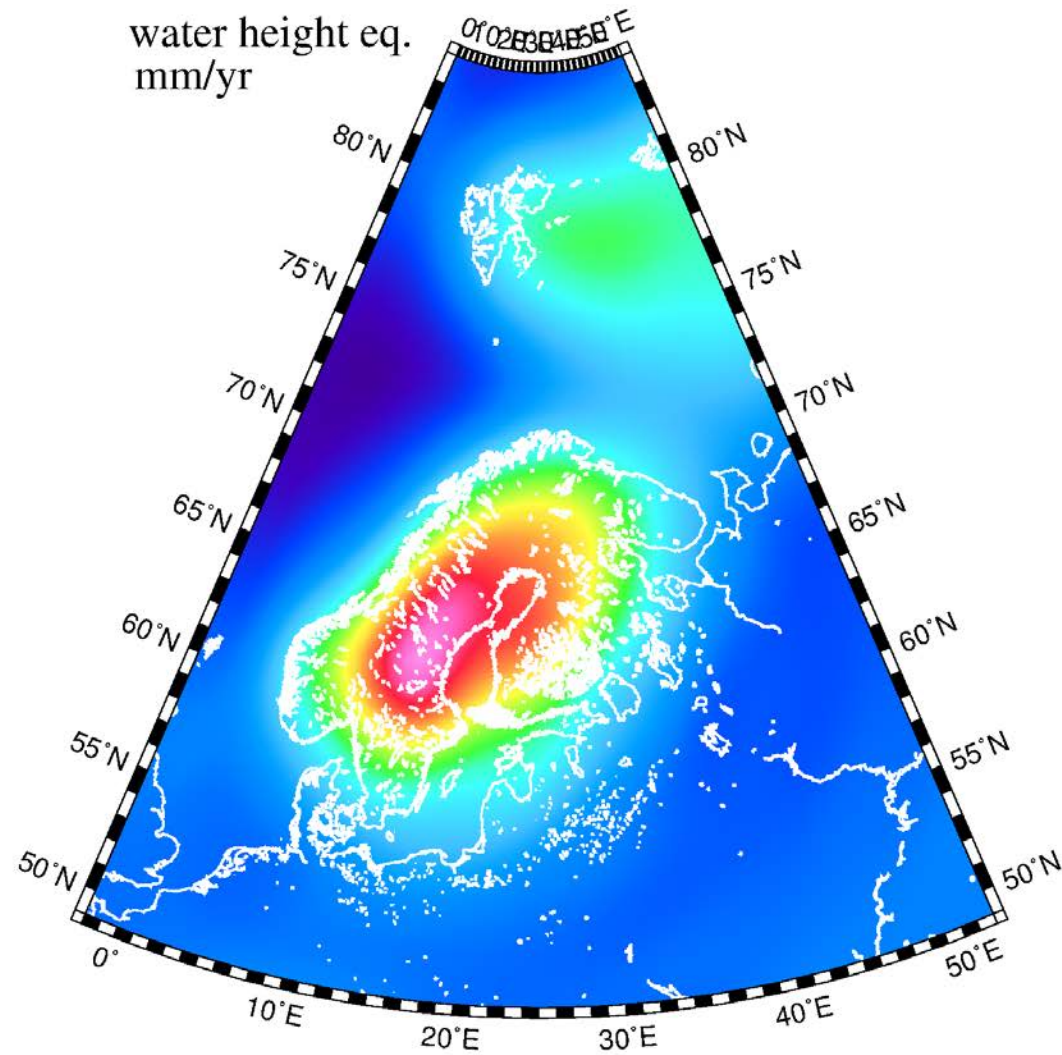
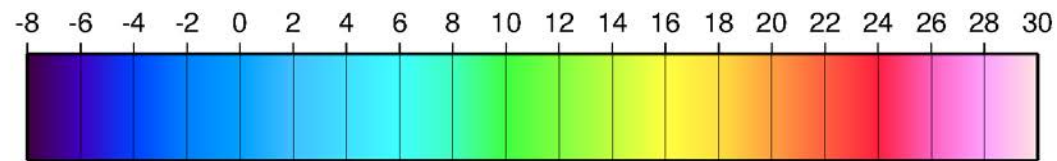
94,000 Bayesian GIA samplings in WHE (1- σ error)



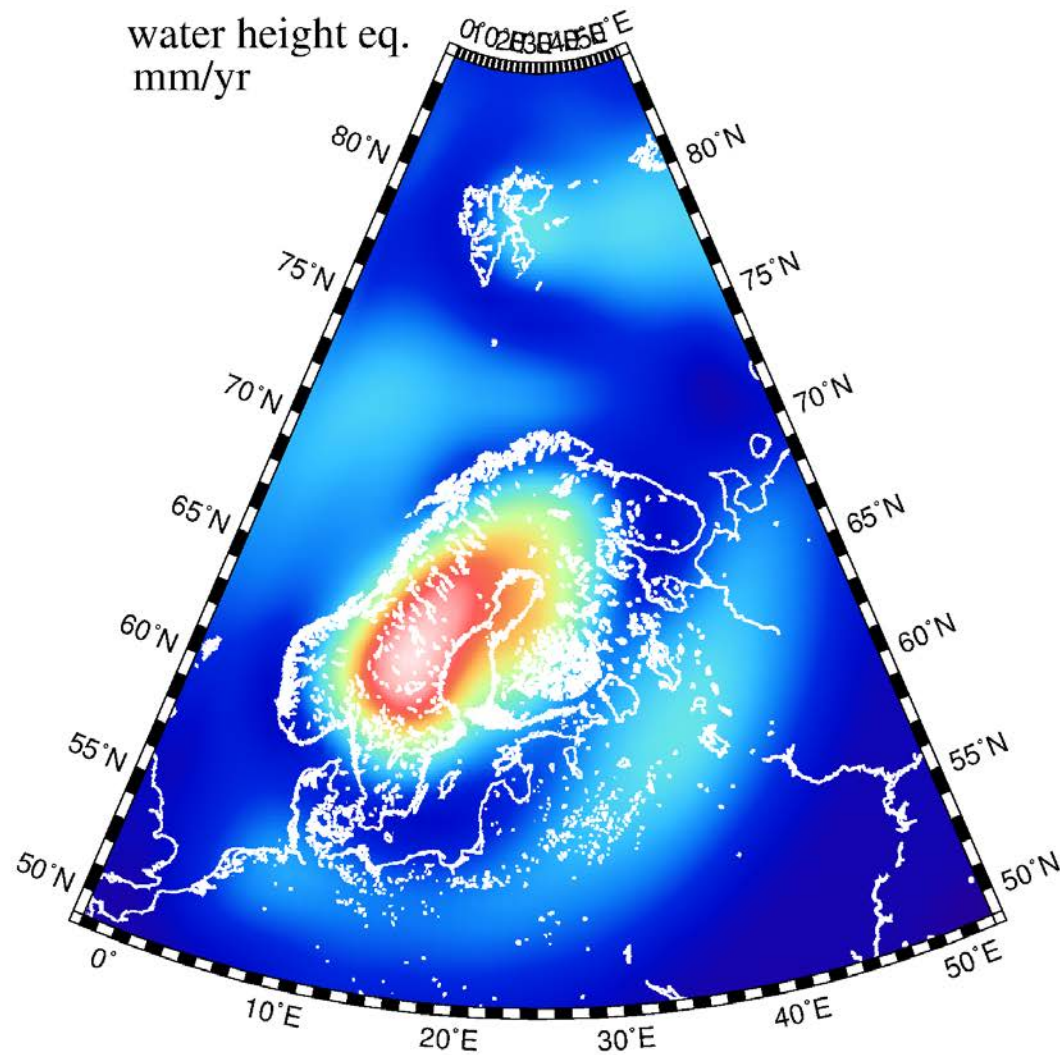
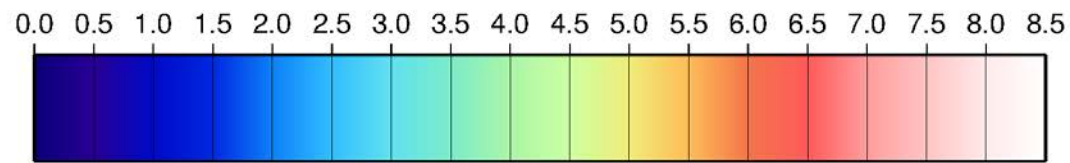
water height eq.
mm/yr

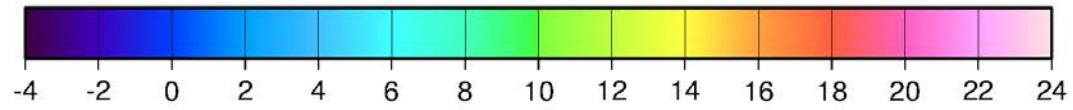


94,000 Bayesian GIA samplings in WHE

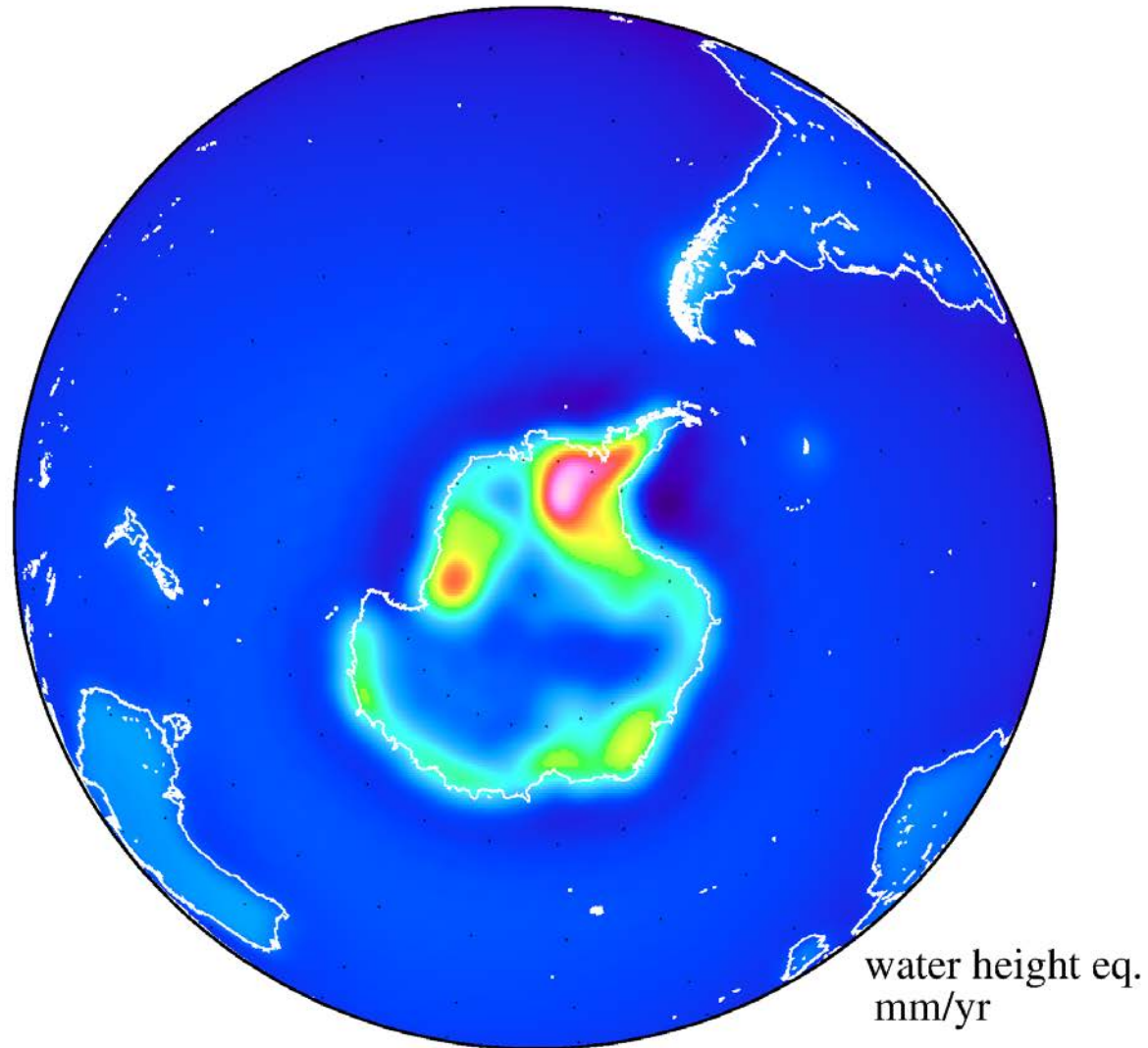


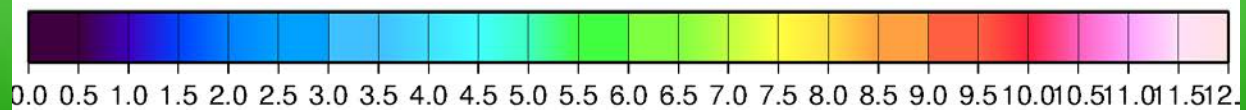
94,000 Bayesian GIA samplings in WHE (1- σ error)



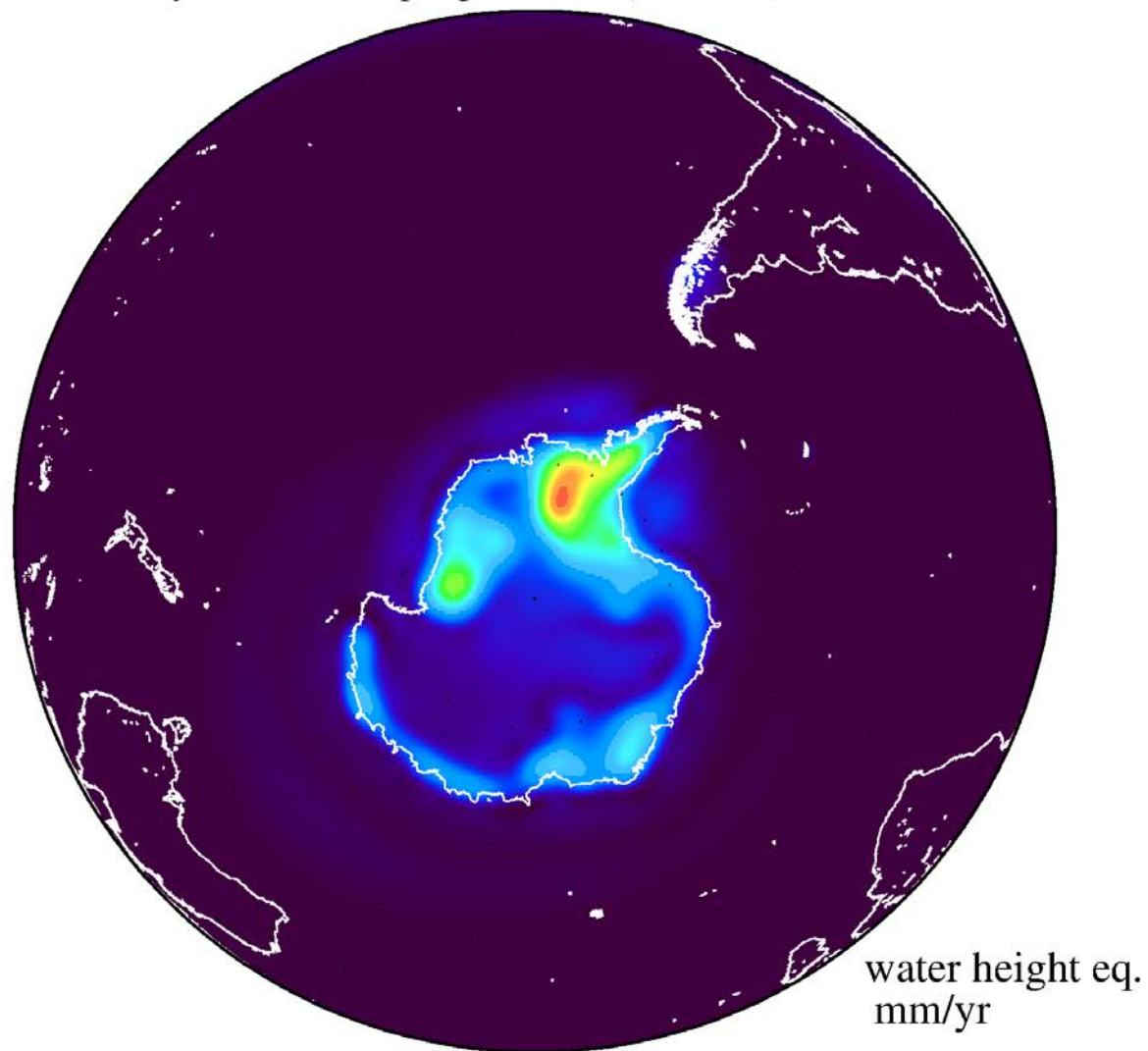


94,000 Bayesian GIA samplings in mm WHE per year (expected value)





94,000 Bayesian GIA samplings in WHE (1- σ error)



water height eq.
mm/yr