CESM LAND ICE WINTER WORKING GROUP MEETING February 22-23 2023

3D Finite Element Modeling for the Glacial Isostatic Adjustment

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Outlines

- Background on GIA process
- Numerical modelling
- Results
- Future works

Background

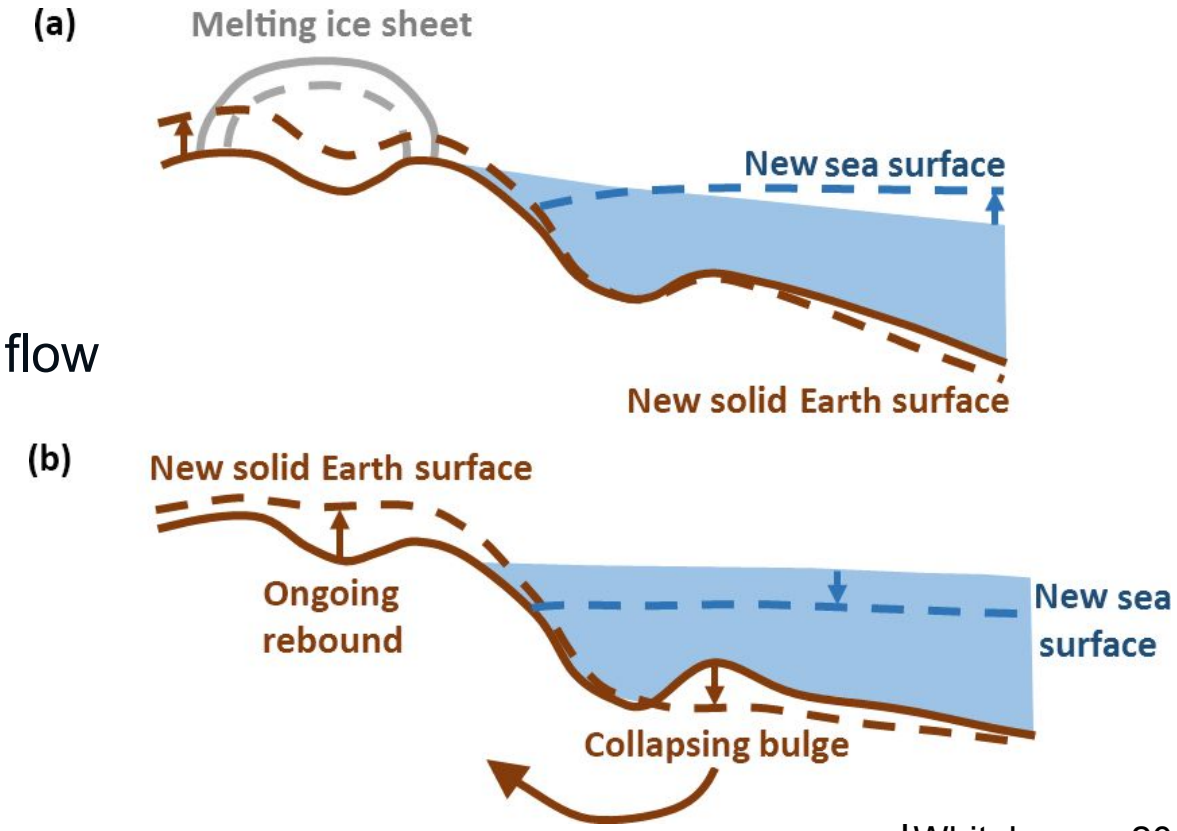
GIA: dynamical interplay among ice, ocean and solid Earth

- Deformational response

  elastic + viscous

- Gravitational response

  ice and ocean mass changes + mantle flow

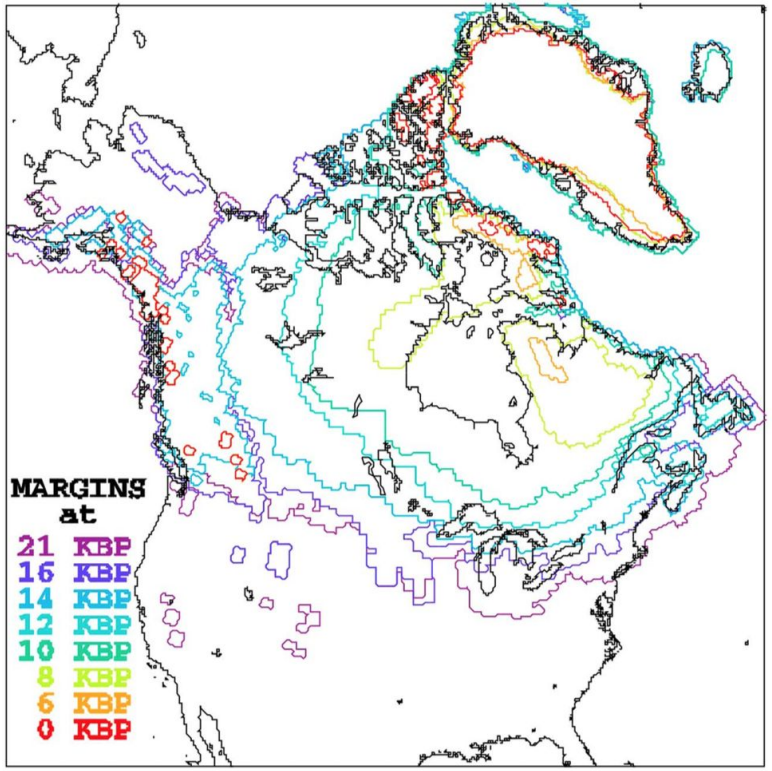


[Whitehouse, 2018]

Background

Widely used ice models in GIA modelling:

- Global ice models:
  - ICE-6G / ICE-7G (Peltier et al., 2015, 2018)
  - ANU (Lambeck et al., 2014, 2017)
- Regional ice deglaciation history:
  - Antarctica ice (Whitehouse et al., 2012; Nield et al., 2014; Rott et al., 2018; Samrat et al., 2020)
  - Greenland ice (DeConto et al., 2016; Parizek et al., 2019)



Deglaciation isochrones

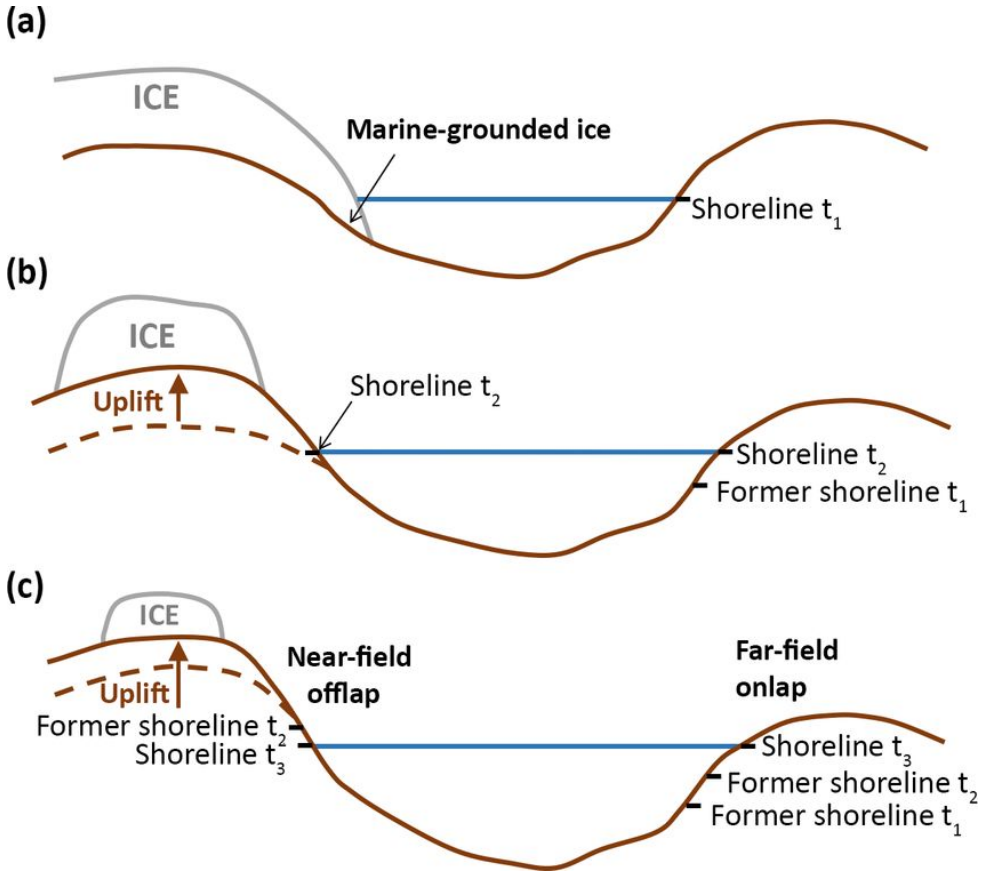
[Peltier et al., 2015]

Background

Ocean models in GIA modelling:

- Gravitational self-consistent ocean (Farrell et al. 1976)
- Shoreline migration (Kendall et al., 2005)
- Ocean influx and outflux in the regions of retreating marine-based glaciers

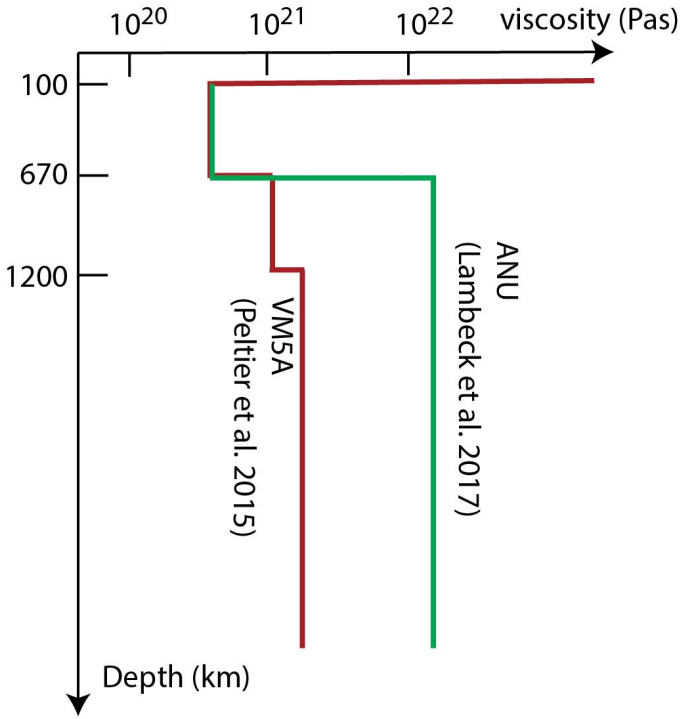
(Mitrovica 2003, 2021; Paulson et al., 2005; A et al., 2013; Kang et al., 2021)



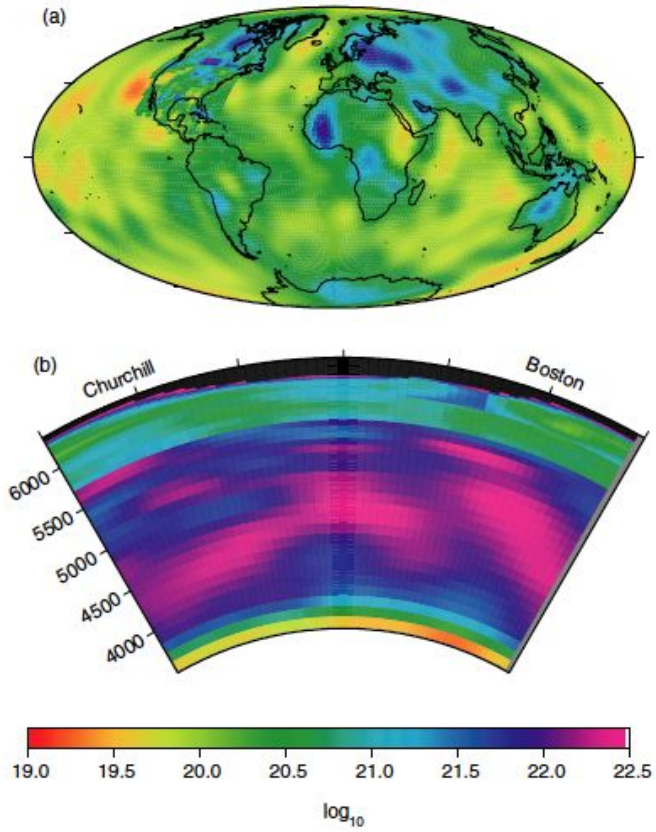
[Whitehouse, 2018]

Background

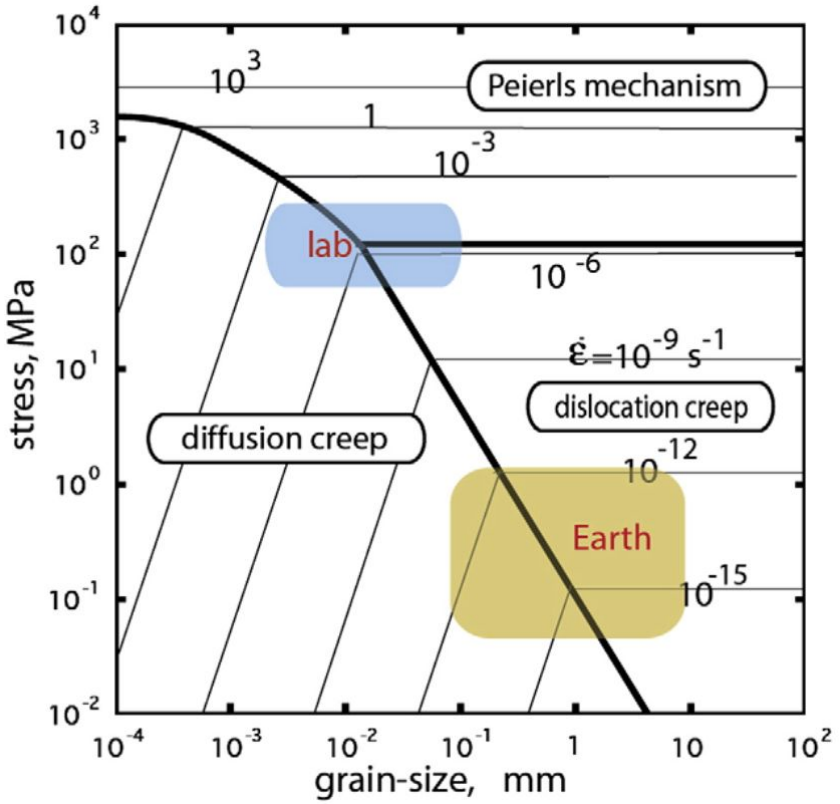
Earth mantle viscosity structures in GIA modelling



[Peltier et al., 2015; Lambeck et al., 2017]



[Paulson et al., 2005]

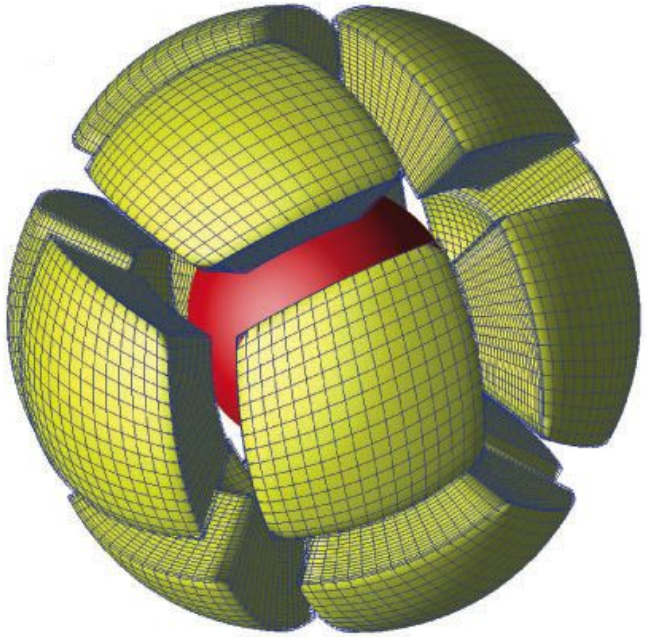


[Karato et al., 2010]

Numerical modeling

CitcomSVE: finite element modeling software package for geodynamics problem

- Open source software
- High computational efficiency with parallel technology
- 3D spherical earth model
- Fully 3D shear modulus and viscosity structure
- Maxwell, frictional sliding, low-temperature plasticity, and non-Newtonian rheology

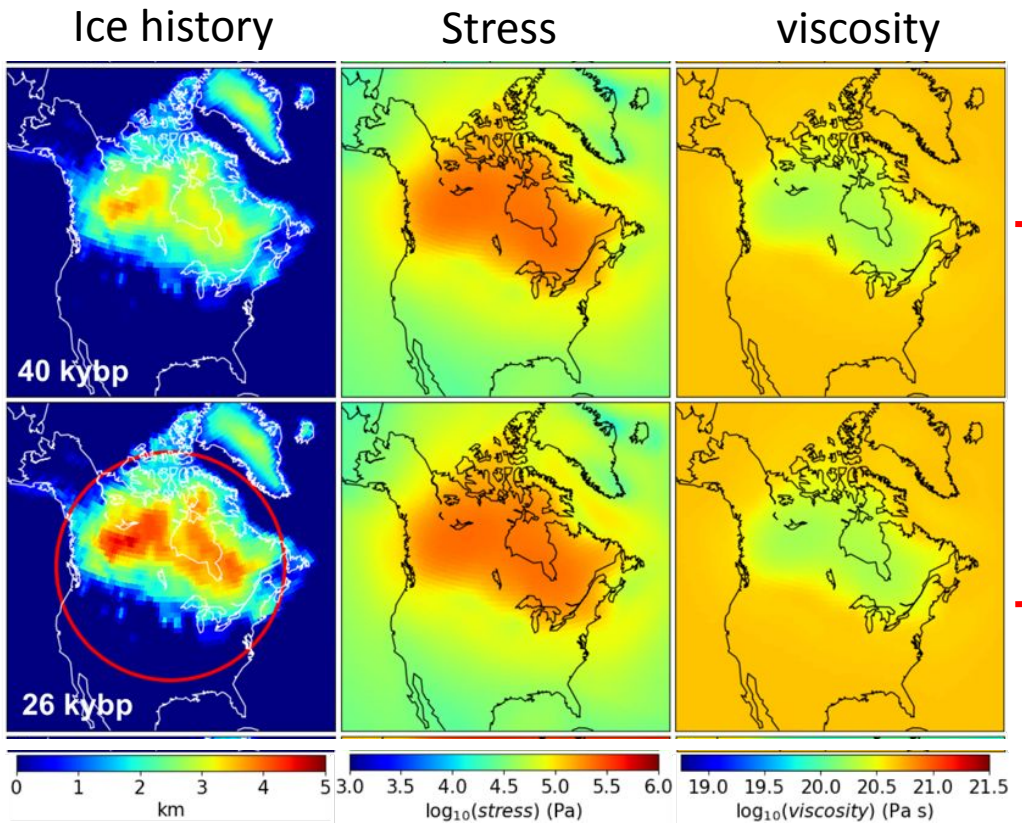


[Zhong, 2000, 2003, 2013, 2022]

Results

Upper mantle stress and viscosity evolution:

Glaciation period

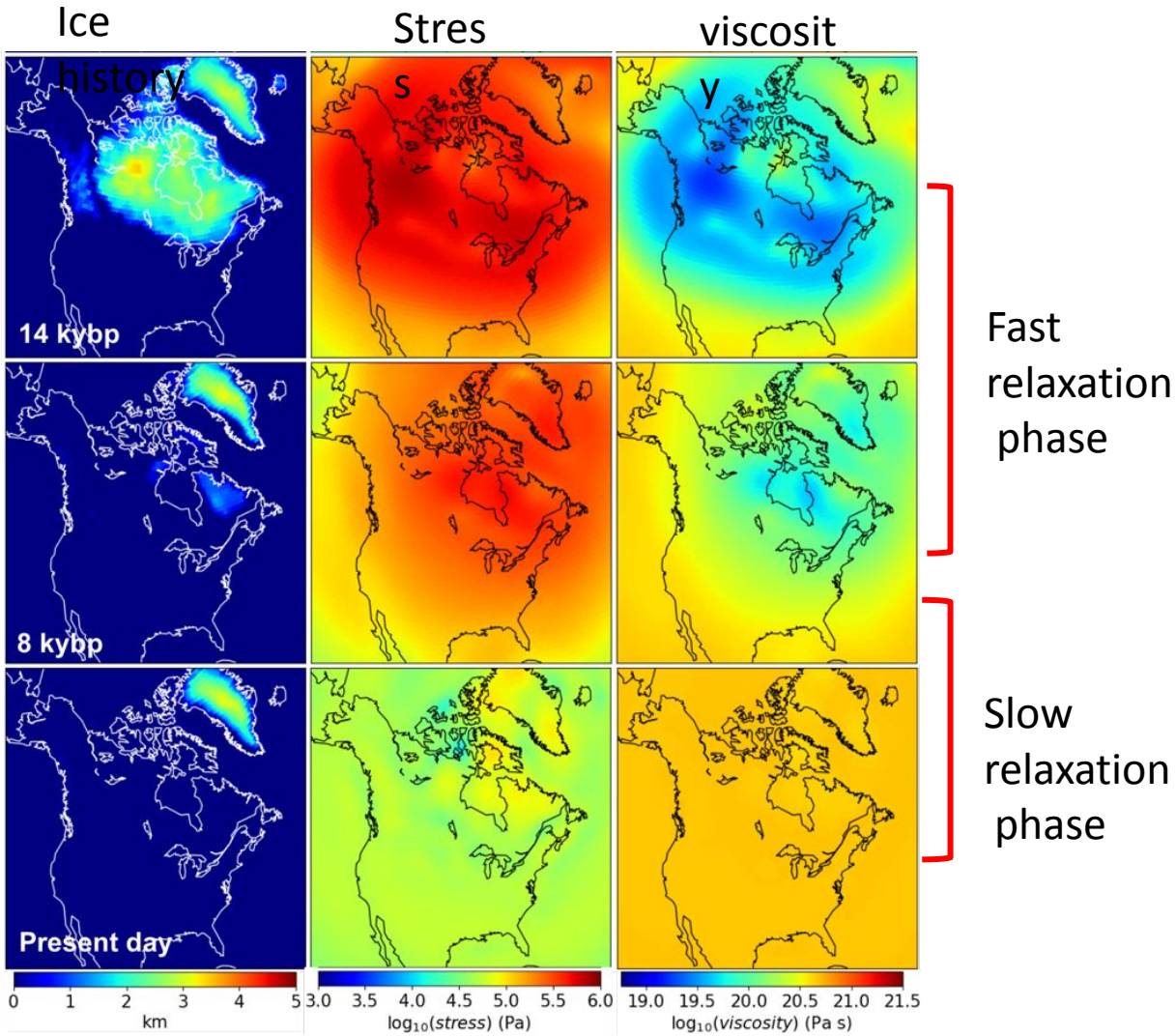


Stress level and spatial patterns are nearly unchanged

[Kang et al., 2022]

Results

Deglaciation period



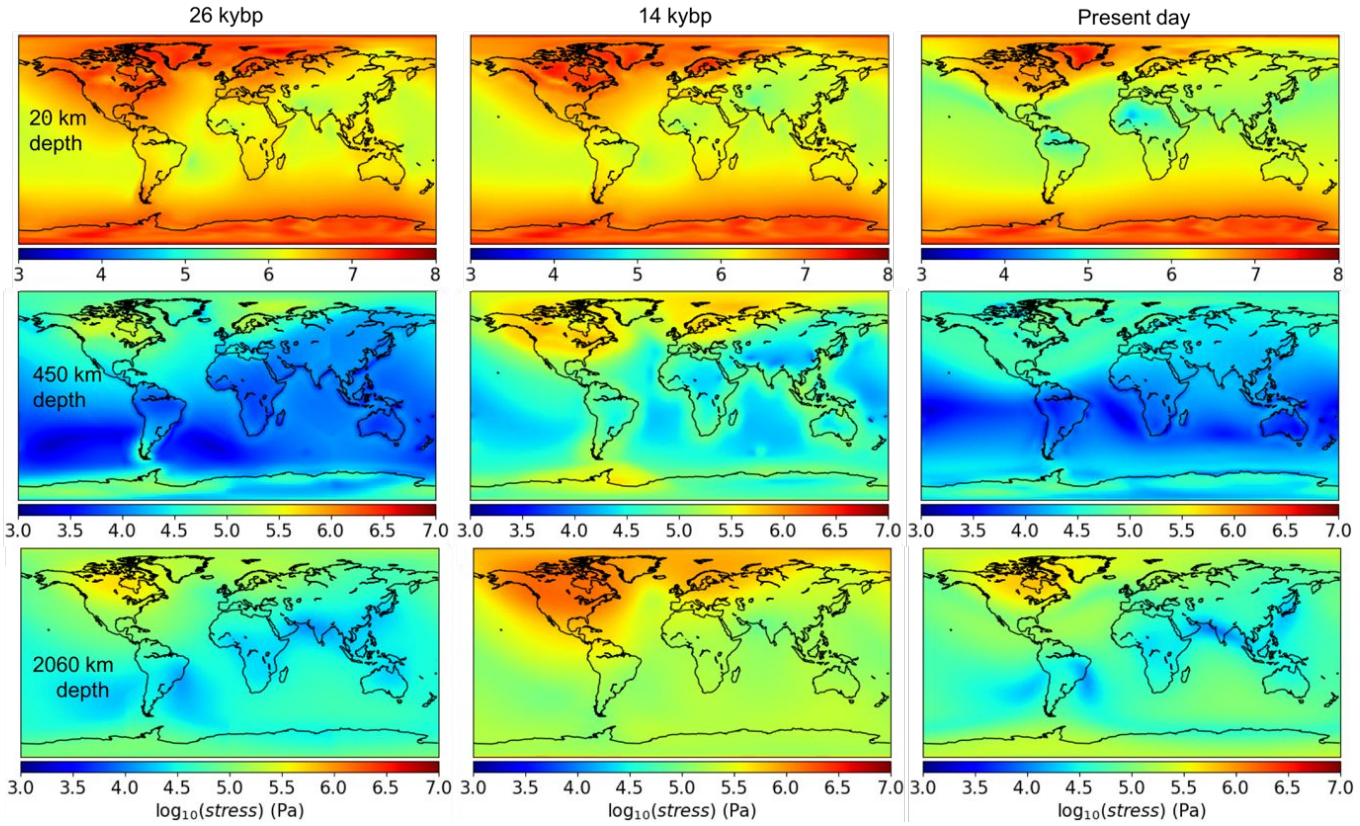
Fast relaxation phase

Slow relaxation phase

[Kang et al., 2022]

Results

Global distribution of the stress at different depth:

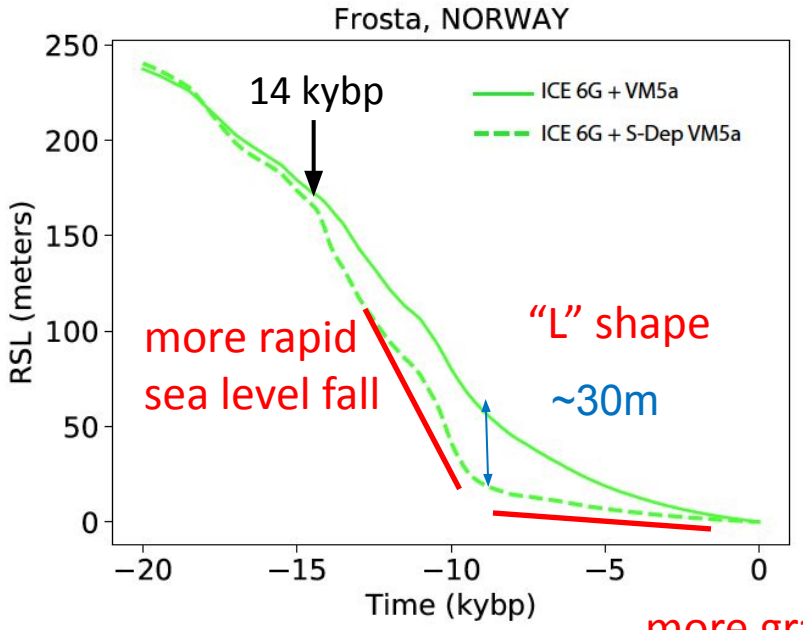


[Kang et al., 2022]

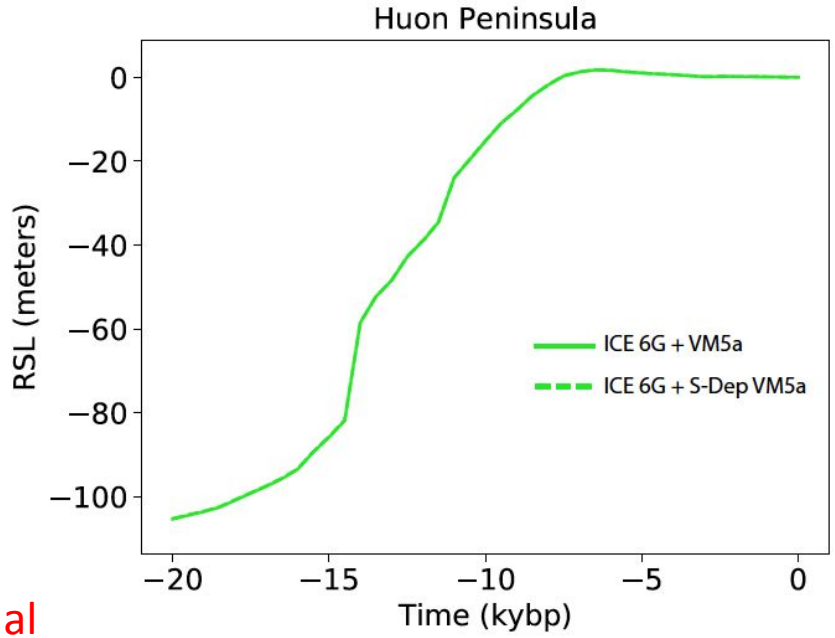
Results

Non-Newtonian effects on Relative Sea Level

Near field



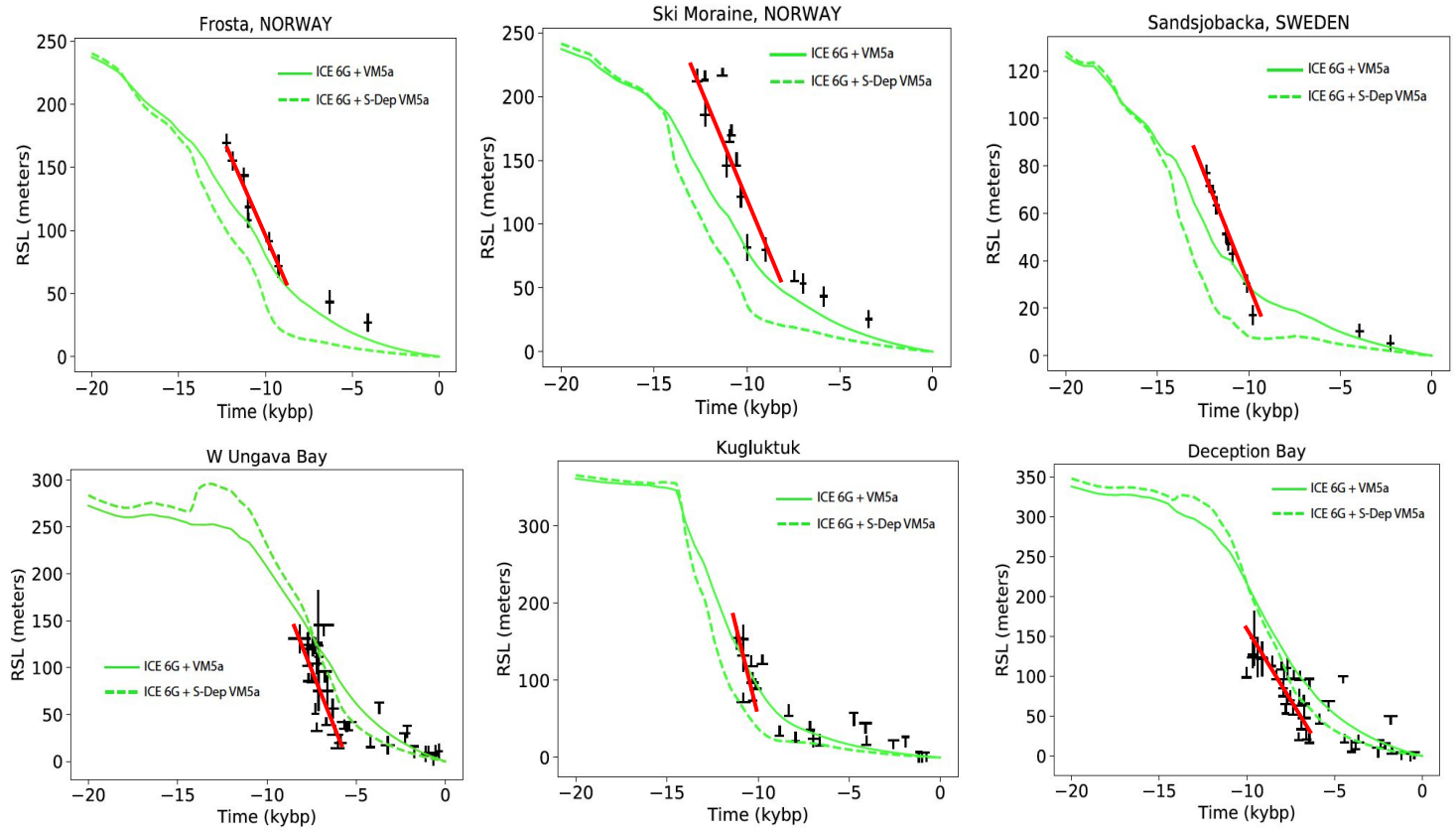
Far field



[Kang et al., 2022]

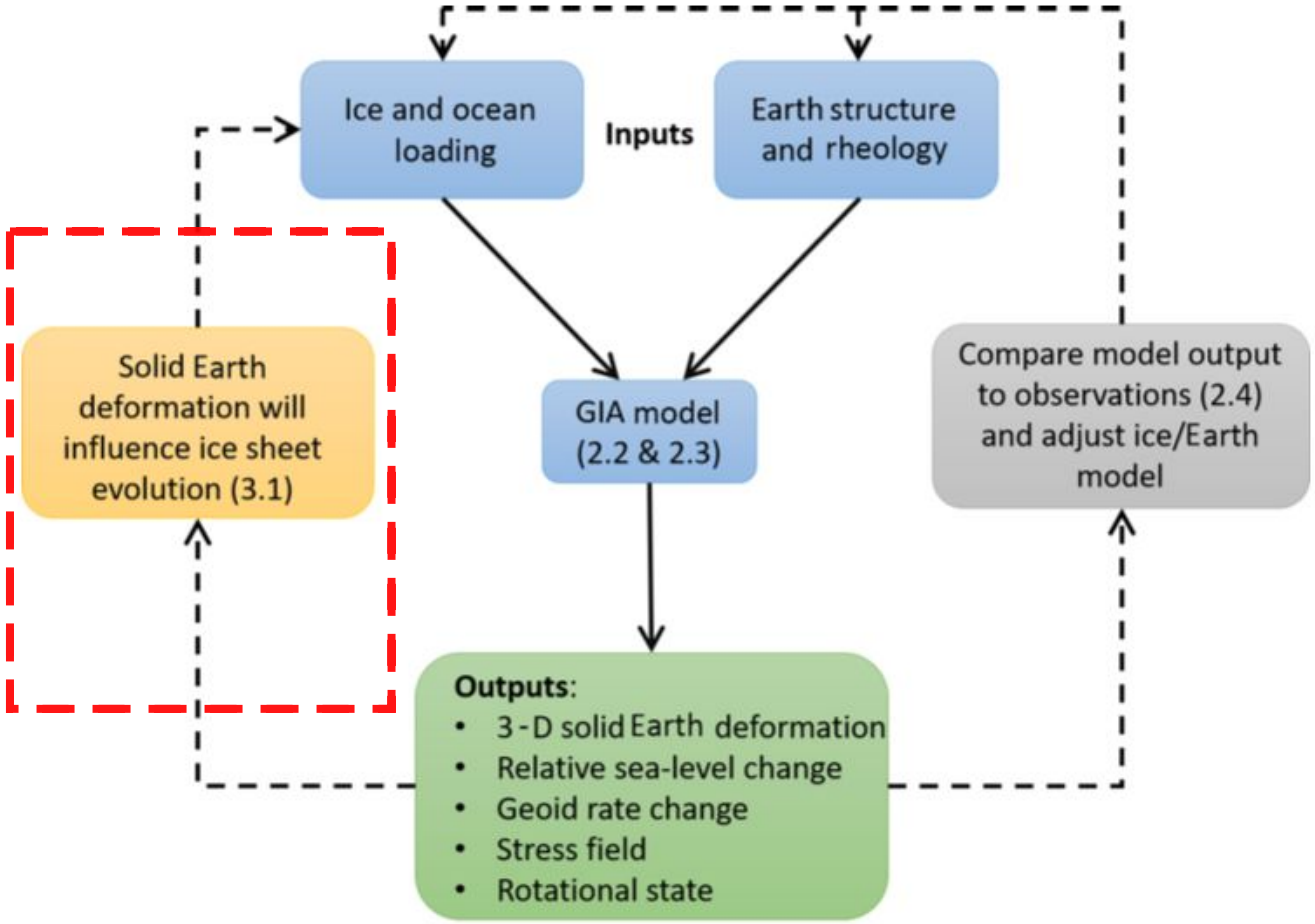
Results

Near-field sites: some observed RSL falls occur more rapidly than from Newtonian model



[Kang et al., 2022]

Future works



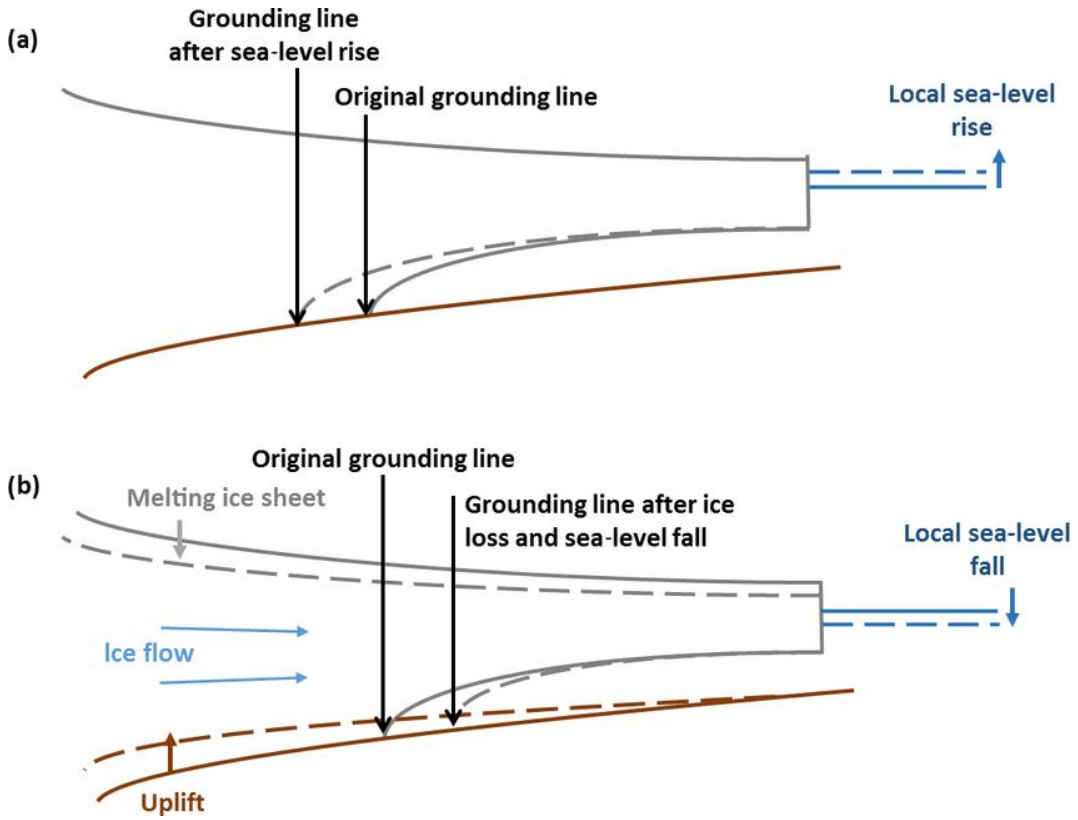
[Whitehouse, 2018]

Future works

GIA-ice dynamic feedback

Far-field ice melt

Near-field ice melt



[Whitehouse, 2018]

Future works

- GIA response with marine-grounded ice sheets (near-field sea level fall, grounding line migration, ice sheet instability, et al.)
- Coupled ice sheet – sea level model incorporating 3D Earth structure

Summary

- GIA related geophysical processes
- Numerical modelling for more complicated Earth structure (e.g., 3D viscosity and non-Newtonian rheology)
- GIA-ice dynamic feedback with incorporating 3D Earth structure