Sensitivity of Coupled Solid Earth - Ice Sheet Modeling of Thwaites Glacier to Coupling Timescale and Earth Rheology

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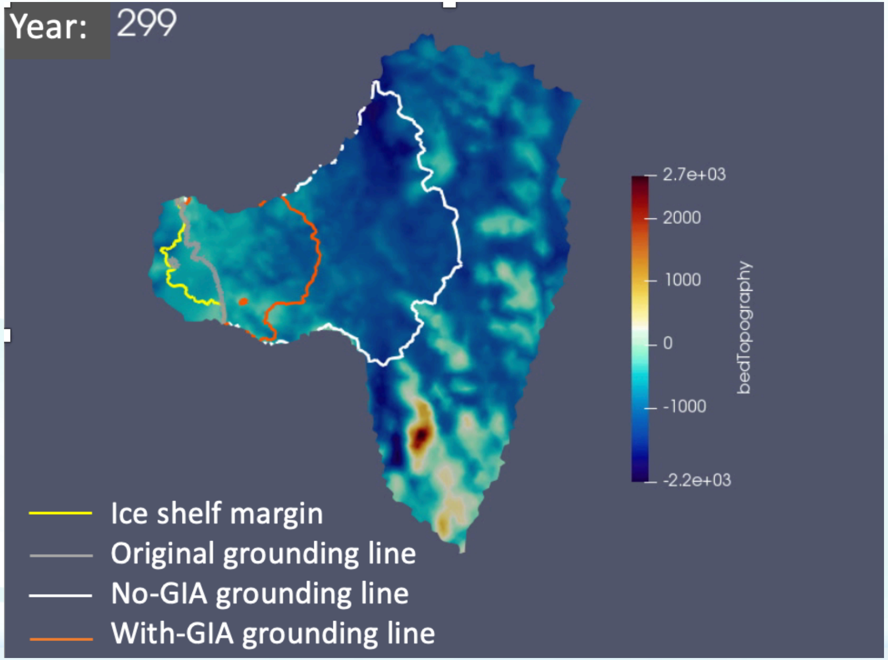
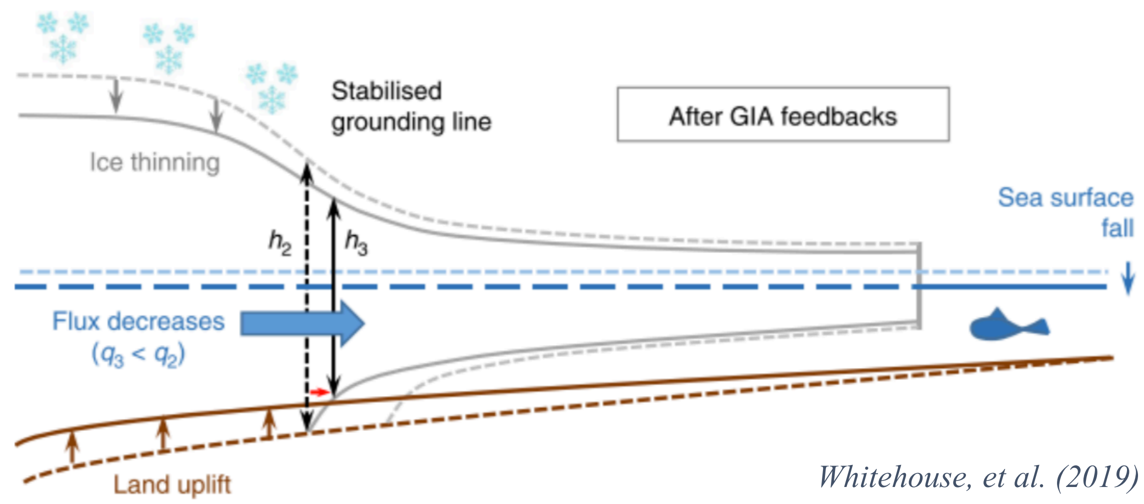


Glacial Isostatic Adjustment & Marine Ice Sheets

- Grounding line on reverse bed slope can be unstable due to flux/thinning positive feedback
- Bedrock uplift has potential to slow grounding line retreat and ice sheet mass loss
- Highly dependent on Earth rheology
  - Low viscosity mantles allow for quicker bedrock uplift

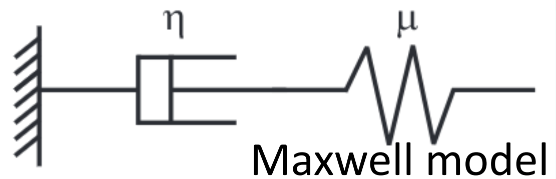


Whitehouse, et al. (2019)

The Earth as a Viscoelastic Solid

Maxwell viscoelastic material

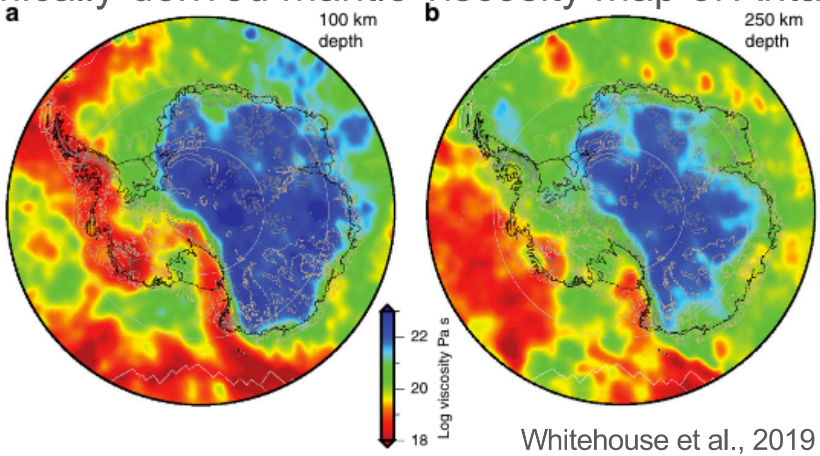
- Properties of both solid and fluid
- Immediate elastic response (modulus regulated)
- Gradual viscous response (viscosity regulated)



Maxwell time: $\frac{\eta}{\mu} \approx \frac{10^{21}\ \text{Pa s}}{10^{11}\ \text{Pa}} \approx 300$ years for Earth's mantle

- Amundsen Sea Sector of AIS overlays very low-viscosity mantle (~ 10^{18} - 10^{19} Pa s) compared to global average (~10^{21})
- Viscous response likely to be important on decadal timescales (Barletta, et al., 2018)

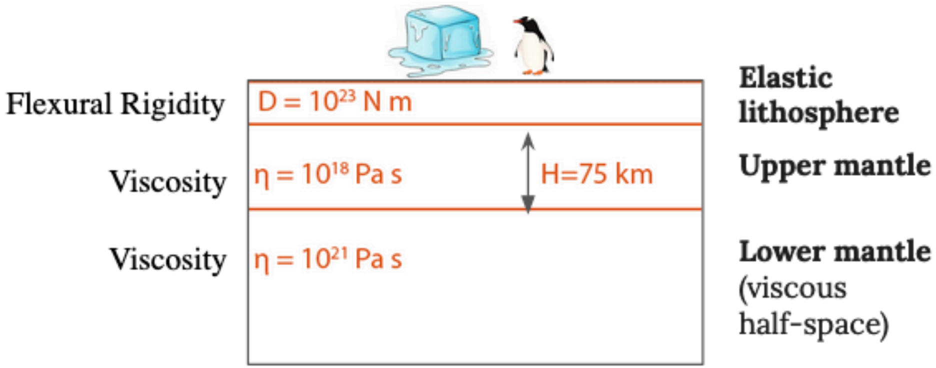
Seismically-derived mantle viscosity map of Antarctica



Whitehouse et al., 2019

Maxwell time: $\frac{\eta}{\mu} \approx \frac{10^{18}\ \text{Pa s}}{10^{11}\ \text{Pa}} \approx 3$ years for West Antarctica

GIA model



- Several simplifying assumptions:
  - Flat-Earth
  - No self-gravitation
  - No perturbations to rotational axis
  - No sea-level change

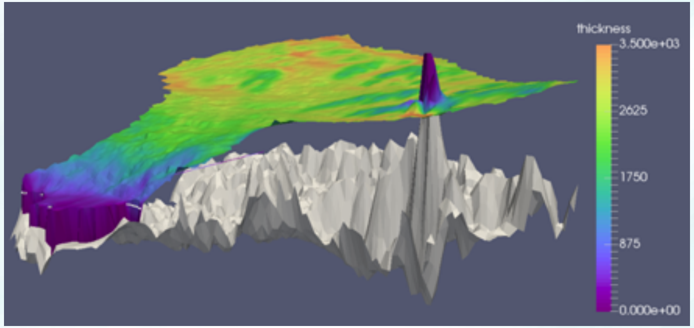
	LV1	LV2	LV-HR	TYP
UMV (Pa s)	1×10^{18}	1×10^{18}	1×10^{18}	1×10^{20}
LMV (Pa s)	1×10^{19}	1×10^{20}	1×10^{19}	1×10^{20}
D (N m)	4.94×10^{22}	4.94×10^{22}	4.50×10^{24}	4.94×10^{22}

Kachuck et al. (2020) *GRL*

Ice sheet model

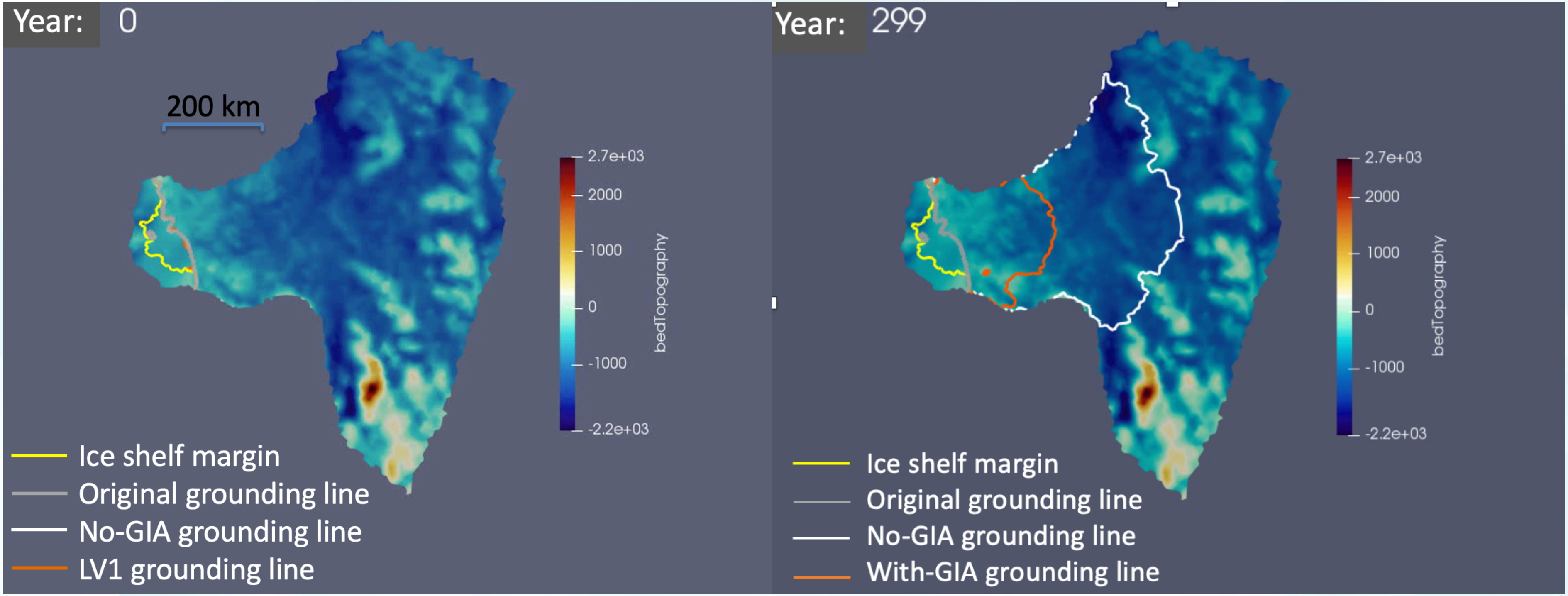
MPAS-Albany Land Ice (MALI) model

- Regional domain of Thwaites Glacier
- *4km mesh* (preliminary results)
- *Linear basal friction law*
- *Fixed temperature field*
- *Fixed calving front*
- *Present day SMB from RACMO2*
- *Parameterized ice shelf melting*



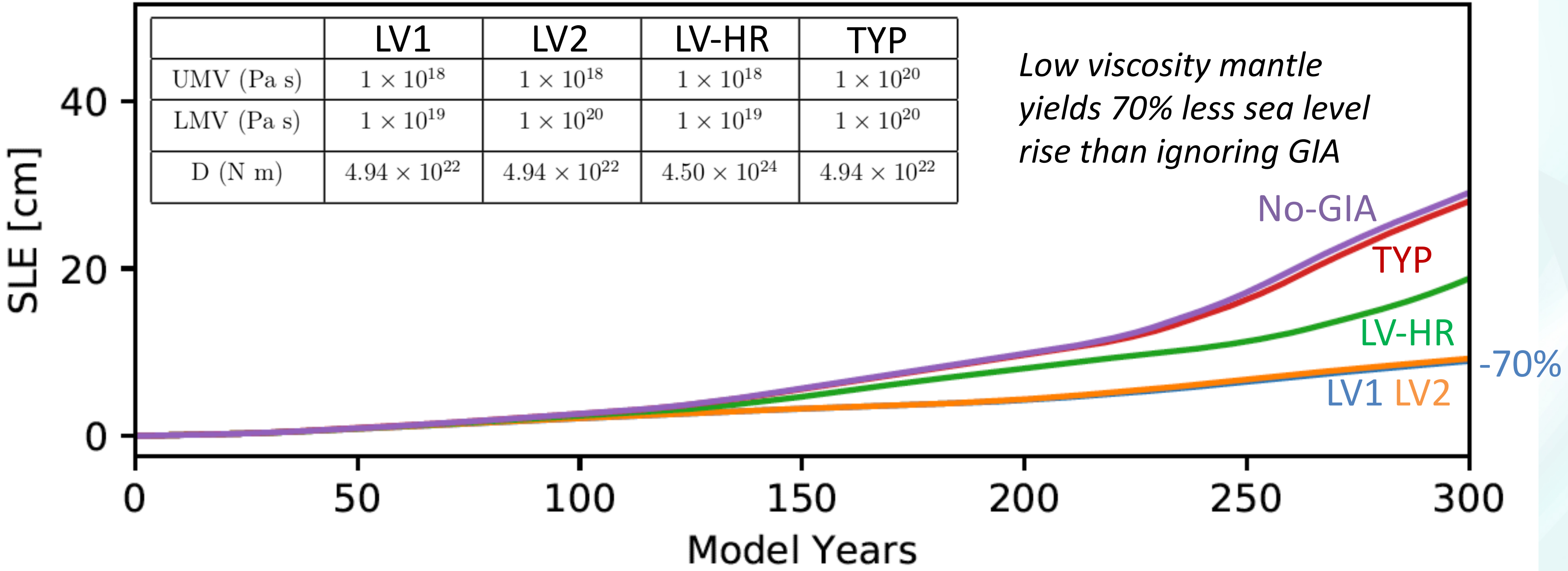
Hoffman et al. (2018) *GMD*
Hoffman et al. (2019) *JGR*

GIA reduces grounding line retreat

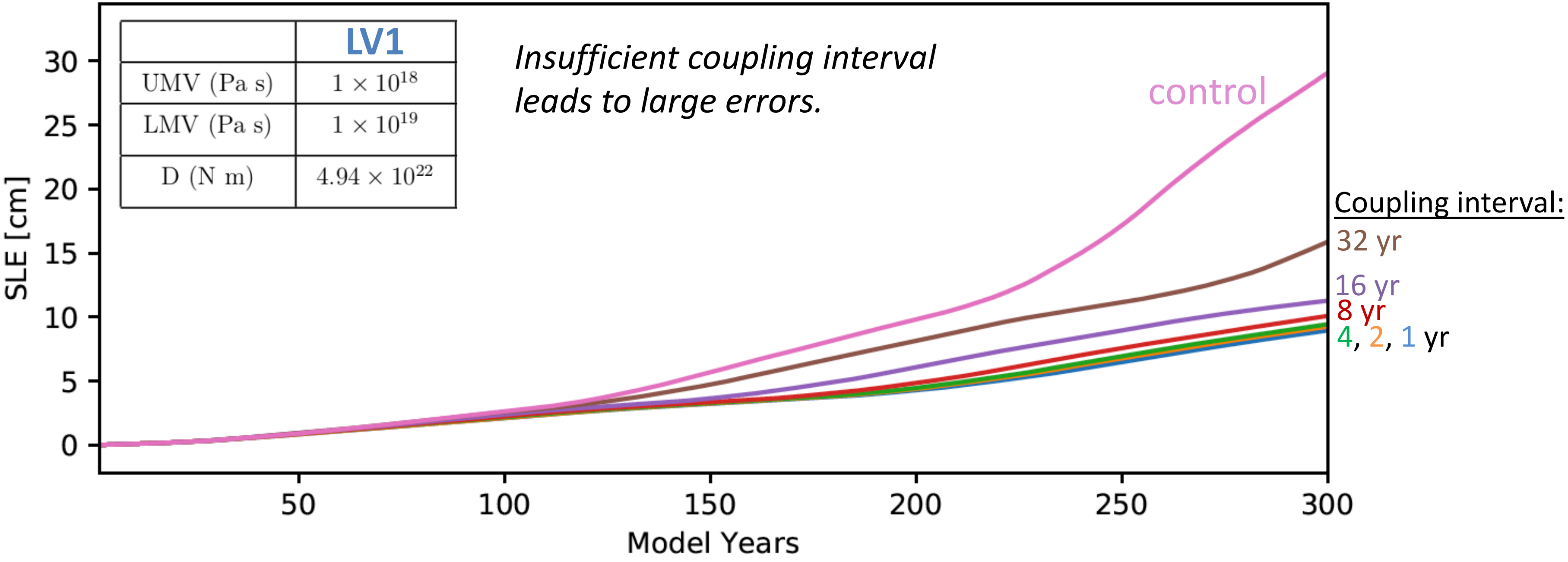


SLR sensitivity to rheology

	LV1	LV2	LV-HR	TYP
UMV (Pa s)	1×10^{18}	1×10^{18}	1×10^{18}	1×10^{20}
LMV (Pa s)	1×10^{19}	1×10^{20}	1×10^{19}	1×10^{20}
D (N m)	4.94×10^{22}	4.94×10^{22}	4.50×10^{24}	4.94×10^{22}

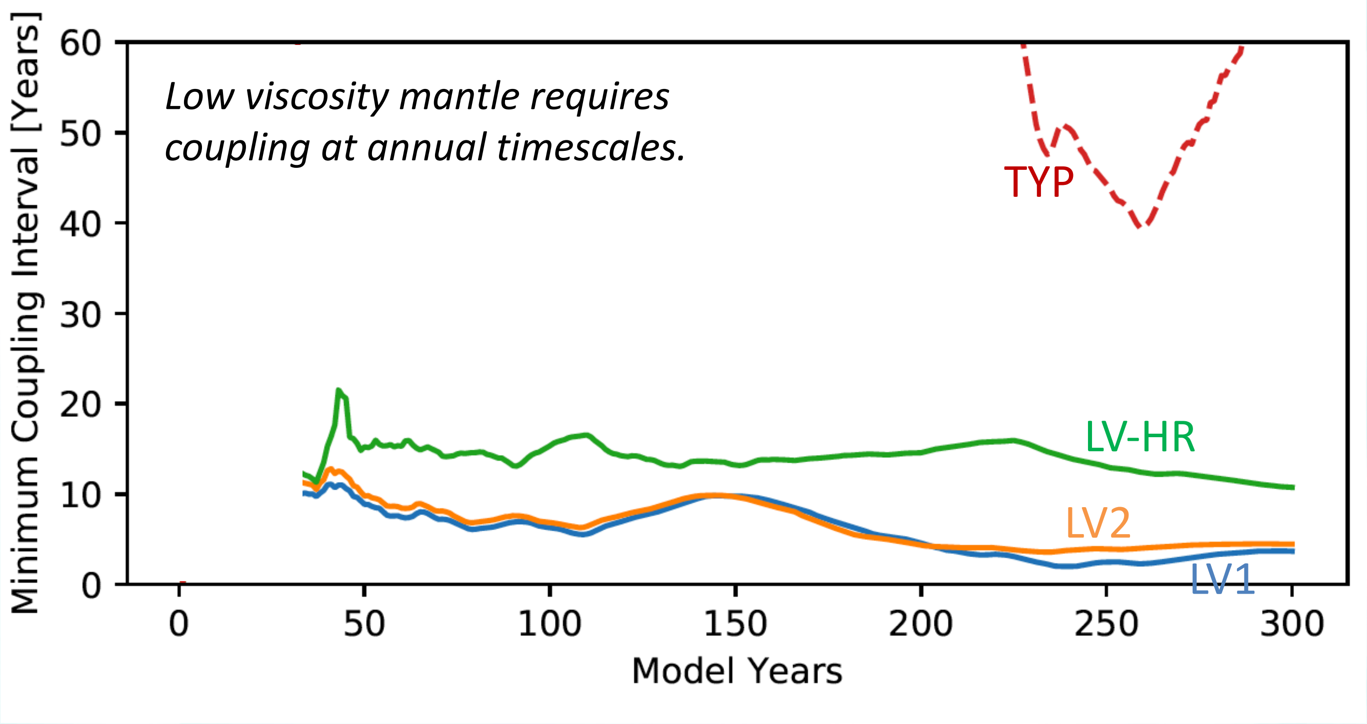


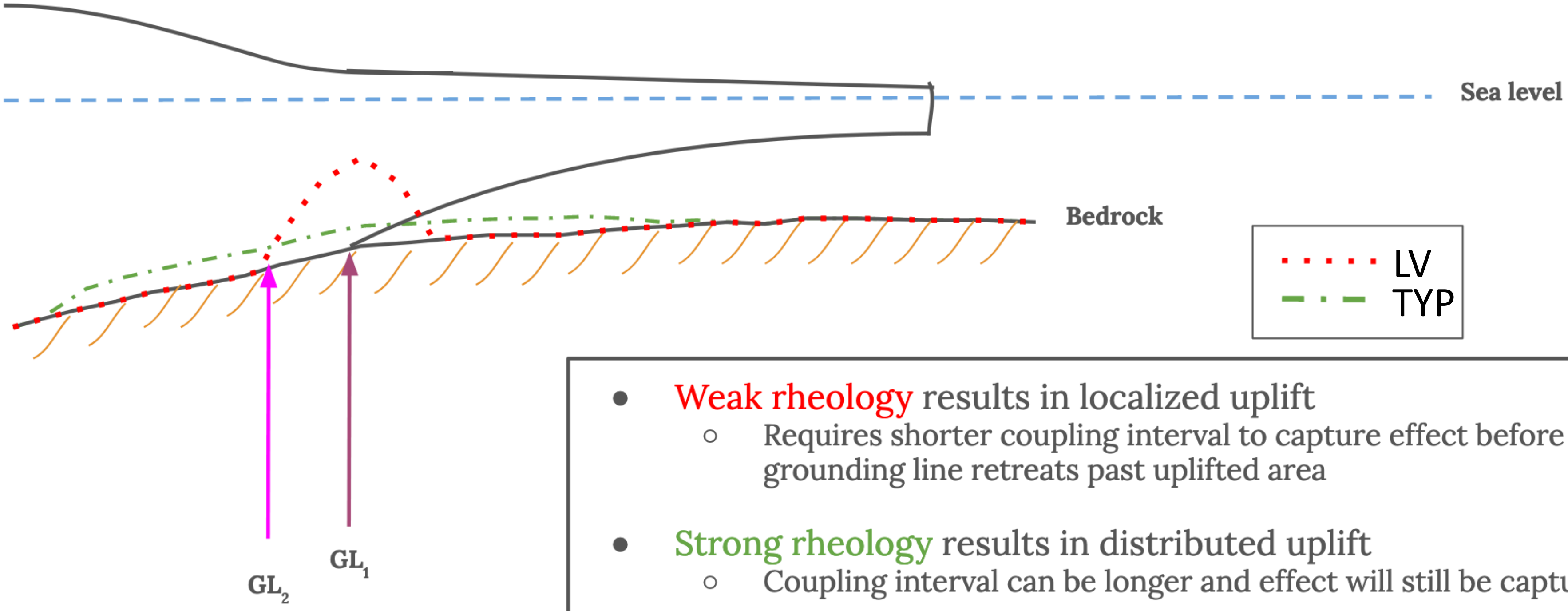
SLR sensitivity to coupling interval between GIA and ice sheet models



Minimum coupling interval:

Defined to be coupling interval that permits <5% error in cumulative glacier mass loss relative to coupling every 1 year.





- Weak rheology results in localized uplift
  - Requires shorter coupling interval to capture effect before grounding line retreats past uplifted area
- Strong rheology results in distributed uplift
  - Coupling interval can be longer and effect will still be captured

Conclusions

- GIA can slow retreat of Thwaites Glacier at decadal-centennial timescales
- This high sensitivity is due to anomalously low mantle viscosity
- Feedbacks between GIA and marine ice-sheet mass loss occur at timescales of less than a decade when mantle viscosity is low
  - Coupling timescale not constant in time – function of bed topography and GL retreat rate
- Insufficient coupling frequency can lead to very large errors in sea level rise contribution