Rapid viscoelastic deformation slows marine ice sheet instability at Pine Island Glacier

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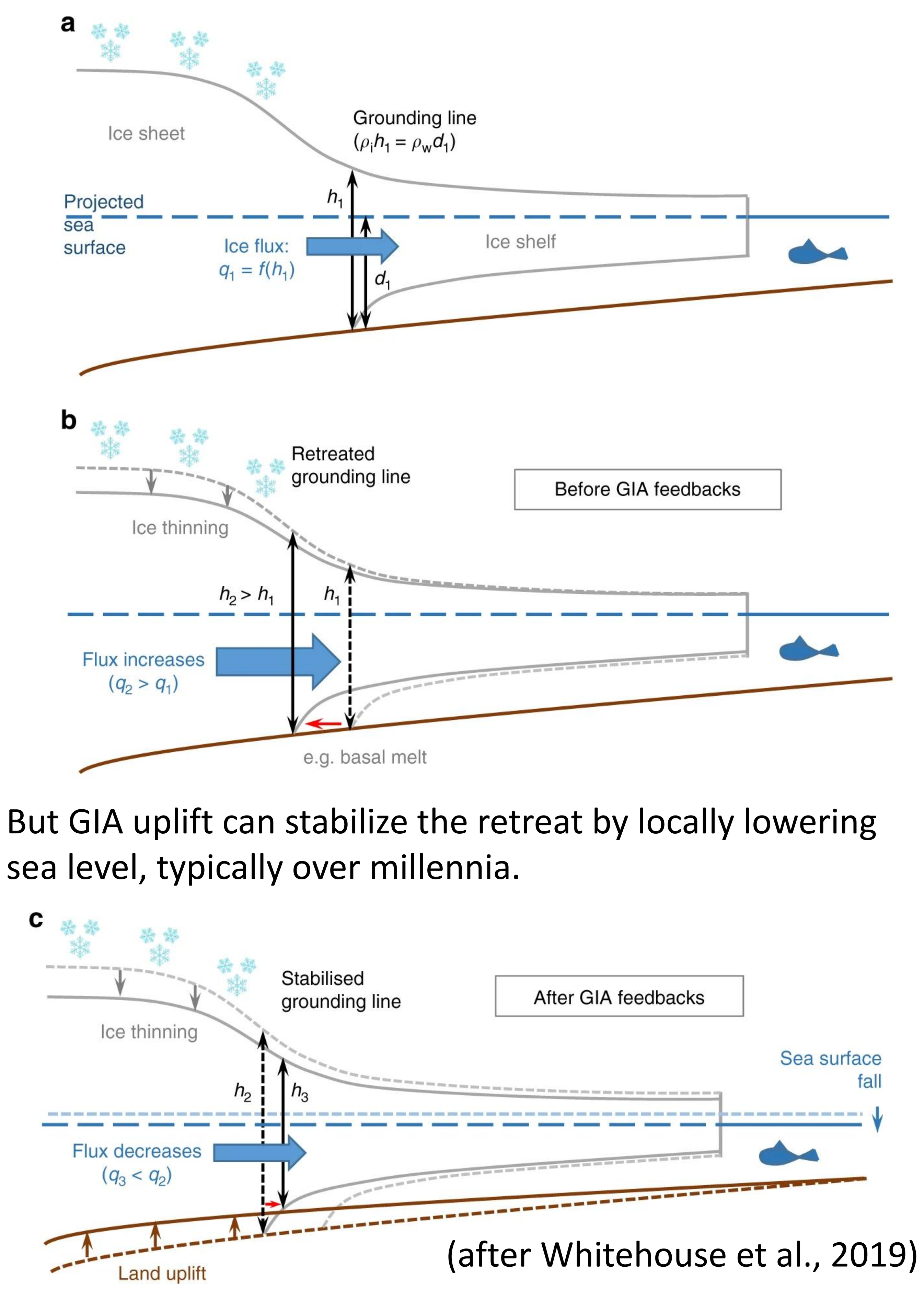
To what extent does rapid viscoelastic Glacial Isostatic Adjustment (GIA) affect grounding line retreat of a vulnerable marine ice sheet, like Pine Island Glacier?

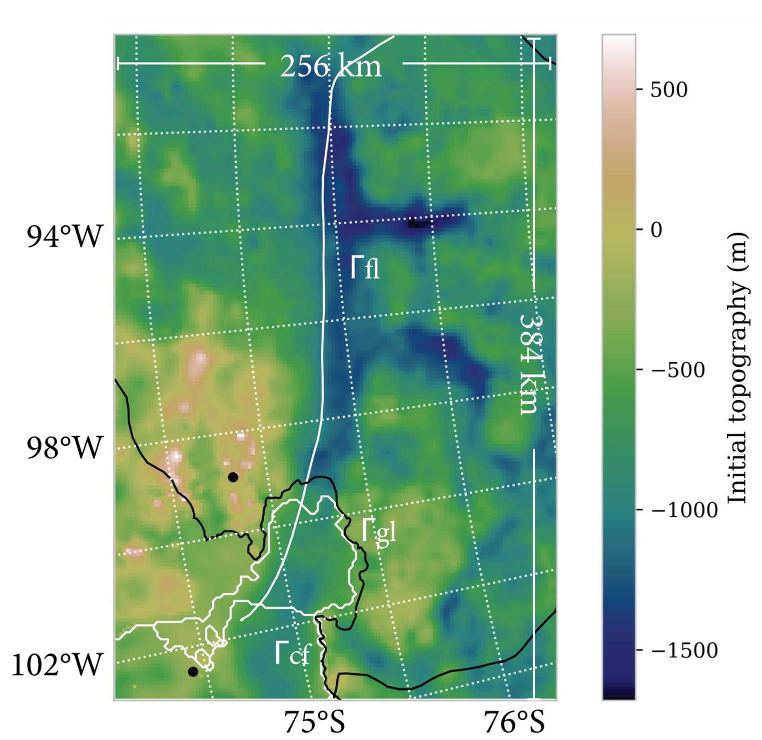
Marine ice sheets on retrograde slopes are vulnerable to an instability because the flow of ice across the grounding line is proportional to its thickness.



But GIA uplift can stabilize the retreat by locally lowering sea level, typically over millennia.

(after Whitehouse et al., 2019)

Pine Island Glacier, in the West Antarctic Rift Zone, has a retrograde bed (right) and is underlain by **low viscosity, rapidly responding, mantle** (e.g., Barletta et al., 2018).



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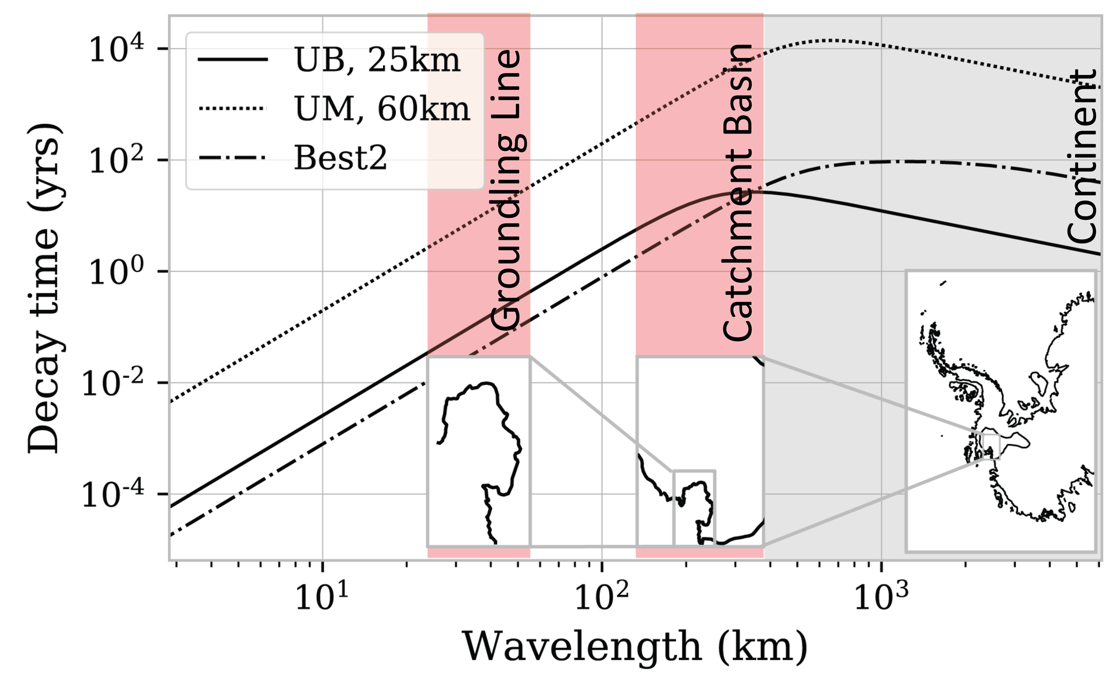
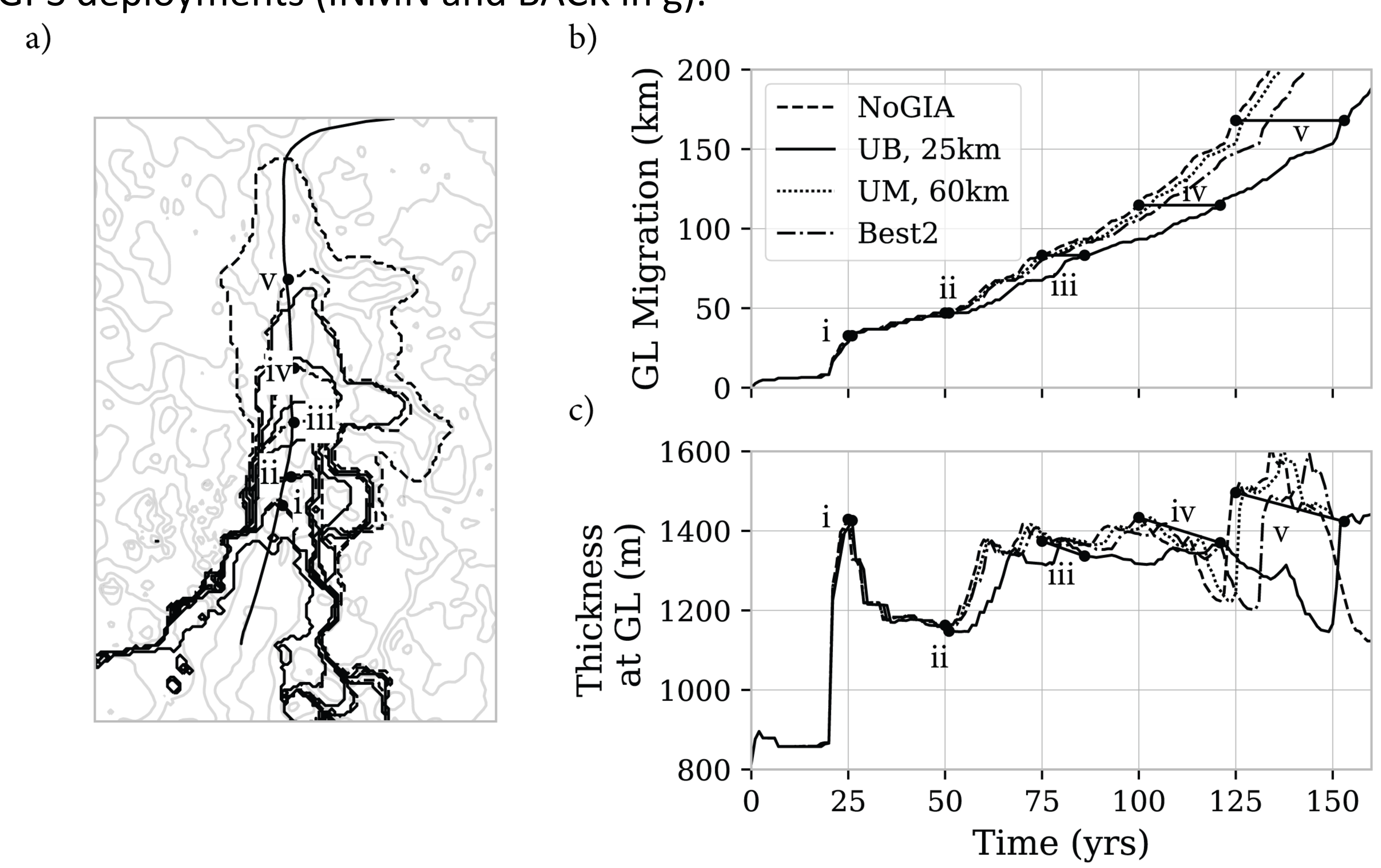
Uplift of the grounding line is rapid and localized for low viscosity mantle.

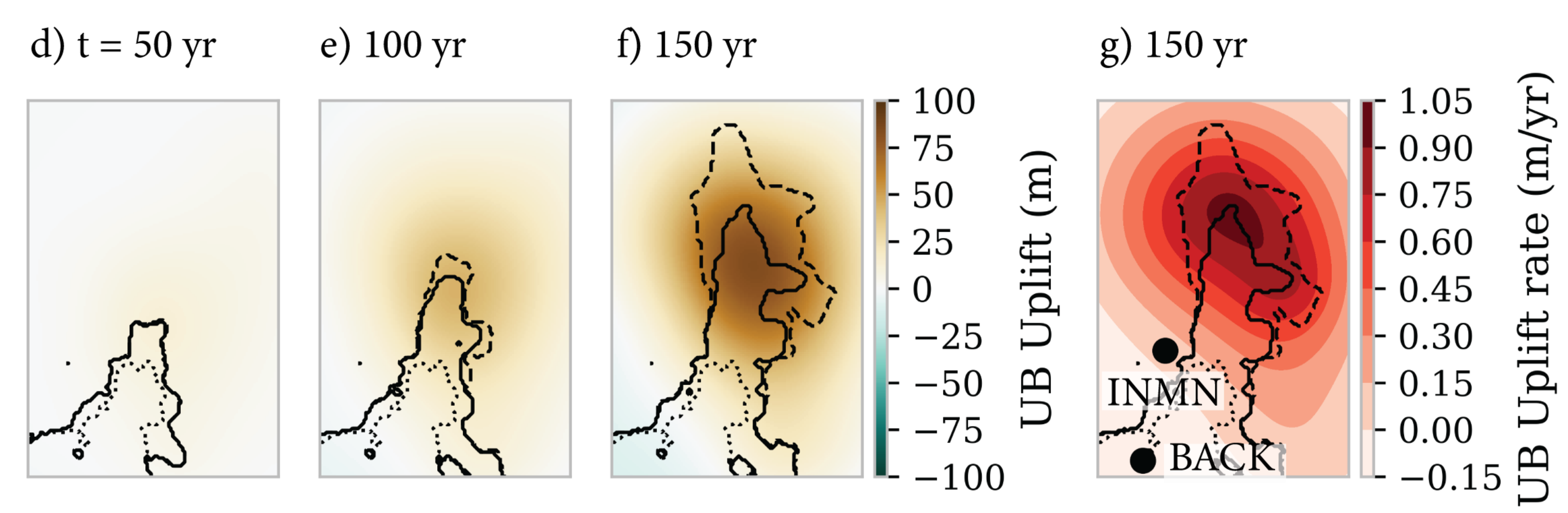
We couple the BISICLES ice flow model at Pine Island with a spectral, time-domain, flat-earth GIA model (Bueler et al., 2007). This captures local viscoelastic behavior as an exponentially decaying uplift with viscosity-, lithospheric-, and wavelength-dependent decay times. The Upper Bound (UB) model comprises low end-member estimates for rheology. Pine Island Glacier is driven into retreat my sub-ice shelf melting (Cornford et al., 2013).



Model	Mantle Viscosity (Pa s)	Lithosphere Thickness (km)
Upper Mantle Avg (UM)	1e21	60
Upper Bound (UB)	1e18	25
"Best 2" (Barletta et al, 2018)	4e18 2e19	60

Rapid viscoelastic uplift (~100 m over 150 years) behind the groundling line (GL) delays its retreat by over 50 km (a-c). The response is highly localized to the region of loss (d-f), not resolved by current GPS deployments (INMN and BACK in g).





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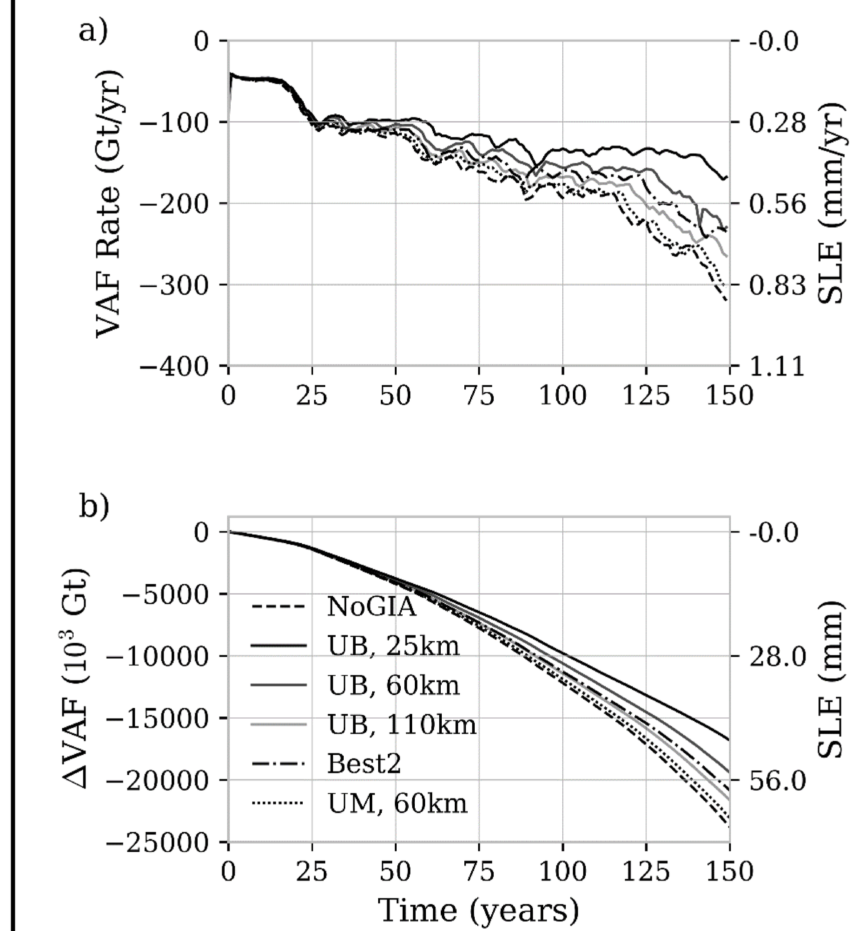
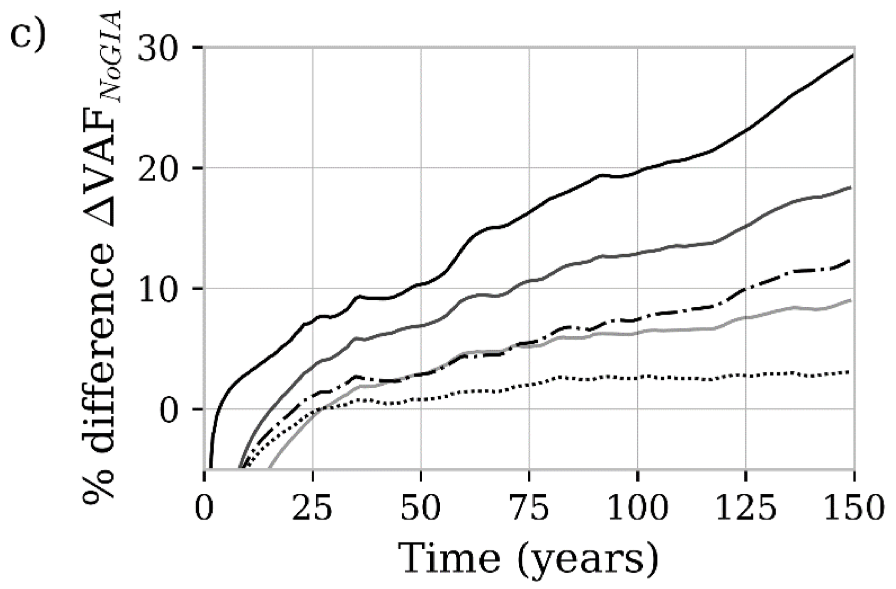
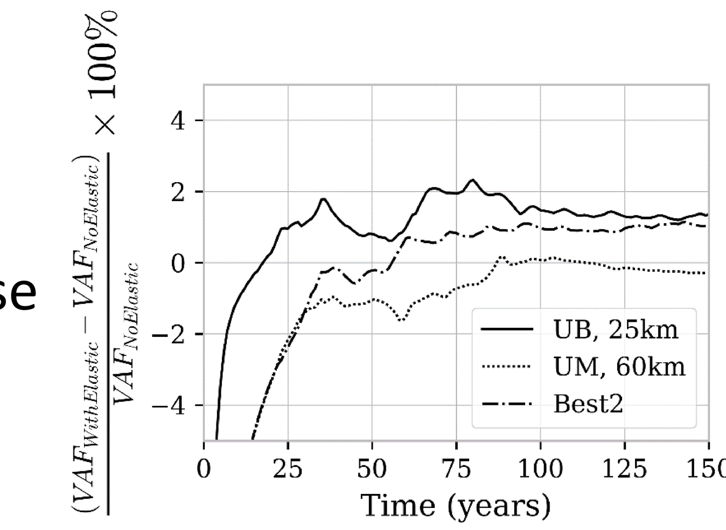
Rapid viscoelastic uplift can slow loss of volume above flotation (VAF) by up to 30% at Pine Island over 150 years.





Thicker lithospheric thickness and higher viscosity decrease the stabilizing effect by limiting and slowing the response.

The effect of instantaneous elasticity was much smaller than viscoelastic uplift (right). Other components of solid-earth response (e.g., gravitational perturbations and ongoing uplift from past mass loss) were similarly small.



We find that rapid viscoelastic uplift that occurs on a time scale comparable to grounding line migration plays a leading order role in controlling stability by solid-earth deformation.

Citations

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