Challenges in near-field sea level predictions at secular scales
(and the need for coupled modelling of ice-ocean-solid earth interactions)

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2024 CESM Workshop

Overview

- Solid earth – ice – ocean coupling summary

- Greenland major outlet glaciers (post-LIA)
- Feedback over Hudson Bay (80 ka BP)
- The Cordillera Ice Sheet retreat & transient SE rheology (14-12 ka BP)

- Modelling implications

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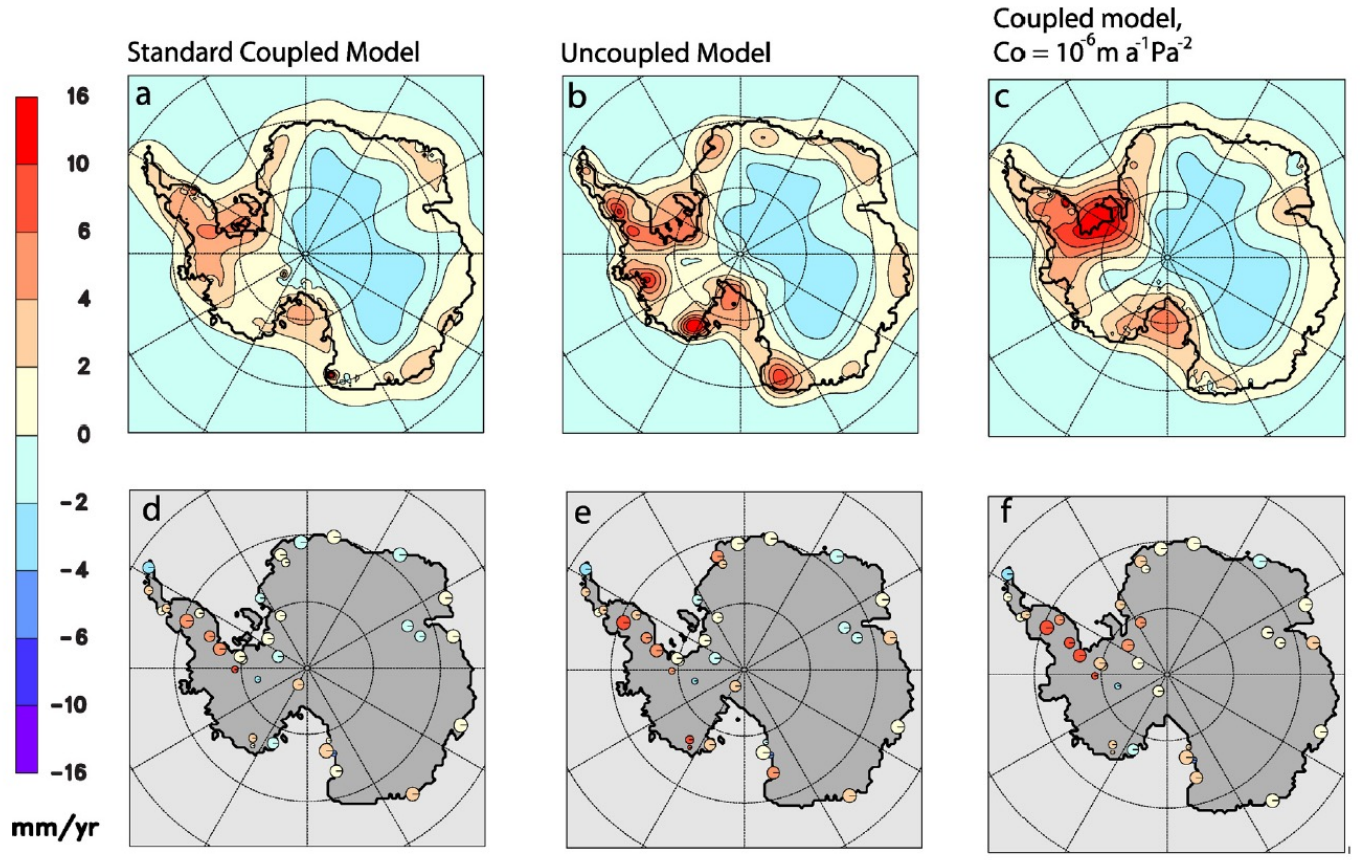
Ice sheet – ocean – solid earth coupling

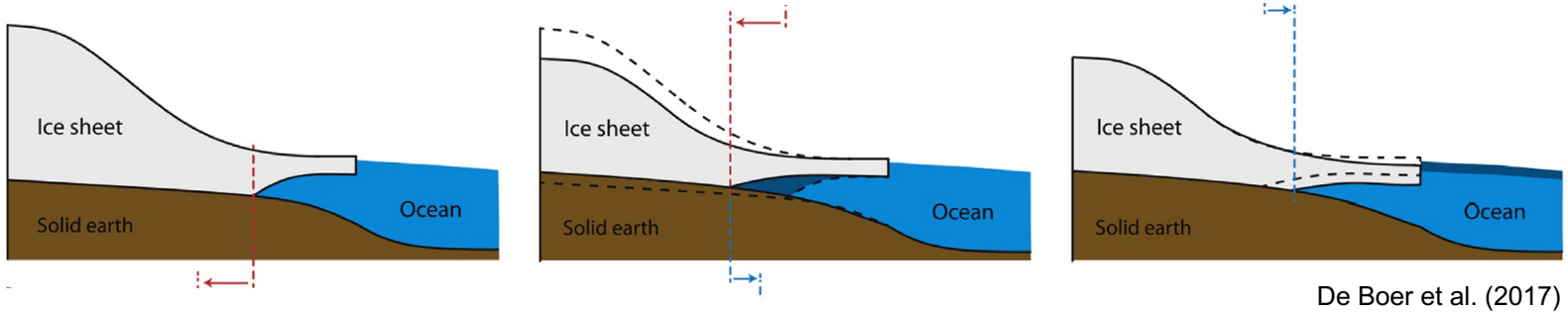
Solid Earth feedback mainly due to elevation changes (isostasy).

Isostatic response modelled locally (LLRA), regionally (ELRA) or globally (SVGE).

For marine ice sheets also important sea level feedback (elevation and gravity).



Gomez et al. (2013)



De Boer et al. (2017)

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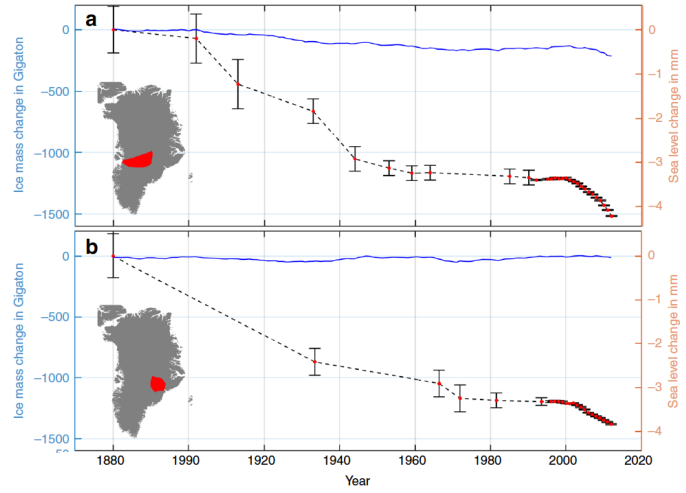
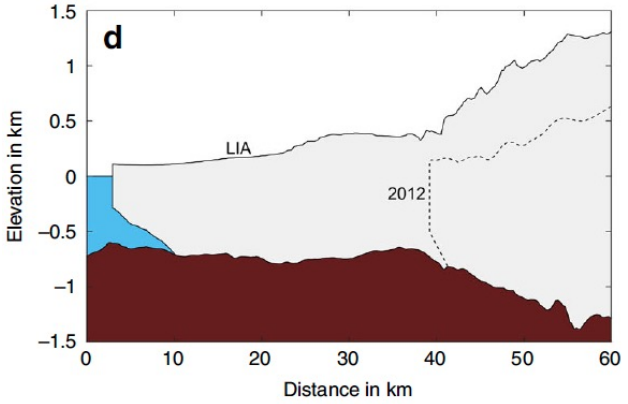
Post-LIA GrIS outlet glaciers

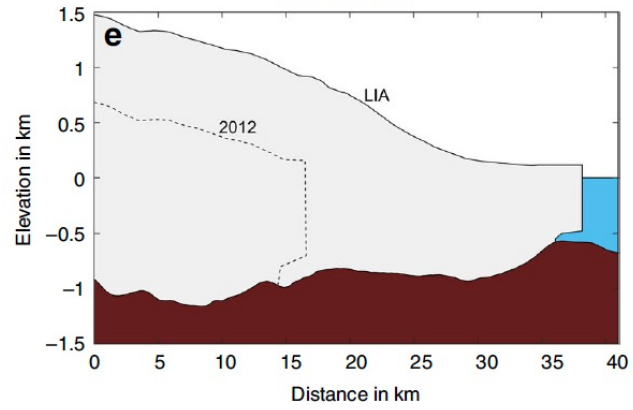
Khan et al. (2020)

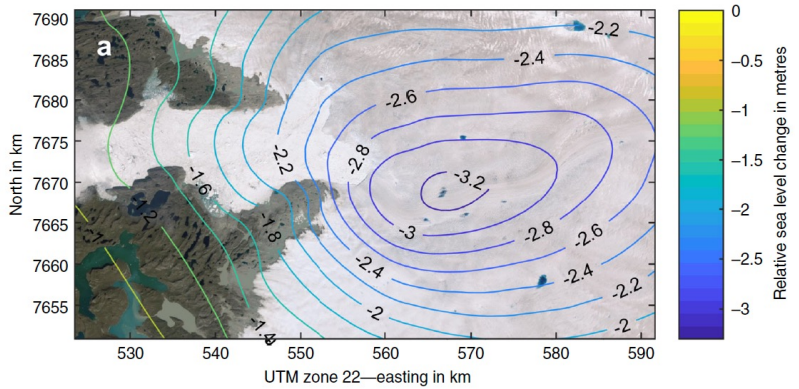
For Jakobshavn Isbræ (top) and Kangerlussuaq Glacier (bottom) large sea level drop close to the grounding line (2.8-4.8 m over 1880-2012, i.e., 21-36 mm/yr average).

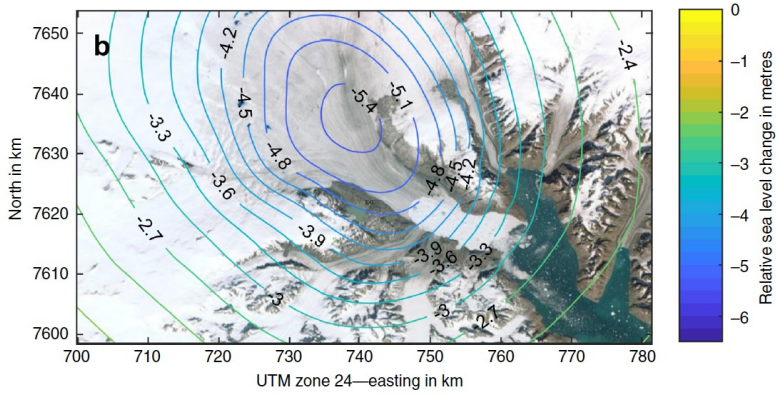
Probably limited effect on ice sheet stability (due to minor floating sections).









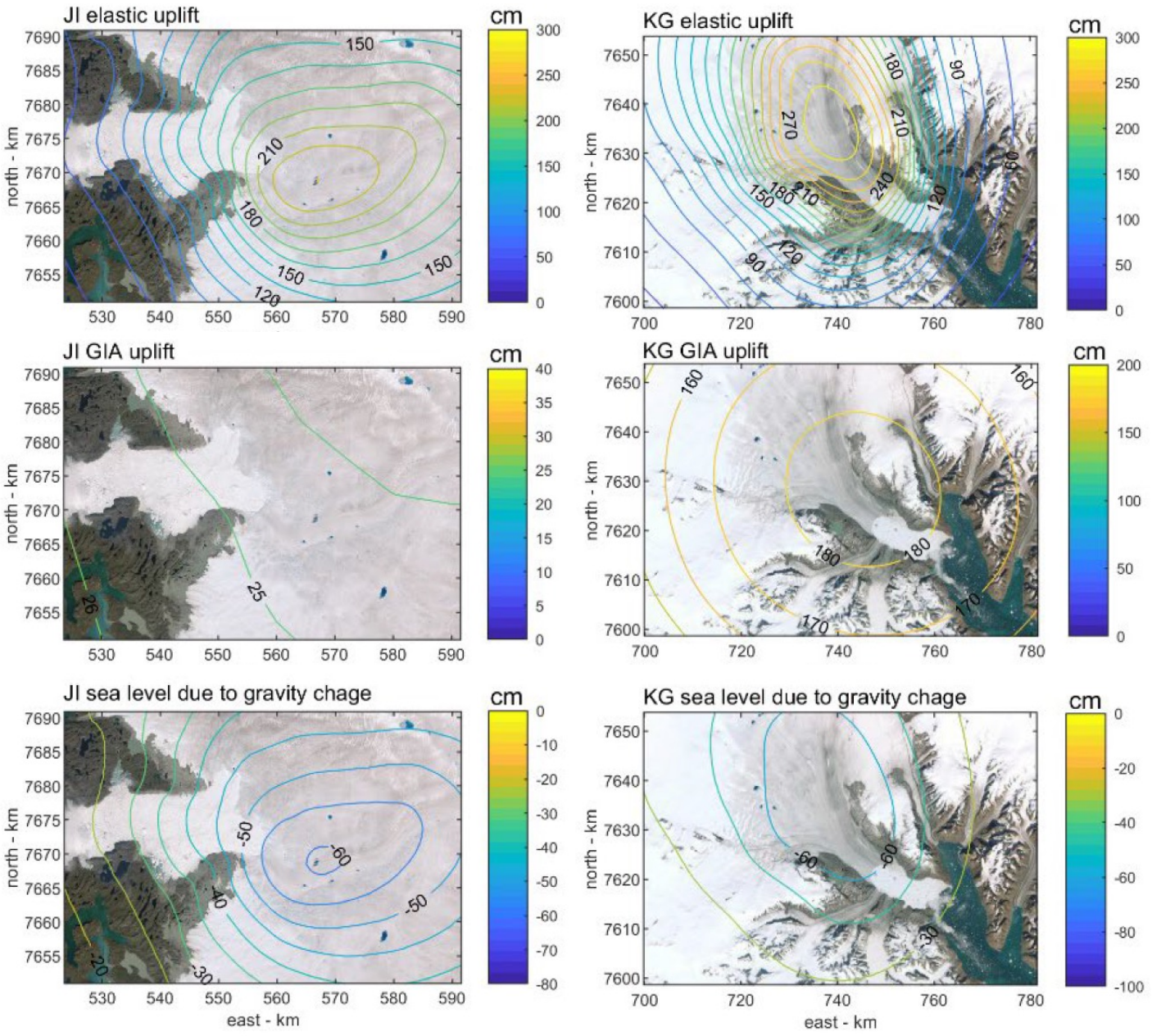


Post-LIA GrIS outlet glaciers

Khan et al. (2020) [cont'd]

Largest signal is elastic uplift.

For Kangerlussuaq Glacier, the viscoelastic (GIA) response is comparable to the elastic one, due to locally low viscosity.



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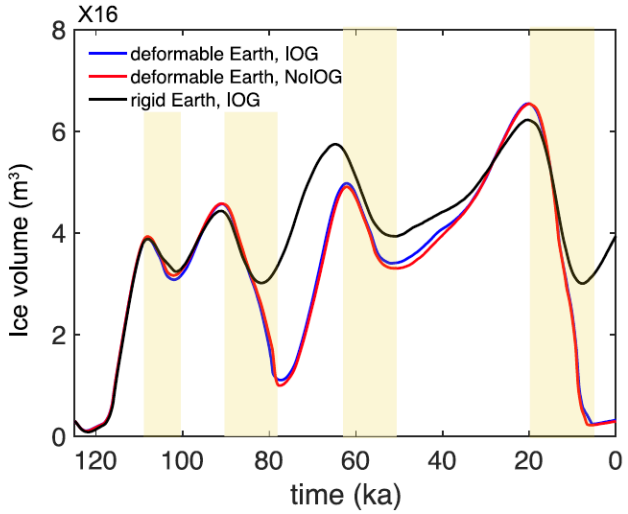
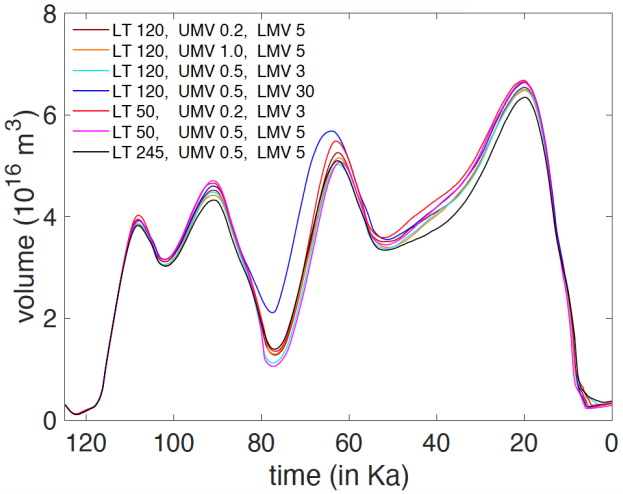
Sea-level feedback, the 80 ka Hudson Bay retreat case

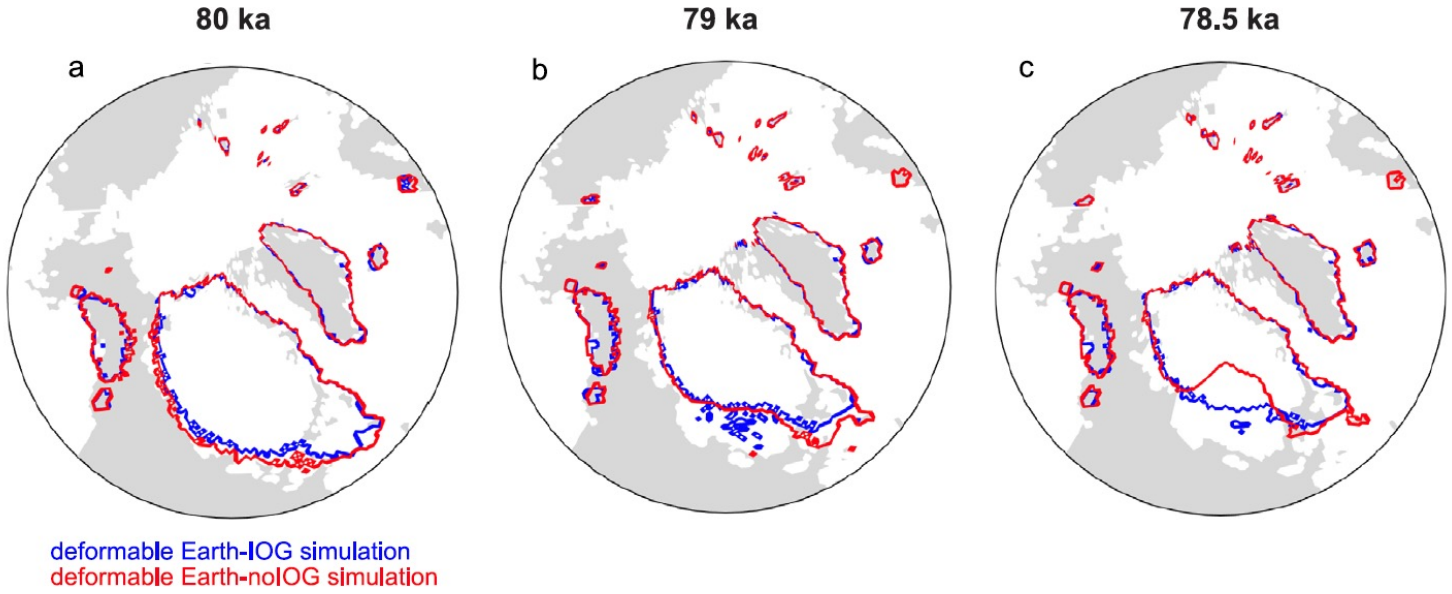
Han et al. (2021) on northern hemispheric ice sheets over the last glacial cycle.

For terrestrial regions, the elevation feedback due to isostatic rebound is positive during both growth and retreat.

Marine-based portions are stabilized by the sea level feedback.







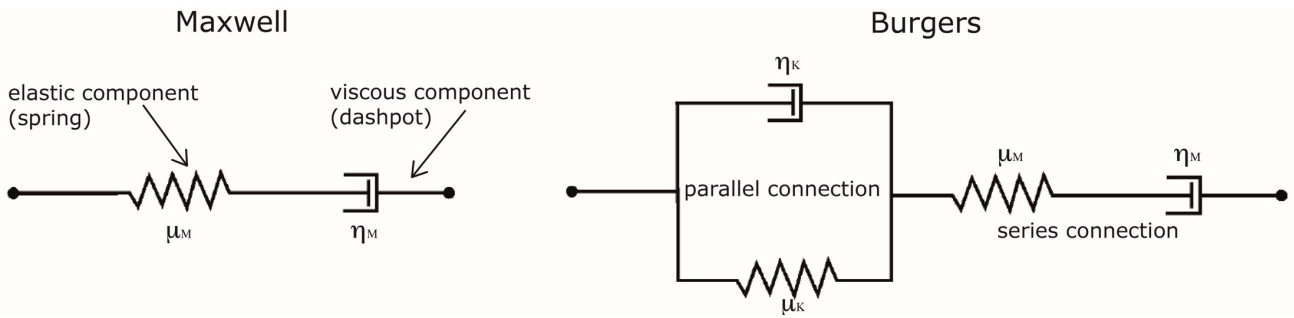
Uncertainties in the viscoelastic response of the solid earth

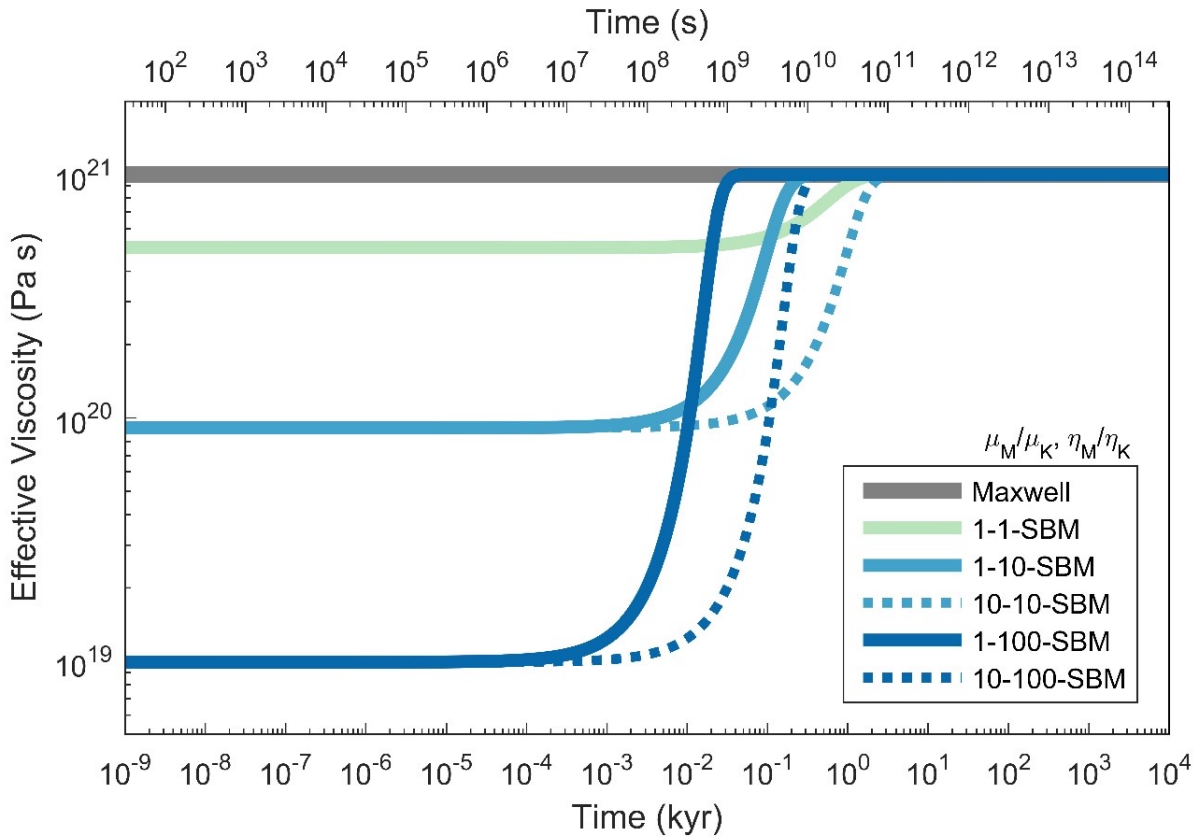
Several possible rheologies: linear, non-linear, transient.

Laboratory experiments tend to prefer non-linear rheologies, but extrapolation to natural conditions is challenging.

Evidence from earthquakes is not directly applicable to GIA (different scales).

Linear rheologies are still largely used in GIA modelling.





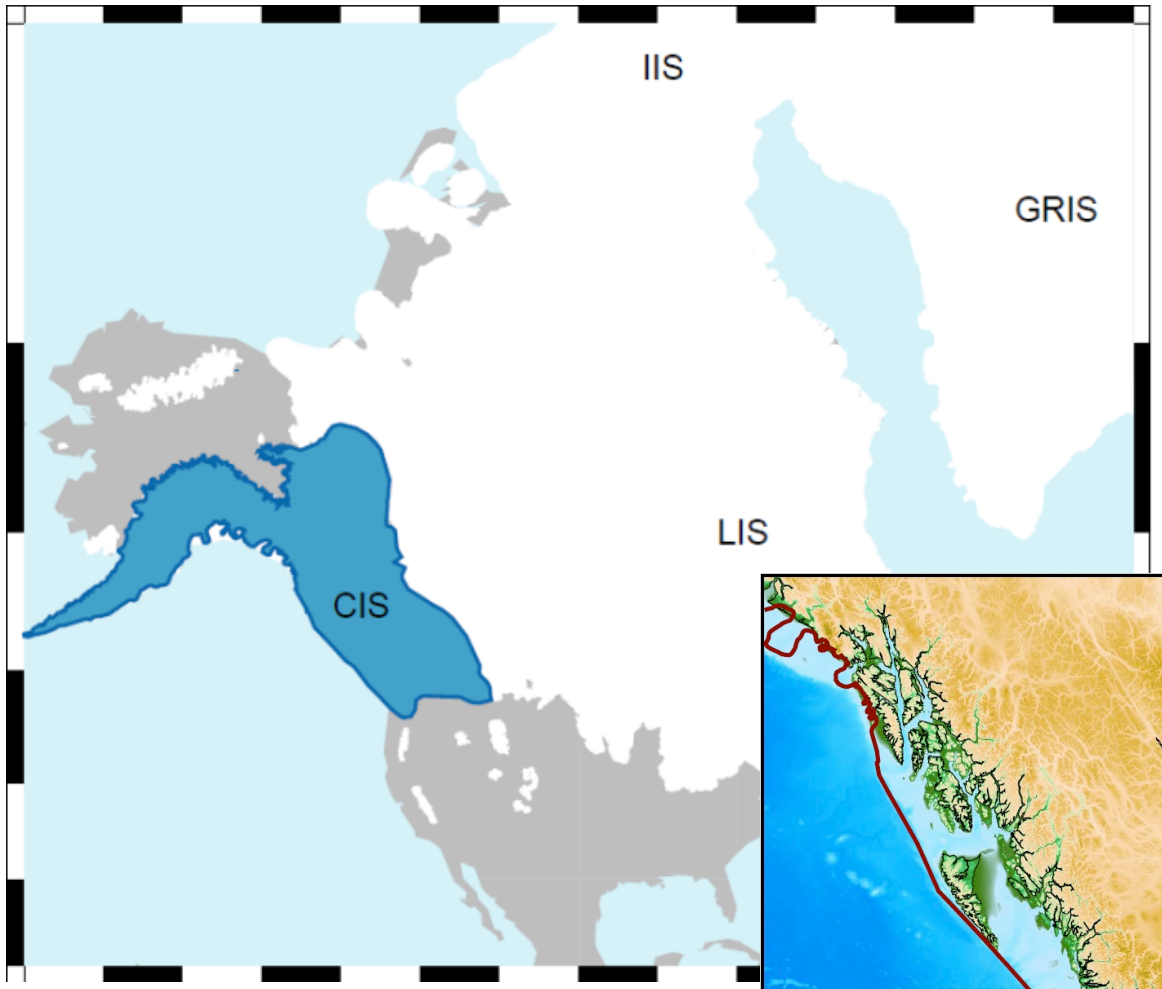
Evidence of transient GIA response

The Cordillera Ice Sheet rapidly retreated between 14-12 kyr BP (30% loss from LGM in 500 yr).

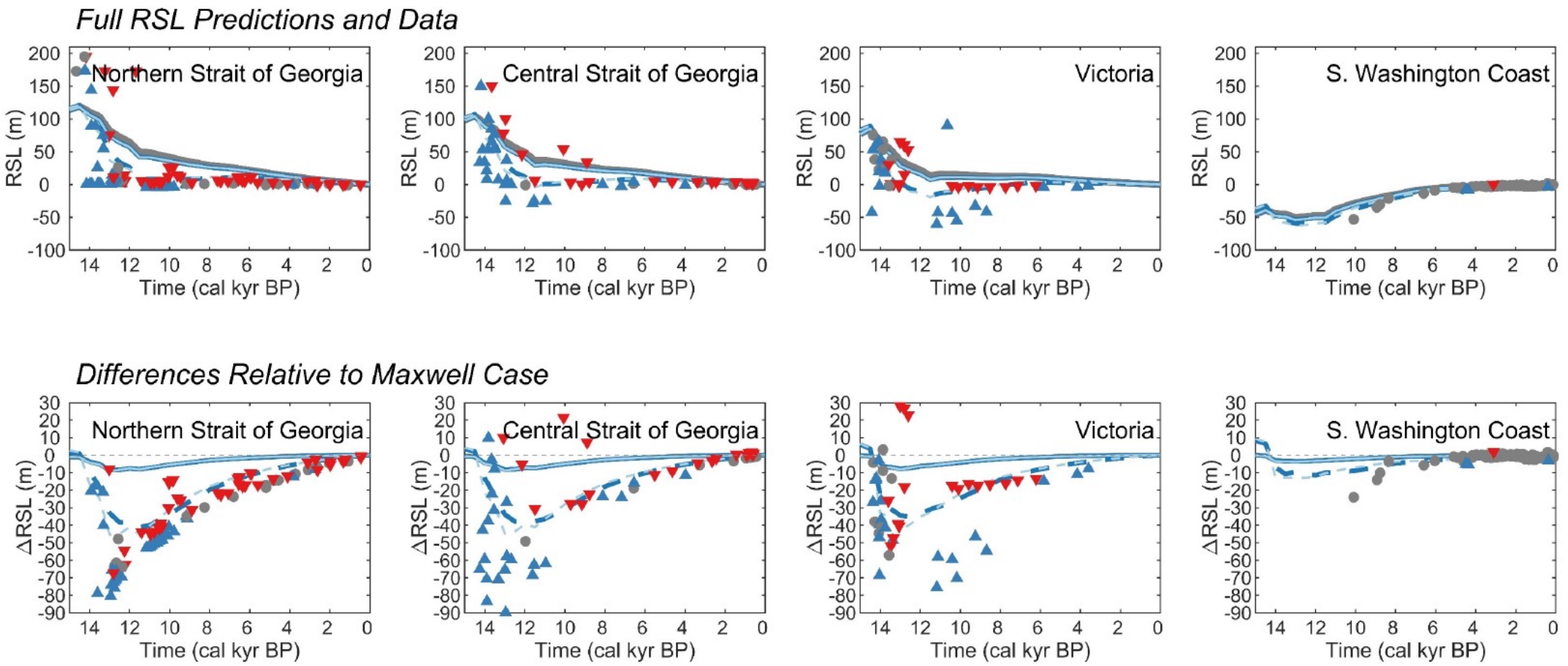
Along the SW LGM margin there are abundant palaeo sea level records of this change.

Assuming a transient rheology largely improves the model fit.

Results from Simon et al. (2022, JGR).



Transient response – global viscosity



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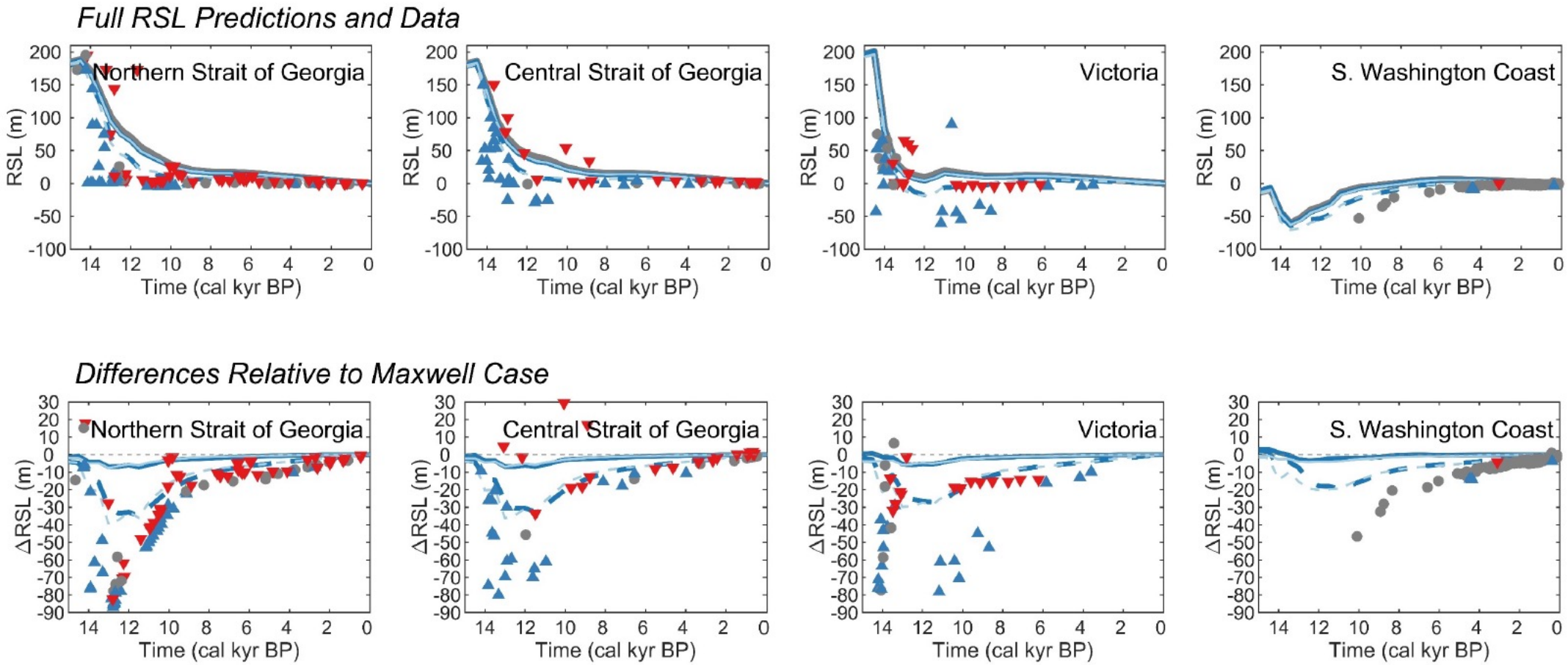
Transient response – subduction zone viscosity



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Modelling implications

- Near-field sea level records are highly sensitive to local solid earth rheology.
- An oversimplified parametrization of the solid earth response to ice and sea level changes might lead to unrealistic ice sheet reconstructions.
- Efforts in coupling ice sheet and ocean models should include the development of an adequate solid earth component.

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