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# A global empirical GIA model based on GRACE data

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#### Introduction

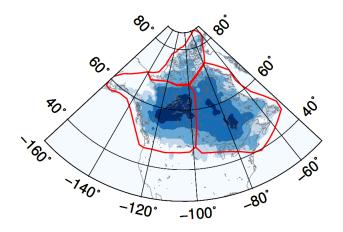
- GRACE does not distinguish between signals from the solid earth (GIA) and the water layer (PD).
- PD geoid fingerprints can be accurately pre-computed (while GIA fingerprints depend on modelling choices).
- PD and GIA fingerprints have <u>very different</u> spectra and temporal evolution, hence:
- => They can be simultaneously constrained by GRACE timeseries.

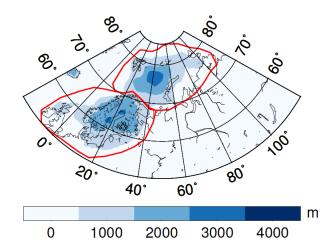


# **GIA fingerprints**

The main control on GIA patterns comes from the ice load at LGM (for past ice sheets).

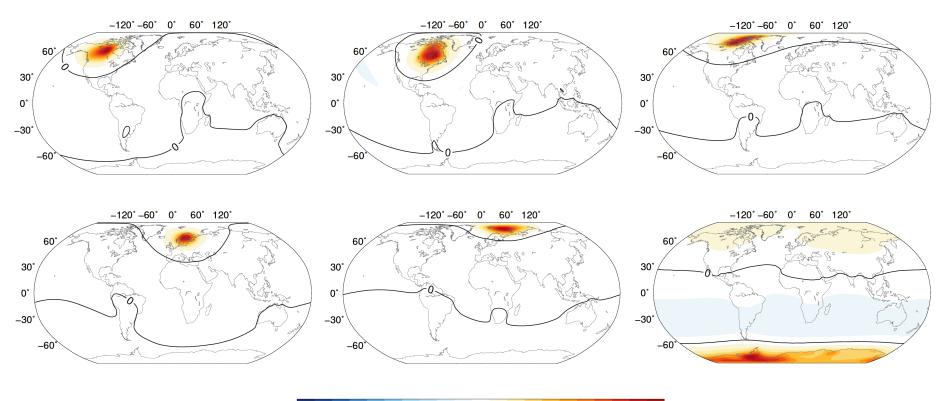
- Northern hemisphere: 5 fingerprints from ICE-5G (no Greenland).
- Southern hemisphere: Antarctica only (IJ05).

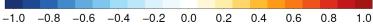






#### **GIA fingerprints** (LM viscosity 10<sup>22</sup> Pa s)

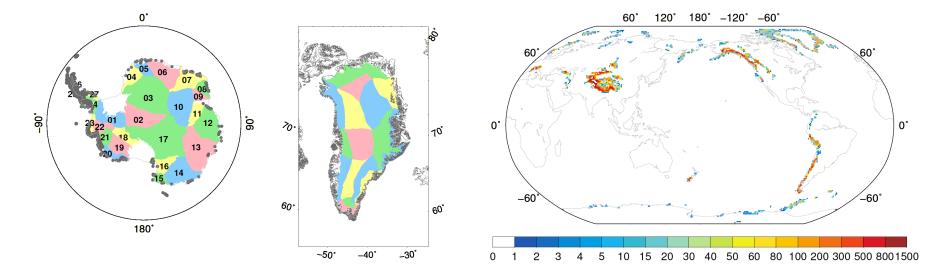






# Land ice fingerprints

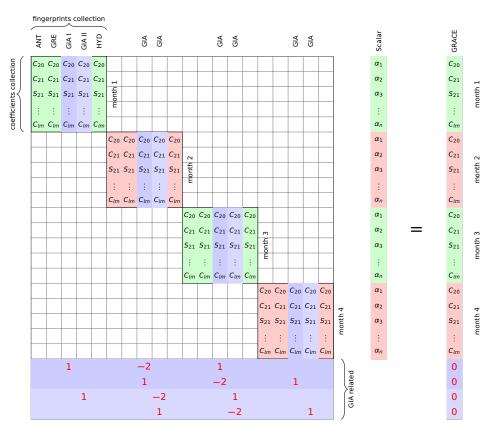
Antarctica and Greenland ISs: one fingerprint per main drainage basin. Glaciers: GLIMPS database (including IS perpherals).



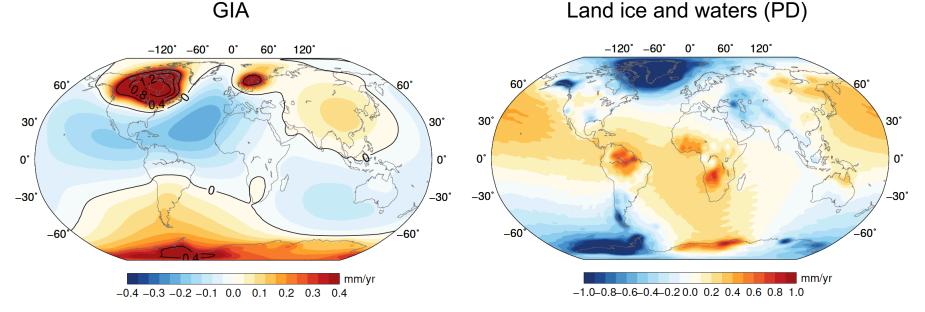
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# **Constraining fingerprints by GRACE monthly solutions**

- GRACE: CSR RL05, 2002.6 2014.9, no pole tide correction.
- Land hydrology: 60 EOFs from WGHM (Rietbroek et al., 2016).
- Additional pole tide trend.
- Passive ocean.
- GIA extra constraint: only linear trend allowed.
- Solution by least squares.



#### **Geoid changes** (LM viscosity 10<sup>22</sup> Pa s)



GIA

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#### **Geoid changes (LM viscosity 10<sup>22</sup> Pa s)**

**GRACE** trend

Residual

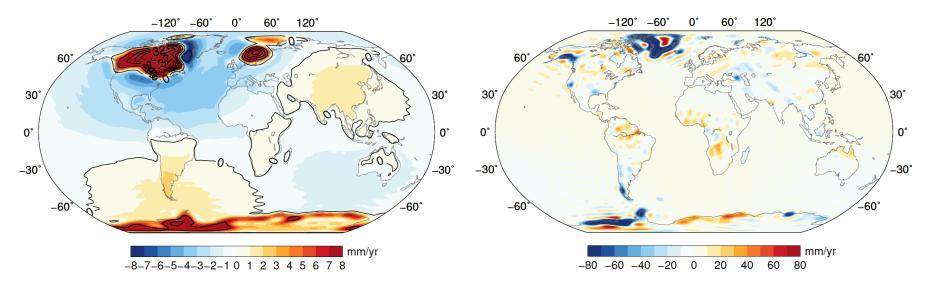
60° 120° -120° -60 60° 120° -120° -60 60° 60 60 **30**° 30° 30 30° **0° 0° 0°** 0 -30° -30° -30° -30 \_60° -60 \_60' -60 mm/yr mm/yr -1.0-0.8-0.6-0.4-0.20.0 0.2 0.4 0.6 0.8 1.0 -1.0-0.8-0.6-0.4-0.20.0 0.2 0.4 0.6 0.8 1.0



#### **Surface mass changes** (LM viscosity 10<sup>22</sup> Pa s)

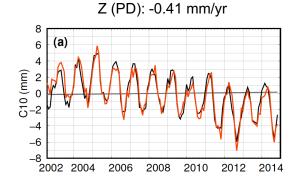
GIA

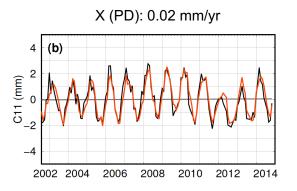
Land ice and waters (PD)

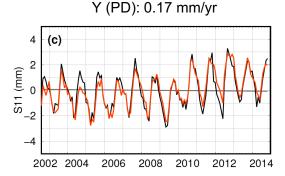




# **Geocentre motion and earth rotation trends**

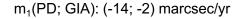






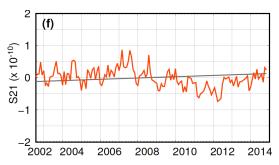
J<sub>2</sub>(PD; GIA): (6.9; -2.7) 10<sup>-11</sup> 1/yr  $\begin{pmatrix} 4 \\ 0 \\ 0 \\ 0 \\ 0 \\ -2 \\ -4 \\ 2002 2004 2006 2008 2010 2012 2014 \\ 2014 2014 2014 \\ 2014 2014 2014 \\ 2014 2014 2014 \\ 2014 2014 2014 \\ 2014 2014 2014 \\ 2$ 

Delft

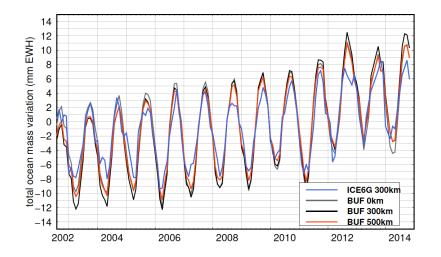




m<sub>2</sub>(PD; GIA): (-2; 1) marcsec/yr

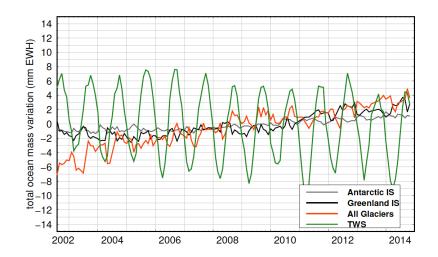


## Ice and water contribution to ocean mass changes



GRACE-ICE6G: 0.52 mm/yr

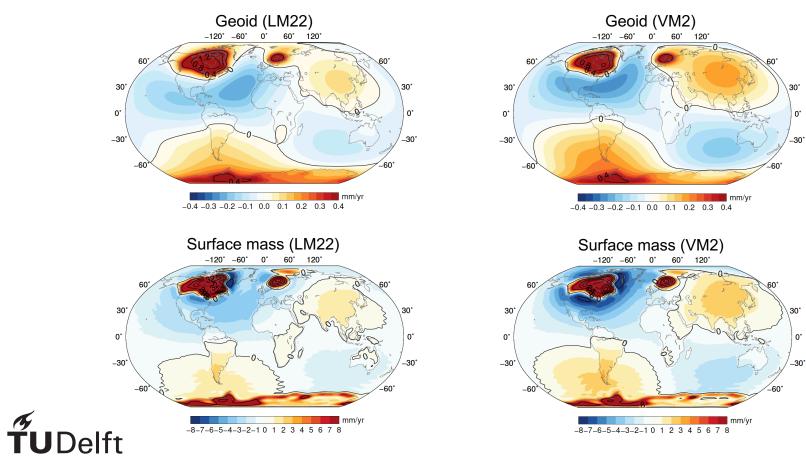
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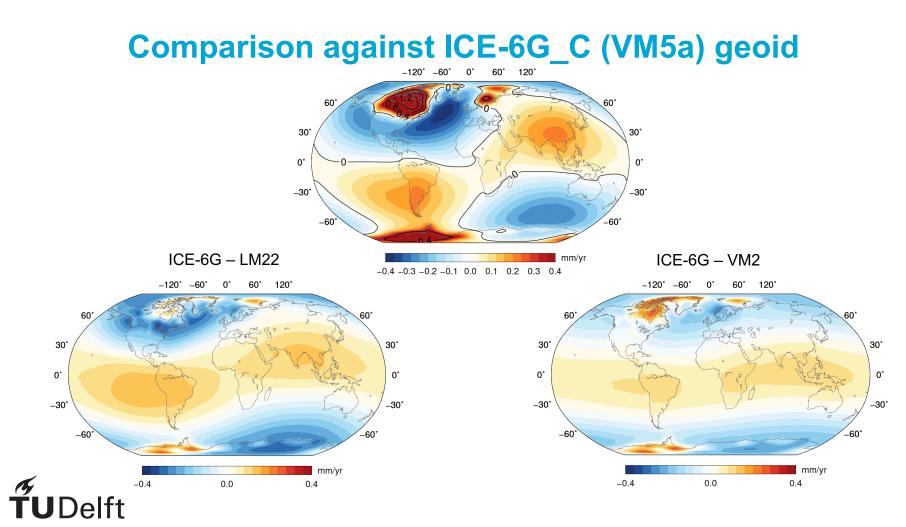


Greenland:	0.63 mm/yr	(-229 Gt/yr)
Antarctica:	0.29 mm/yr	(-106 Gt/yr)
Glaciers:	0.30 mm/yr	( -109 Gt/yr)
Land waters:	-0.27 mm/yr	(+98 Gt/yr)

Global ocean: 0.96 mm/yr Residual: 0.03 mm/yr

## Sensitivity to lower mantle viscosity





## Conclusions

- Fingerprints are physical basis functions that allow separation of GIA from PD signals in GRACE.
- The PD trend has little sensitivity to lower mantle viscosity.
- The estimated pole tide can provide an independent estimate for modelling purposes.



## Surface mass changes (LM viscosity 10<sup>22</sup> Pa s)

120° 60° 120° –120° -60 60° -120° -60 0 60° 60 30 30° 30 **0**° **0°** 0 -30° -30 -30 . -60° -60 -60 mm/yr

-80 -60 -40 -20 0 20 40 60 80

**GRACE** trend

-80 -60 -40 -20 0 20 40 60 80

Residual



30°

**0°** 

–30°

\_60°