Think globally, sing locally: Stories from the Minch Ice Stream on Solid Earth Feedbacks in Marine Ice Sheet Retreat

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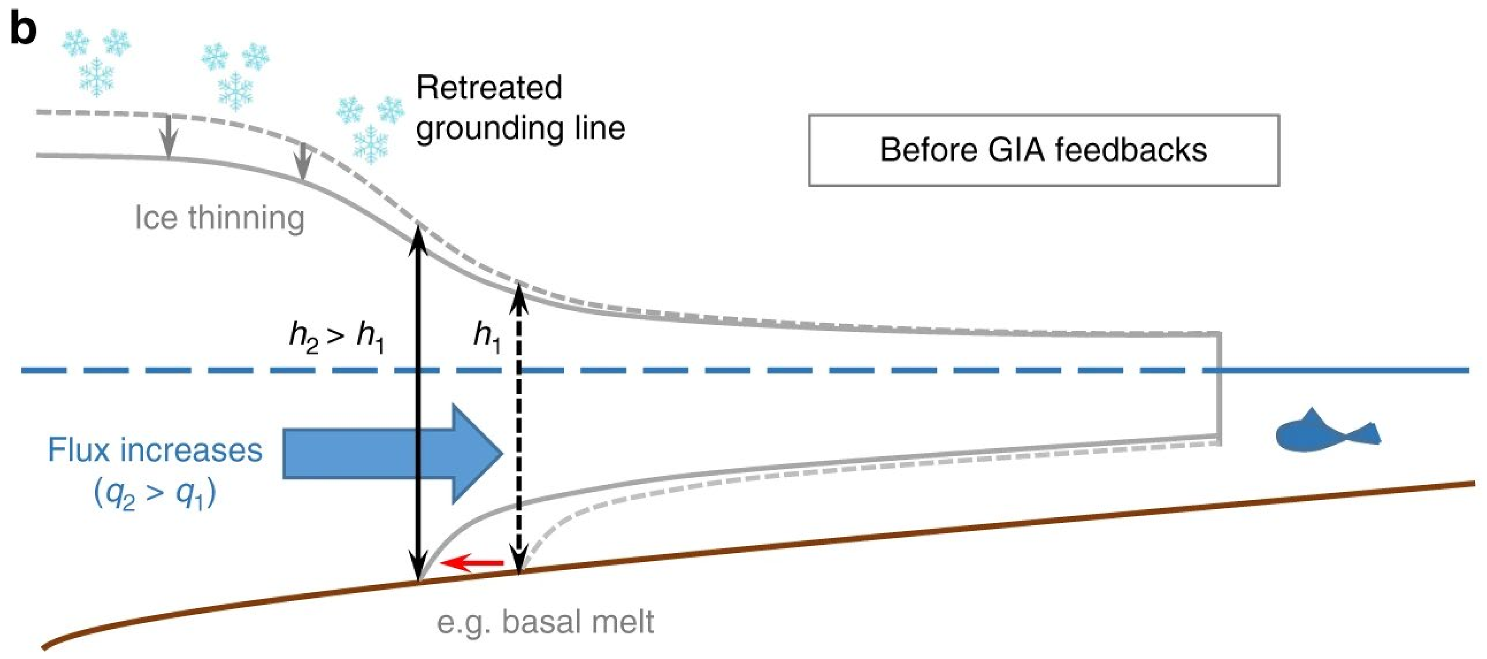
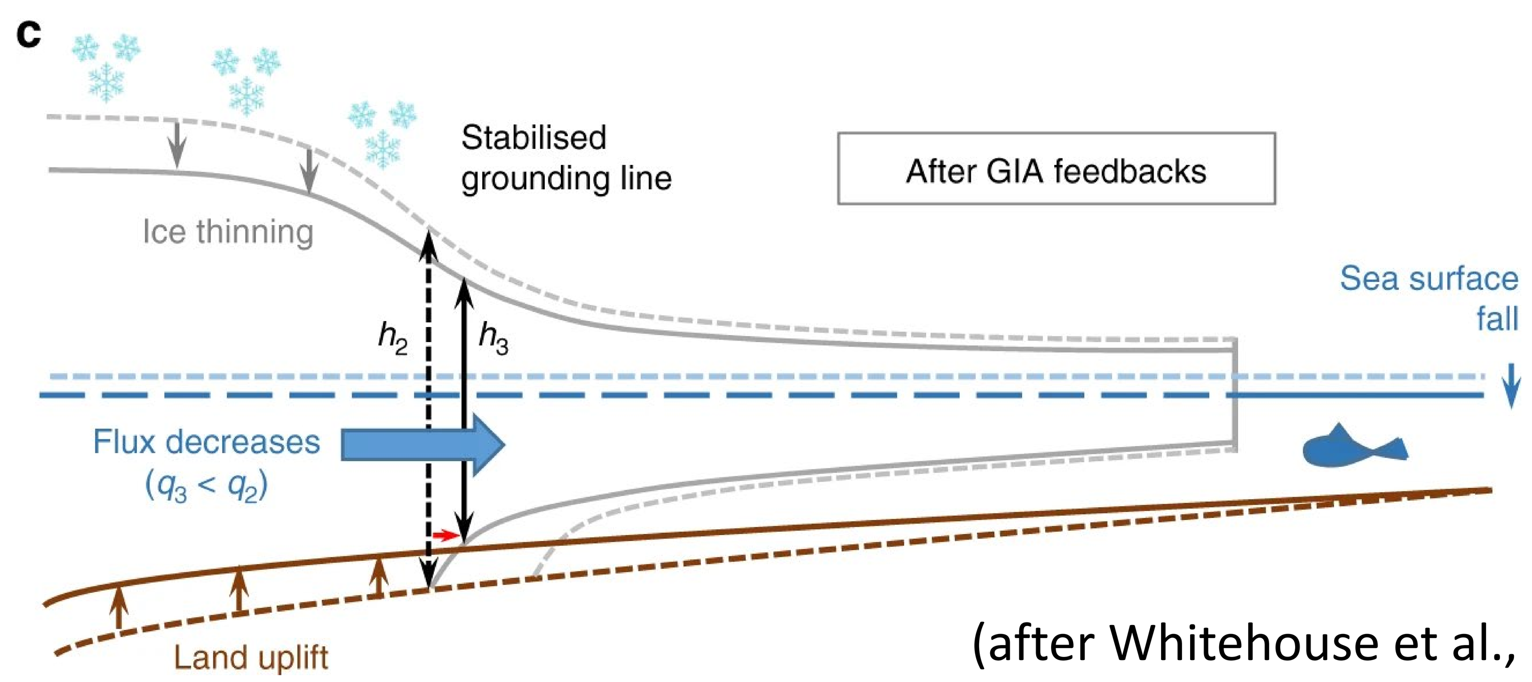
What drives the retreat of vulnerable marine ice sheets?

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

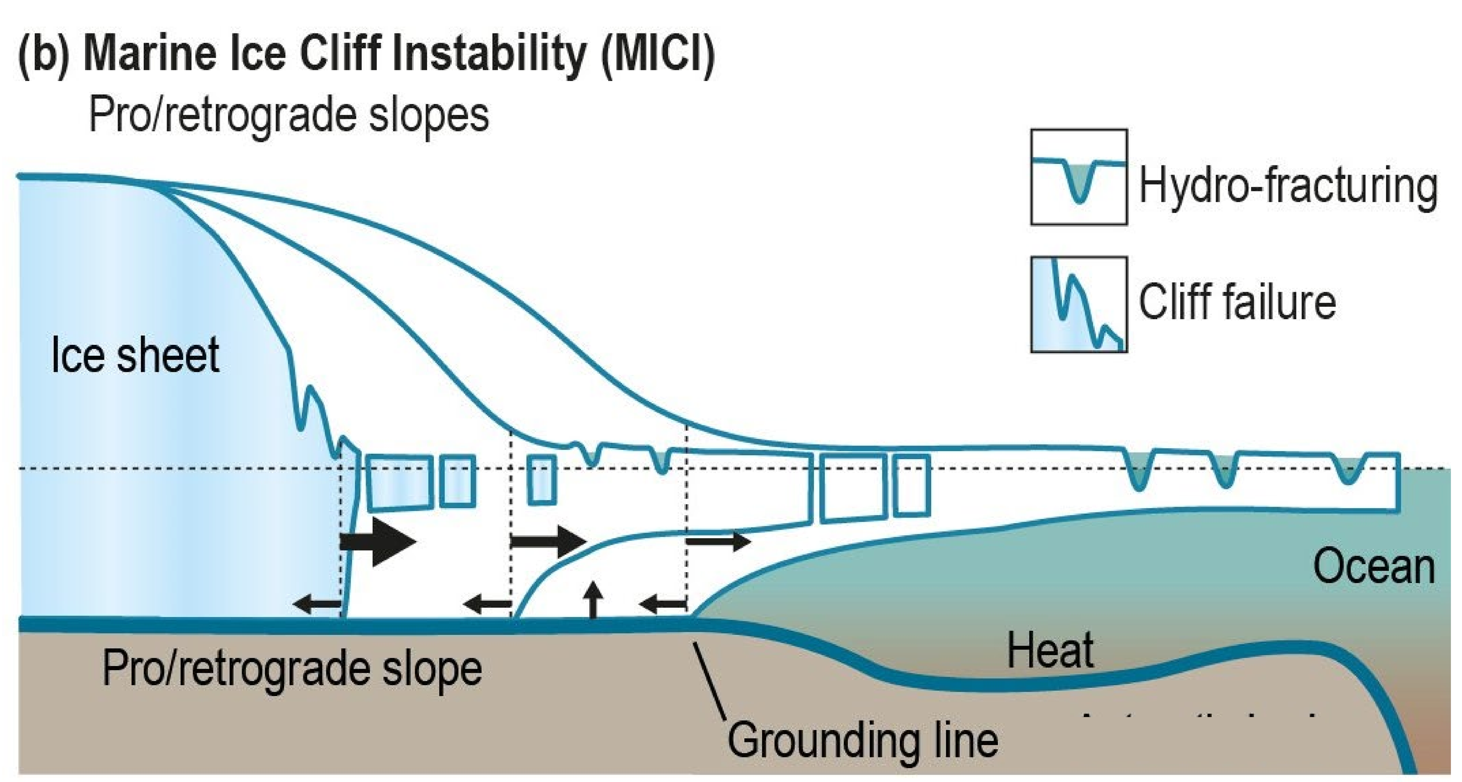


Viscoelastic uplift can stabilize retreat by lowering local sea level, over decades to millennia, depending on mantle properties.



(after Whitehouse et al., 2019)

Marine ice sheets are vulnerable to another form of rapid retreat from a calving instability, although direct observations of this mechanism are scant.



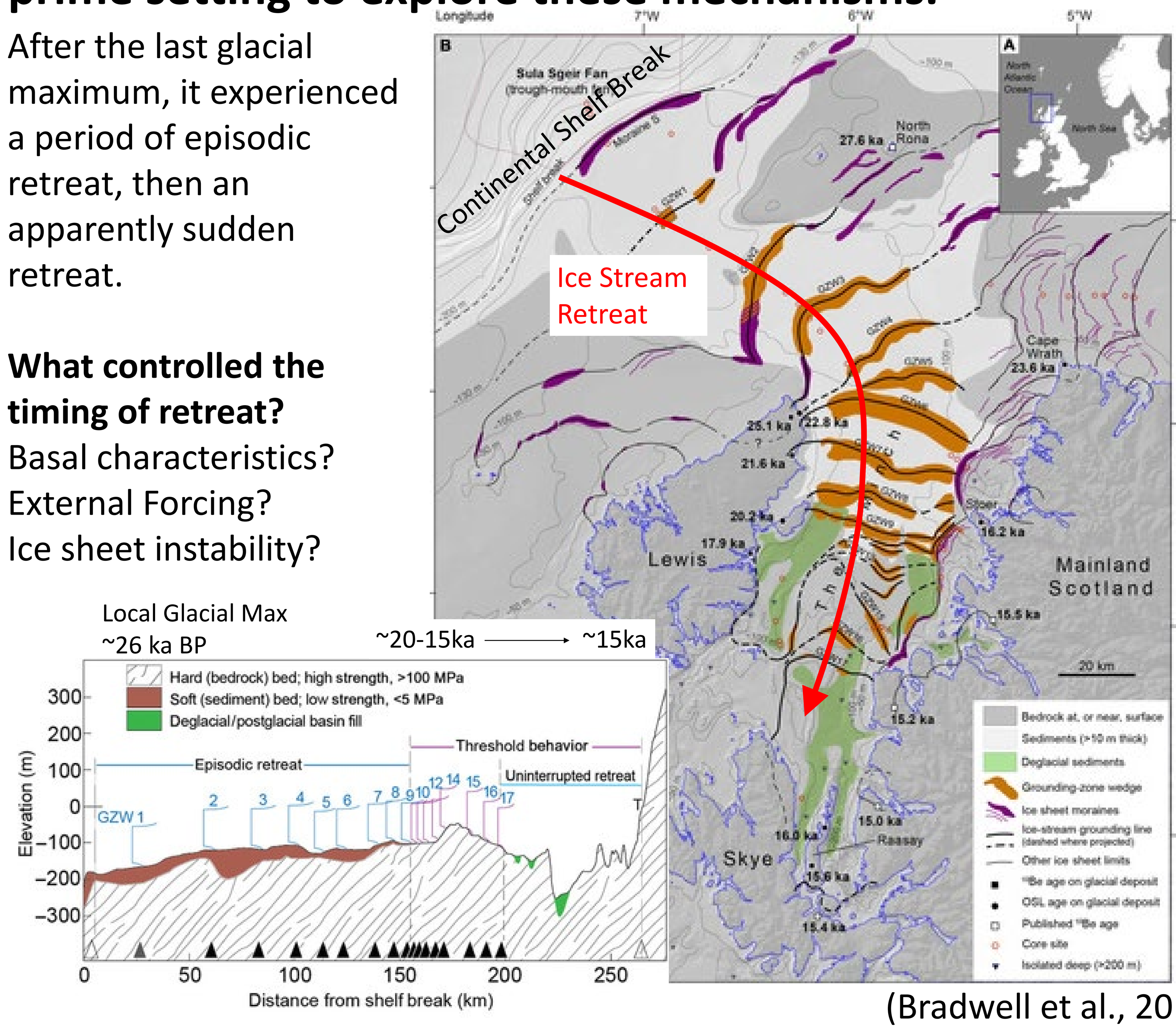
(after IPCC SROCC)

Can we test these intersecting hypotheses using observations of paleo ice sheets?

The retreat of the Minch Ice Stream in NW Scotland is a prime setting to explore these mechanisms.

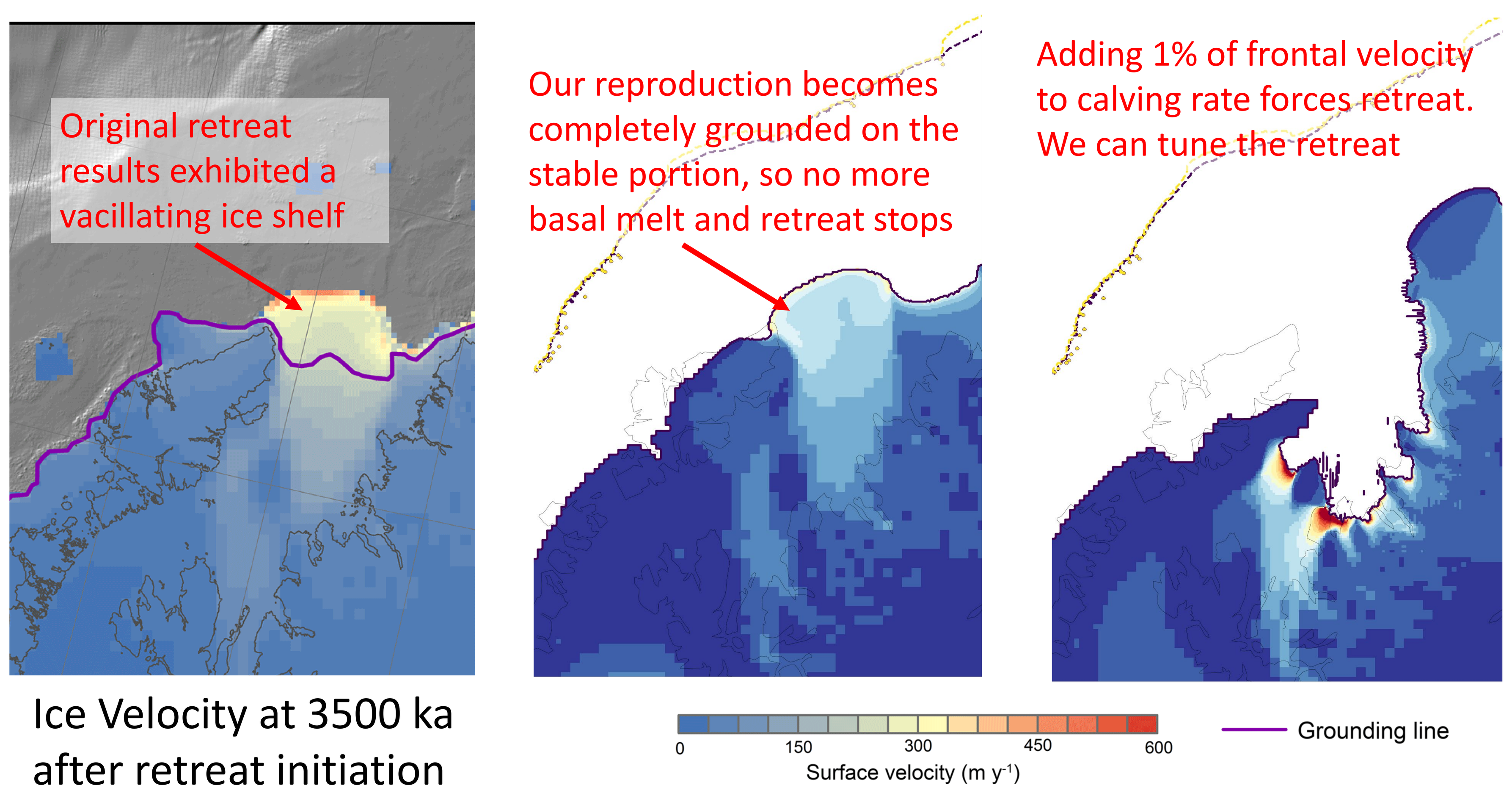
After the last glacial maximum, it experienced a period of episodic retreat, then an apparently sudden retreat.

What controlled the timing of retreat?
Basal characteristics?
External Forcing?
Ice sheet instability?



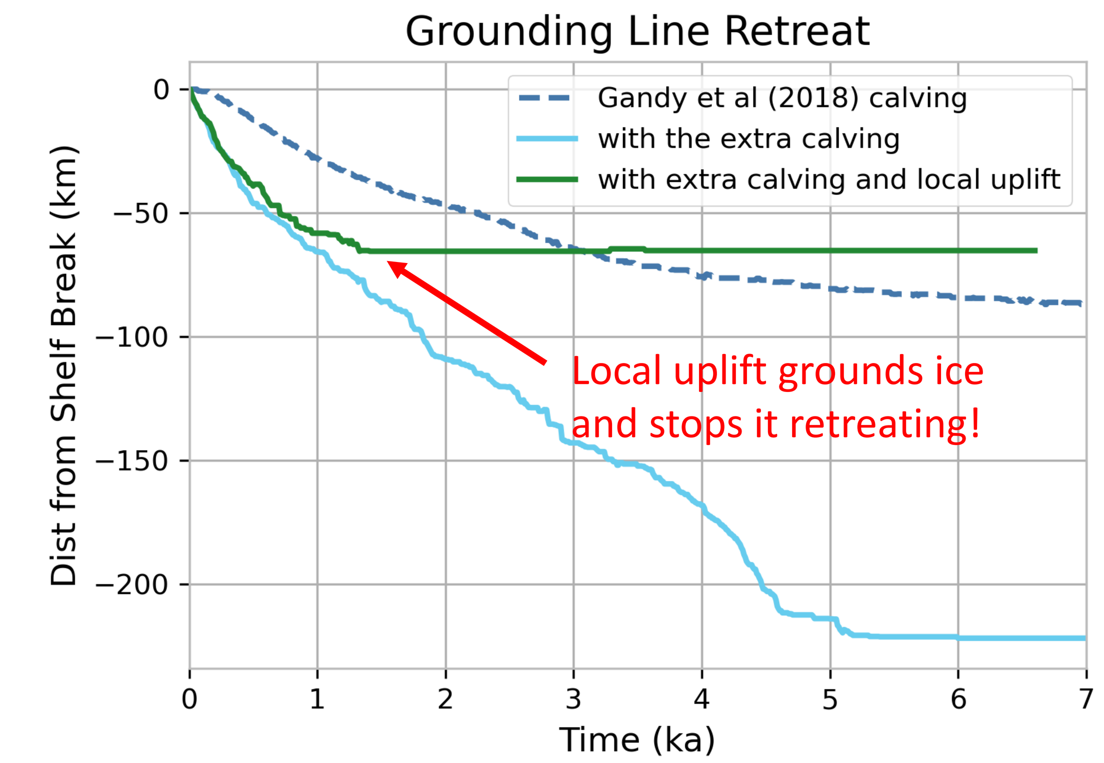
(Bradwell et al., 2019)

Modeling retreat is a sensitive process. Beginning with the local Glacial Maximum spin-up of Gandy et al (2018), with time-invariant surface mass balance and constant basal melt (23 m a^{-1}) and frontal ablation (250 m a^{-1}) rates. We try to drive retreat by decreasing surface mass balance, melting more (47 m a^{-1}) and increasing ablation (350 m a^{-1}). However, **sustained retreat requires a bigger kick; Below, we apply calving proportional to velocity of the ice at the ice front.**



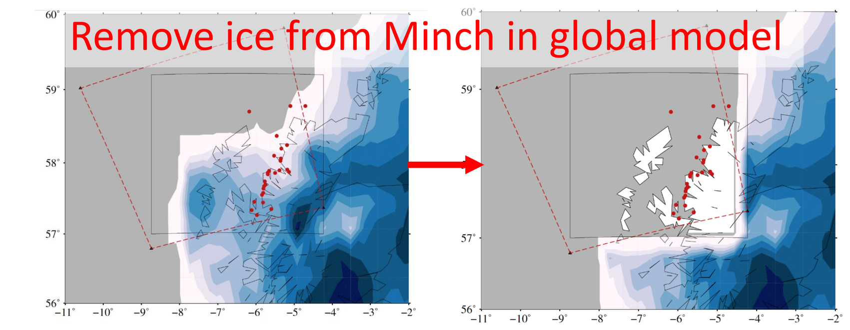
Ice Velocity at 3500 ka after retreat initiation

How do solid-earth feedbacks affect the retreat? How important are regional/global uplift for local dynamics?

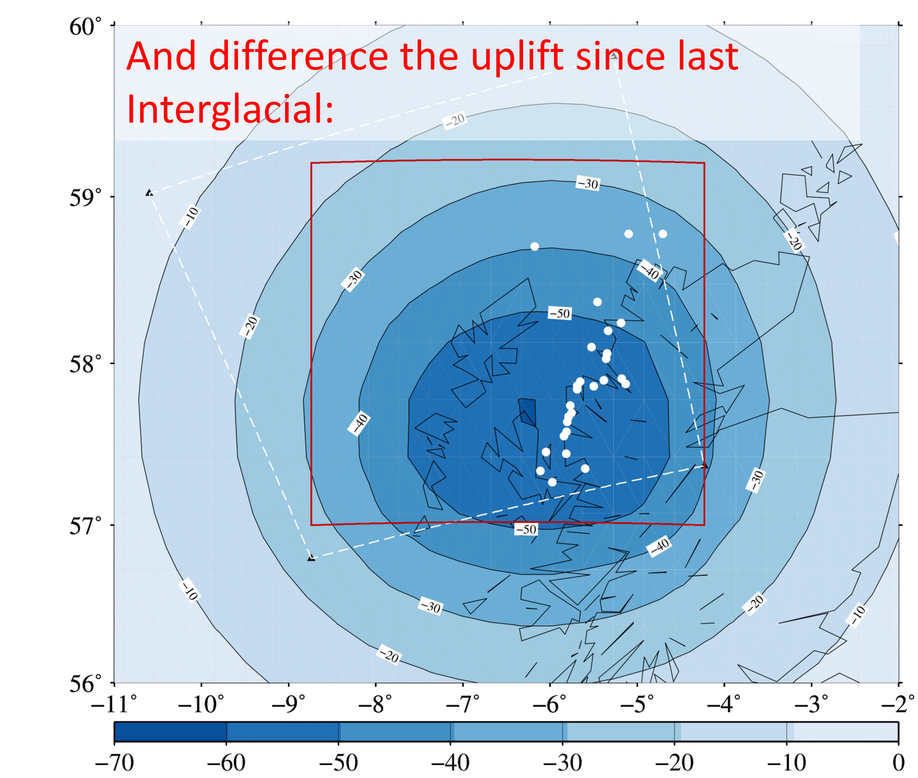


Local uplift to local deglaciation lifts the ice stream out of the marine environment, stopping its retreat.

The local earth surface also responds to all the mass redistribution across the globe.



Some of this will cause additional uplift, some causes subsidence. The net result could counteract the local uplift to the local Minch deglaciation.



Difference in solid surface at 24 ka BP (m)

Parting Questions:

Are ice sheet models too stable in general?

What aspects of the configuration and history of the Minch are applicable elsewhere?

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Citations

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