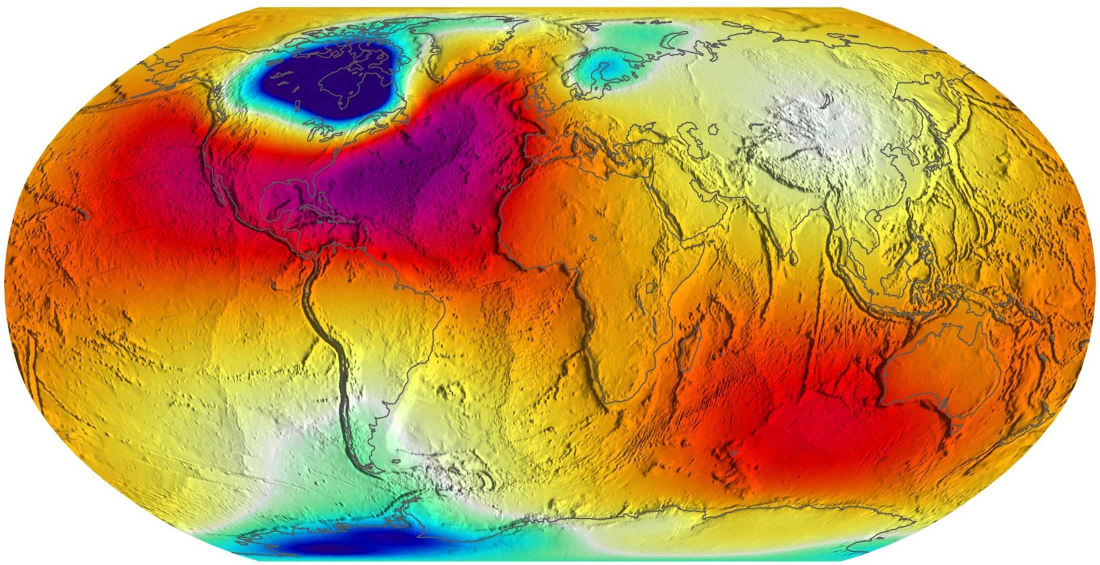
# Impacts of GIA Modeling Uncertainties on the Closure of the Global Mean Ocean Mass Budget



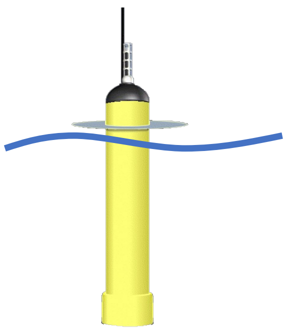
A. Bellas-Manley[1], R. Steven Nerem[1,2]

*[1]Colorado Center for Astrodynamics Research, University of Colorado Boulder*

*[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder*

# Closing the Sea Level Budget

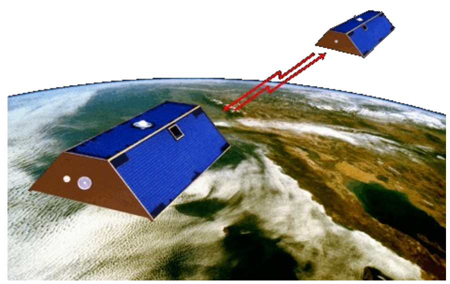
Addition of Heat



**Argo**

+

Addition of Freshwater

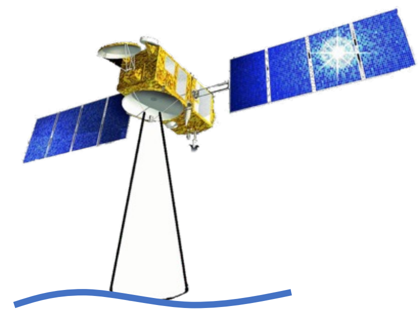


**GRACE**

=

(roughly)

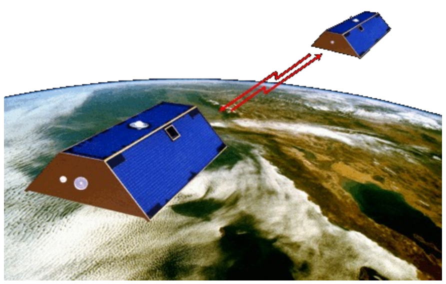
Total Sea Level Rise



**Altimetry**

# Closing the Global Ocean Mass Budget

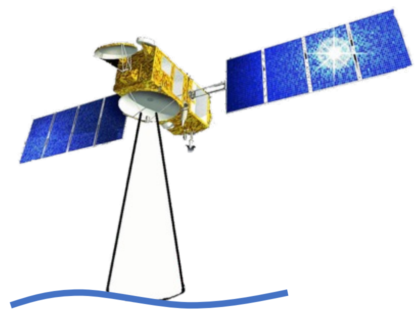
Addition of Freshwater



**GRACE**

= (roughly)

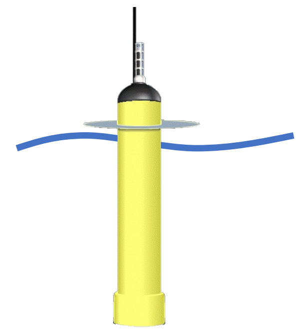
Total Sea Level Rise



**Altimetry**

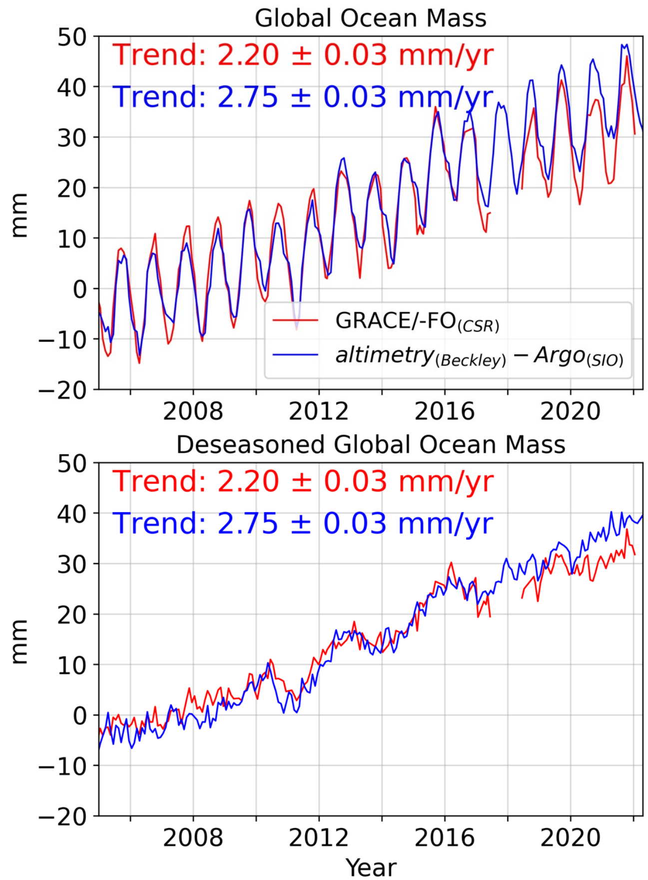
−

Addition of Heat



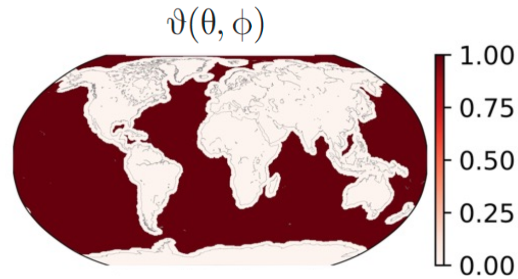
**Argo**

# Global Ocean Mass from GRACE/-FO, Altimeters, and Argo




GRACE data (CSR SH coefficients)

- $l_{max}$ = 60
- Replace $C_{1,0}$, $C_{1,1}$ with TN13
- Replace $C_{2,0}$, $C_{3,0}$ with TN14
- Correct for GIA (ICE-6G*VM5a)




$$\vartheta(\theta,\phi) = \begin{cases} 0 & \text{outside the basin} \\ 1 & \text{inside the basin} \end{cases}$$

$$\overline{\Delta\sigma}_{\text{region}} = \frac{a\ \rho_E}{3\ \Omega_{\text{region}}} \sum_{l=0}^{\infty} \sum_{m=0}^{l} \frac{(2l+1)}{(1+k_l)} \left(\vartheta_{lm}^{c} \Delta C_{lm} + \vartheta_{lm}^{s} \Delta S_{lm}\right),$$

(equations from Swenson & Wahr, 2002)

Altimeter data (Beckley et al., 2021)

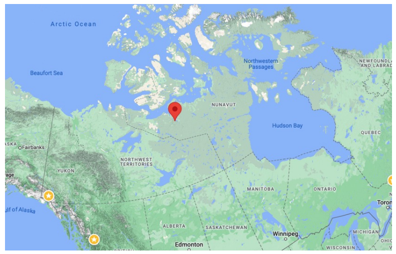
- Smoothed global mean geocentric sea level (60-day Gaussian type filter)
- Correct for GIA (ICE-6G*VM5a)

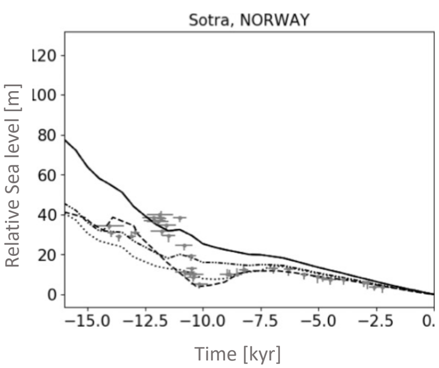
Steric sea level data (MEaSUREs/HOMaGE)

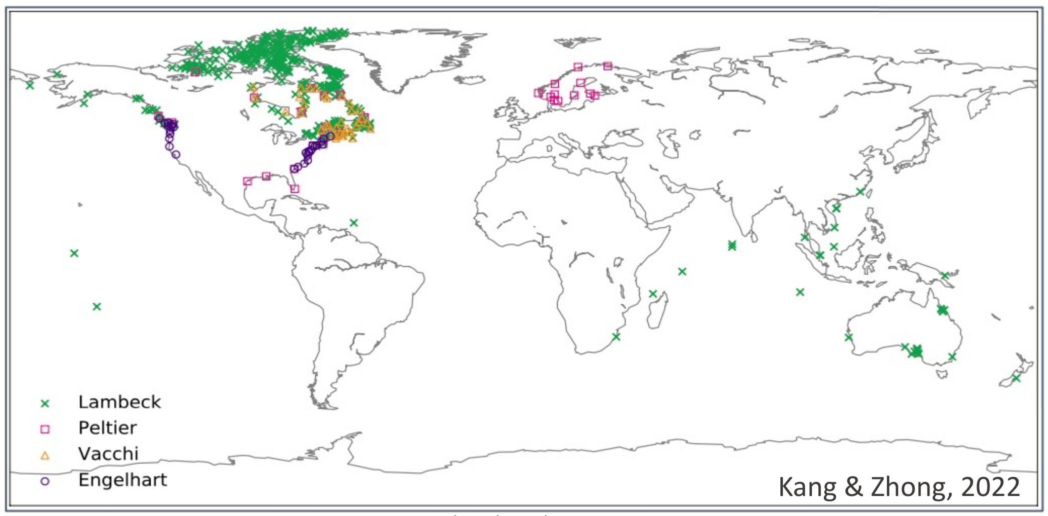
- Total steric sea level anomaly from the Scripps timeseries

# Relative Sea Level Histories at Paleoshorelines

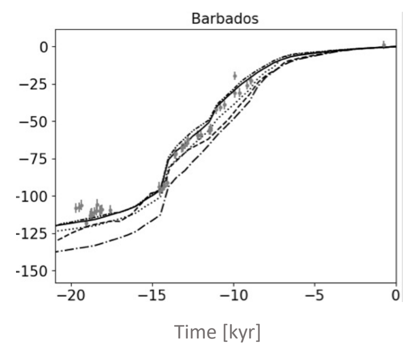
Bathurst Inlet, Nunavut, Canada






Paleoshoreline sites



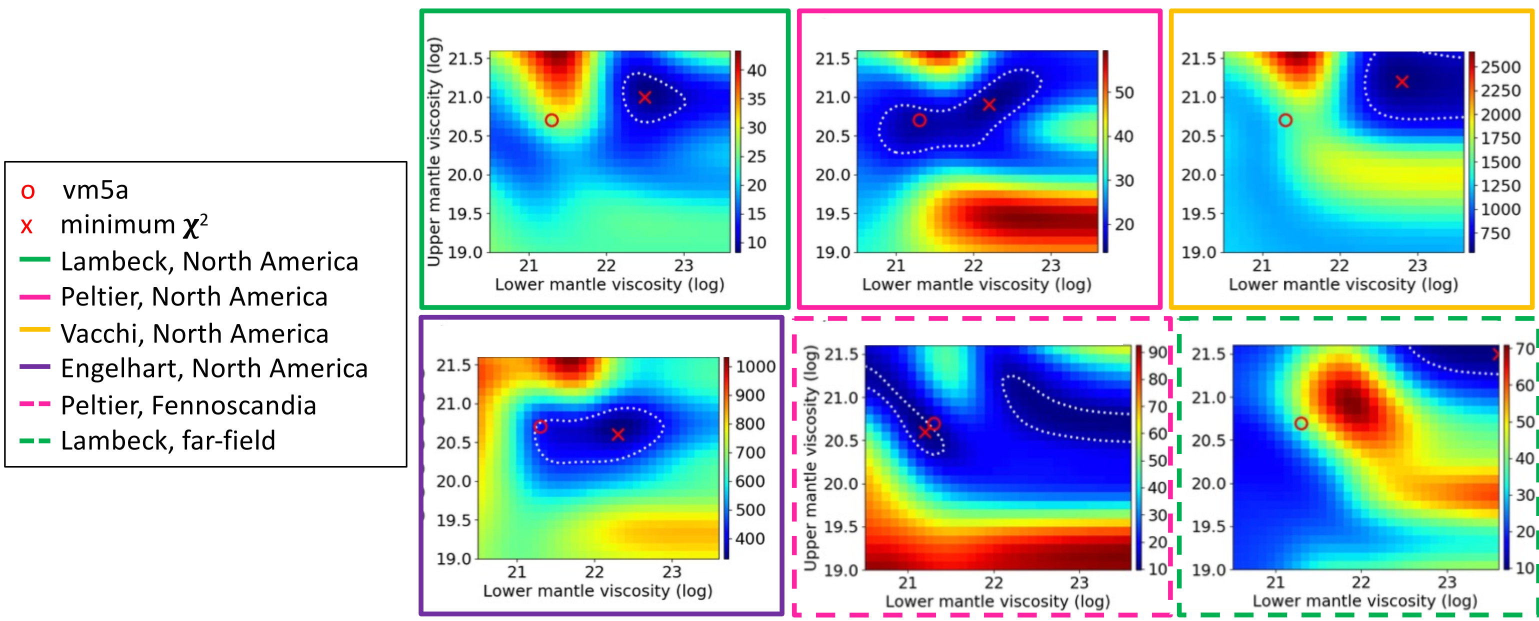
# Computing Glacial Isostatic Adjustment

1. A 3D spherical compressible viscoelastic loading model computes the gravitational, deformational, and rotational response of the Earth to a surface loading history

   (*Han & Wahr*, 1995; *Paulson et al*., 2005; *A et al.*, 2013)

2. Calculations include polar wander feedback, apparent motion of center of mass, sea level change, and coastline migration
3. Mantle density structure, shear modulus, and bulk modulus are based on PREM
4. The solution method is semi-analytic which requires that viscosity varies only in the radial dimension

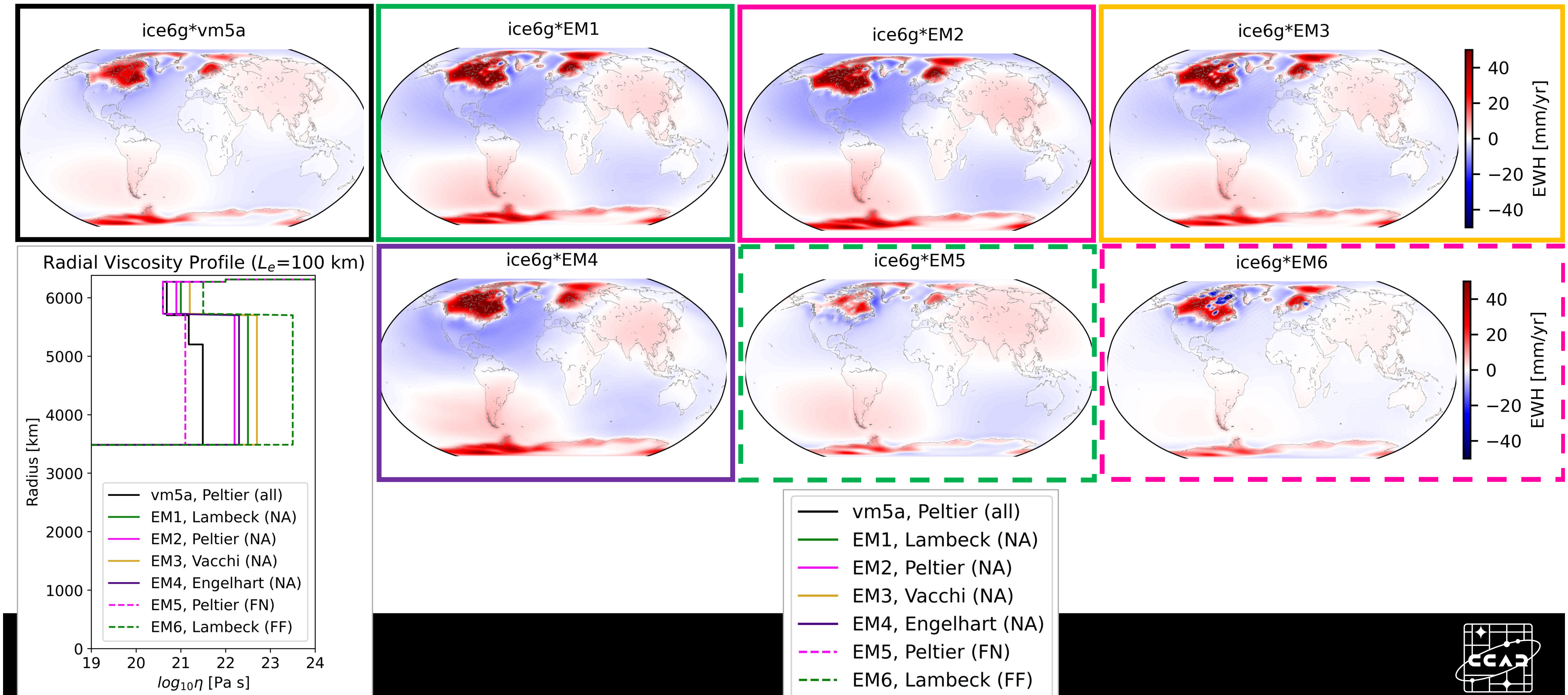
# $\chi^2$ misfit of the GIA Prediction to Relative Sea Level at Paleoshorelines




Kang & Zhong, 2022

We compare the observed relative sea level histories to the GIA model prediction of relative sea level at those sites.

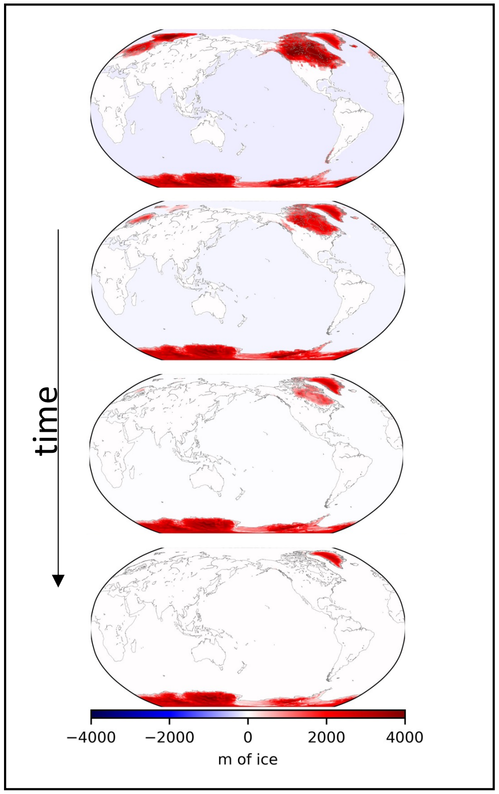
# Six New Best-Fit GIA Models Constrained by Paleoshorelines in Different Regions (Kang & Zhong, 2022)



# The GIA Response

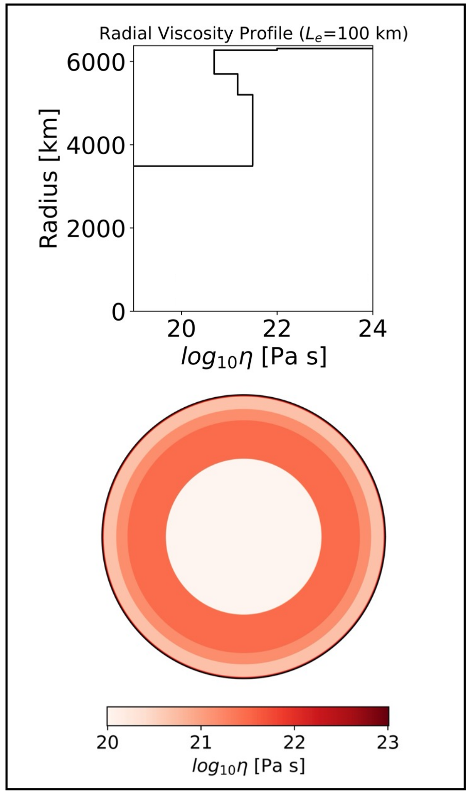
$$RSL'(\theta,\varphi) = GSL'(\theta,\varphi) - v_z(\theta,\varphi)$$

$$\int_{ocean} RSL'\,dA = \int_{ocean} GSL'\,dA - \int_{ocean} v_z\,dA = GMSL' \cdot A$$



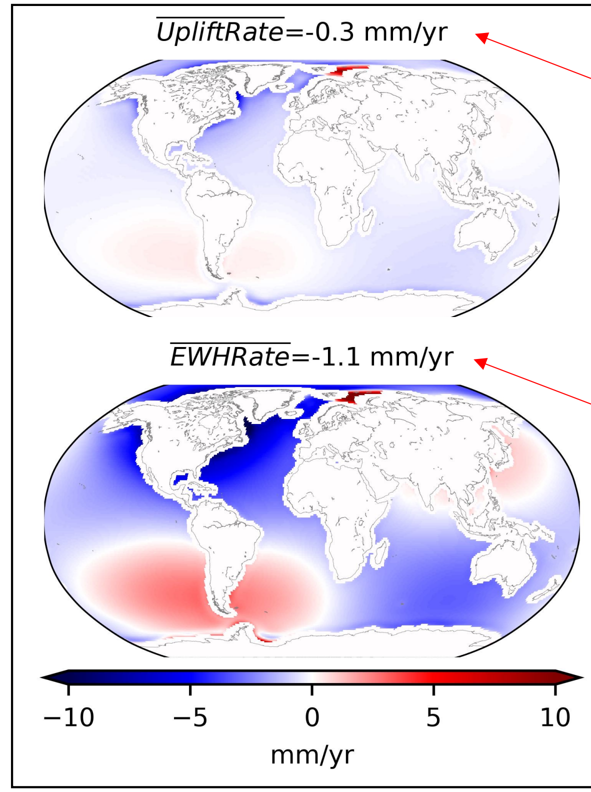

ICE-6G_C

*




VM5a

=

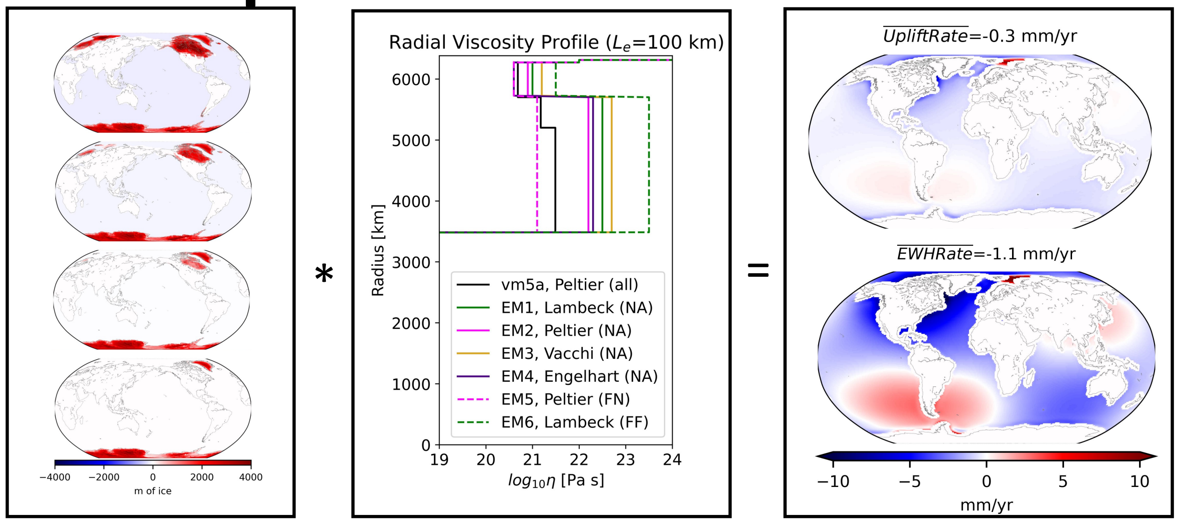


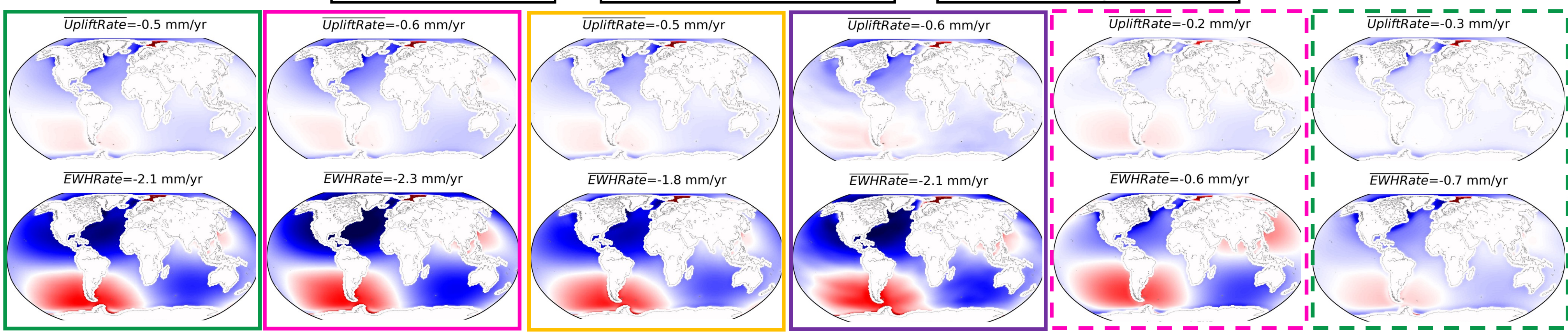

GIA response

Corrects GMGSL from altimetry for GIA

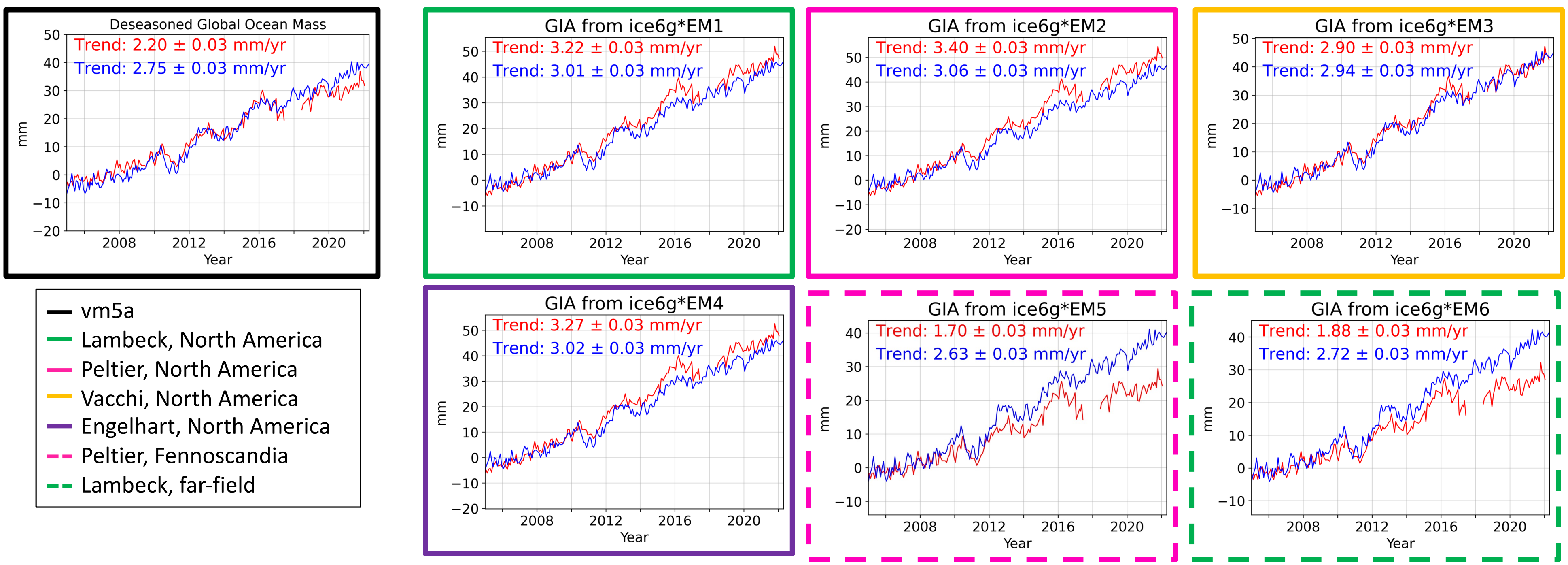
Corrects GMOM from GRACE/-FO for GIA

# The GIA response of 7 Earth Models to ICE-6G

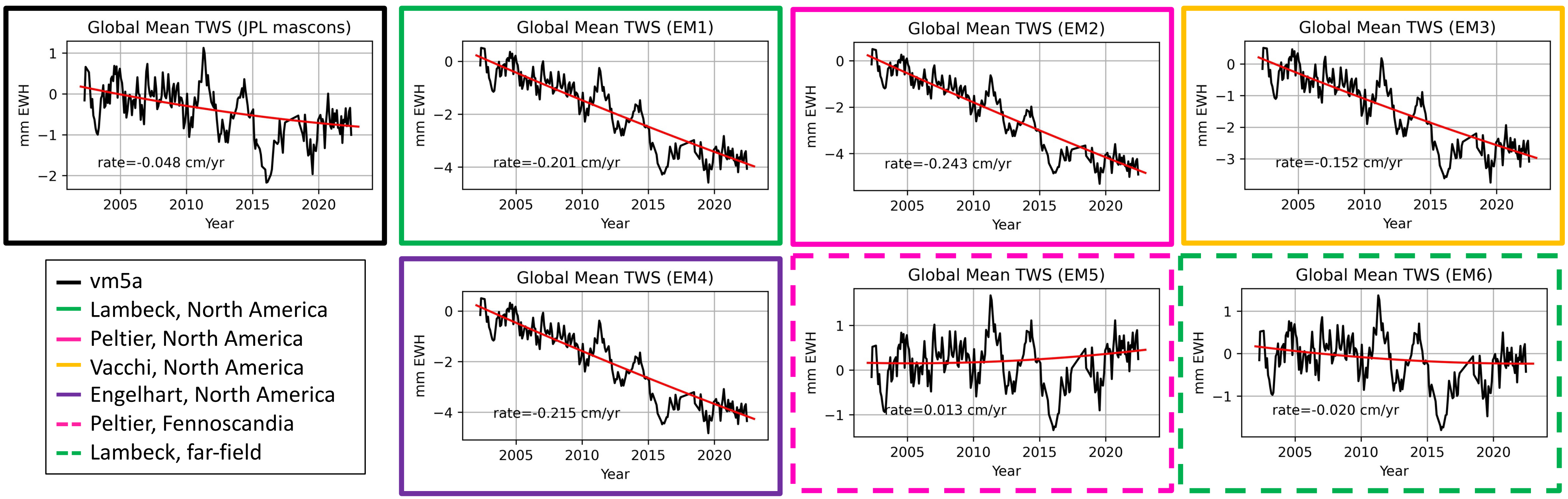


# De-seasoned Global Mean Ocean Mass



# Global Mean Terrestrial Water Storage Trend with Different GIA Corrections (ice covered regions not considered)



# Conclusions & Future Work

1. Reasonable variations in the GIA model are capable of significantly reducing the GMOM budget misclosure from GRACE/-FO, altimeters and Argo
2. Paleoshorelines from different geographic regions indicate different models of GIA that significantly affect observations from GRACE/-FO and altimeters
3. If the Earth's viscosity structure varies in 3D, then how do we constrain the most appropriate 1D viscosity structure?
4. Does the best-fit 1D viscosity structure depend on what region of the GIA response one is concerned with?
5. How do the results change for different ice deglaciation histories (e.g., ANU ice model, Gowan et al. ice model)?
6. The GMSL misclosure is likely caused by a variety of errors (TOPEX (see Beckley poster), Jason-3 wet trop, Argo, and GIA) and not any single cause.