POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

P I K

Dynamic regimes of the Greenland Ice Sheet emerge from competing feedbacks

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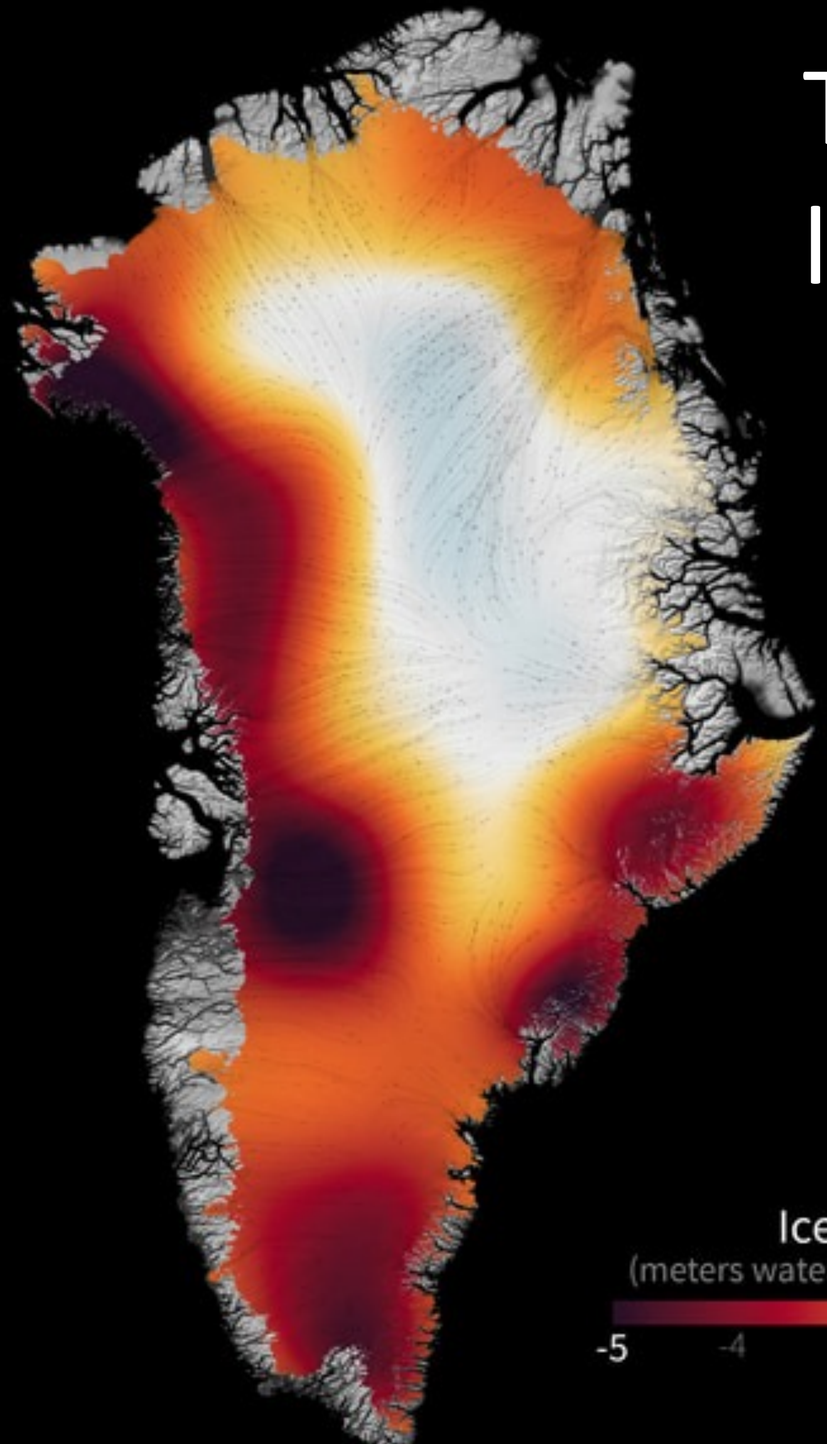
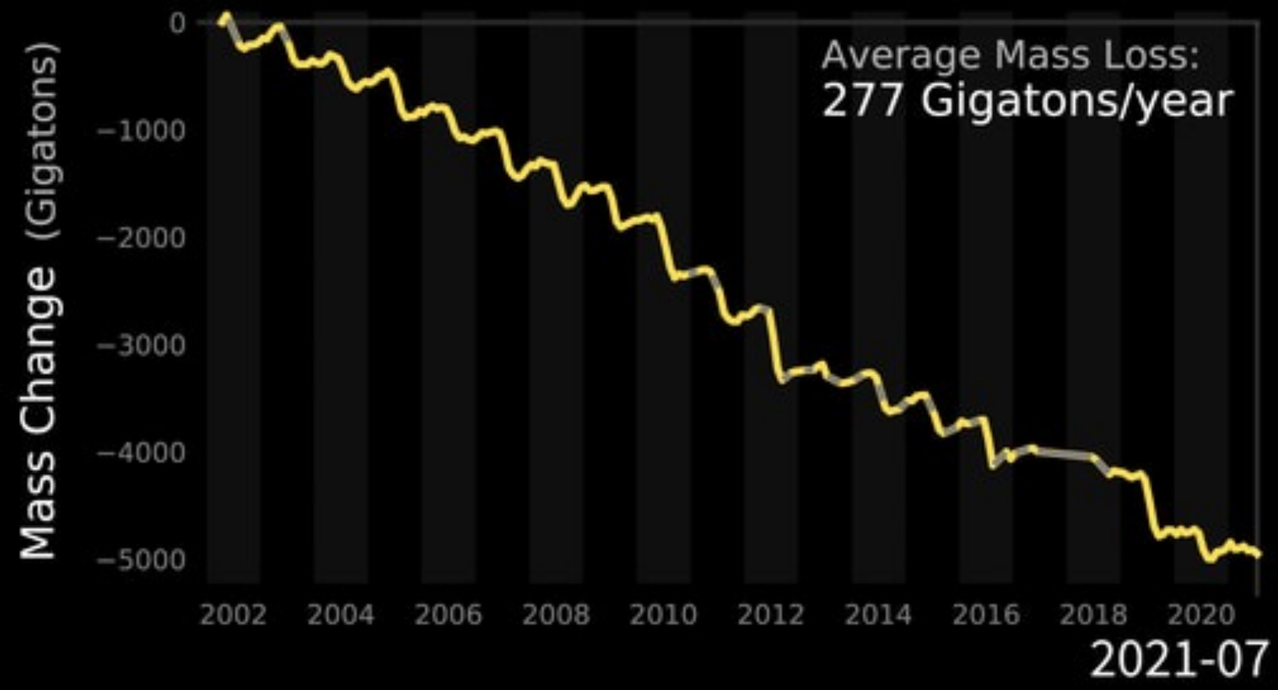
Leibniz Association

The Greenland Ice Sheet is losing mass





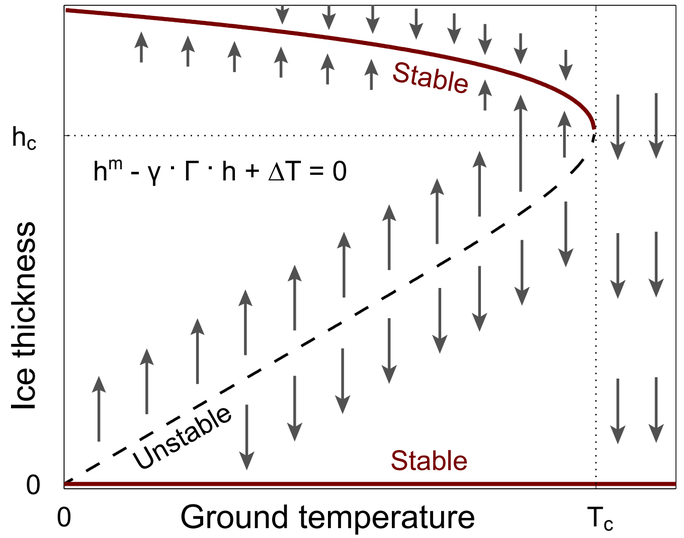
Ice Mass Change
(meters water equivalent relative to 2002)

-5 -4 -3 -2 -1 0 0.5

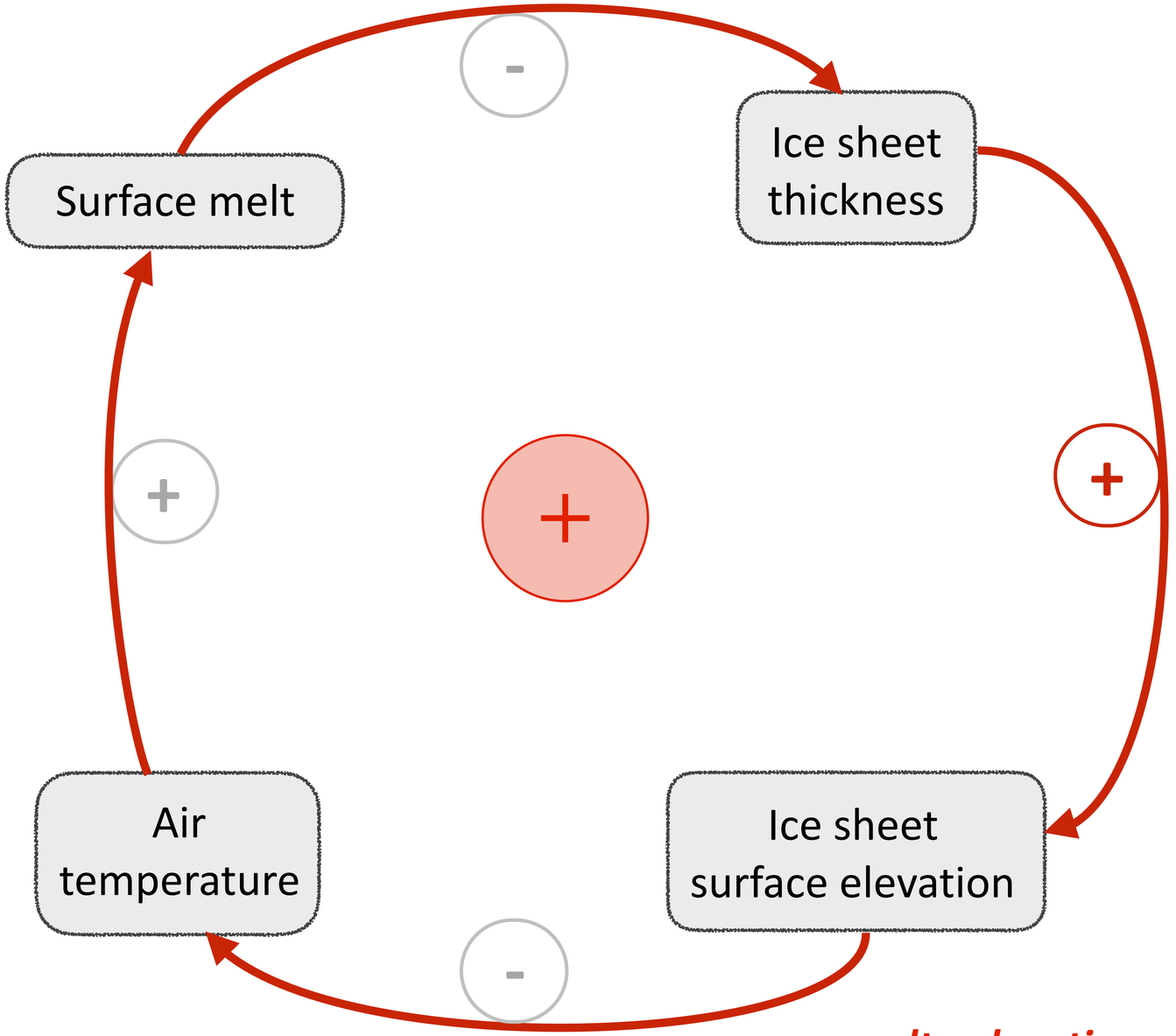
source: NASA

The positive melt-elevation feedback enhances ice losses of Greenland Ice Sheet

… and could make it unstable



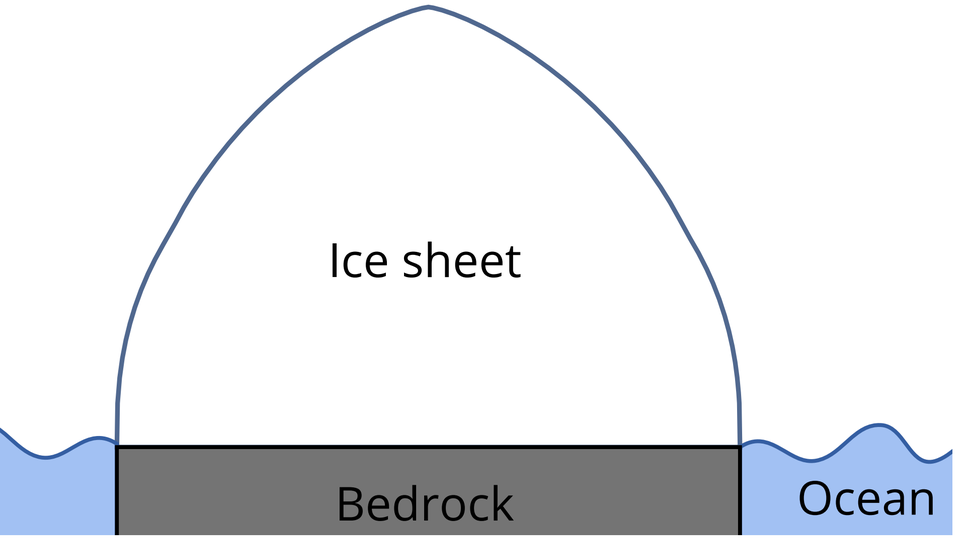
Levermann, Winkelmann 2016

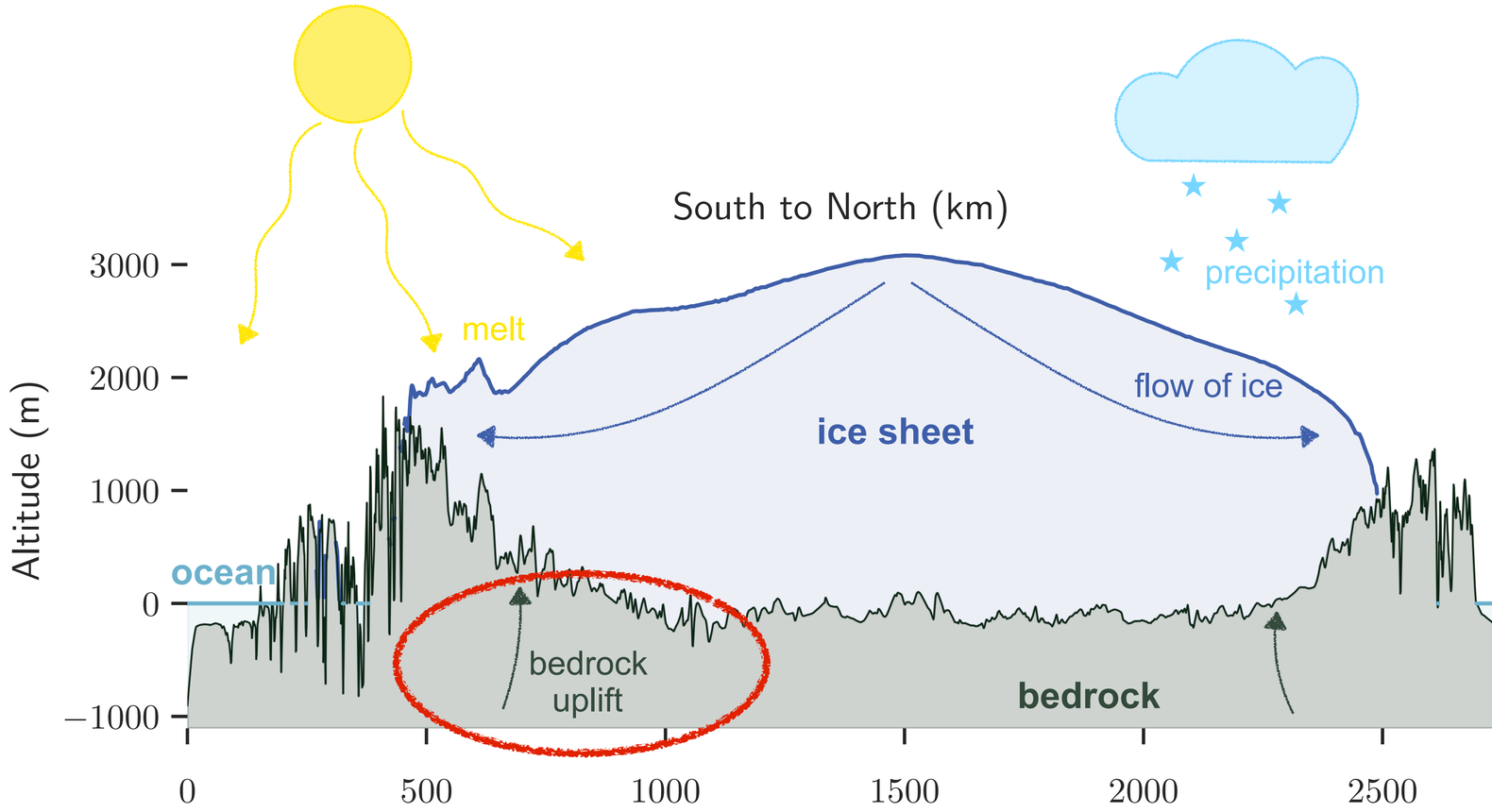


melt - elevation feedback

+/- positive / negative correlation

But isn’t this picture too simple?





Reduction in ice load leads to a bedrock uplift … and two competing feedbacks

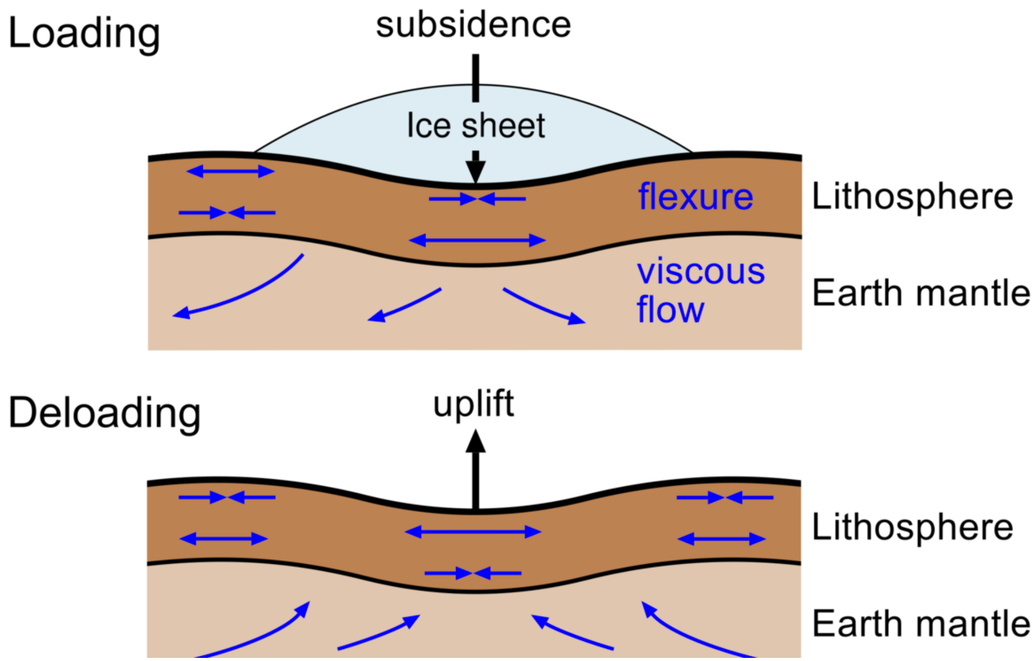
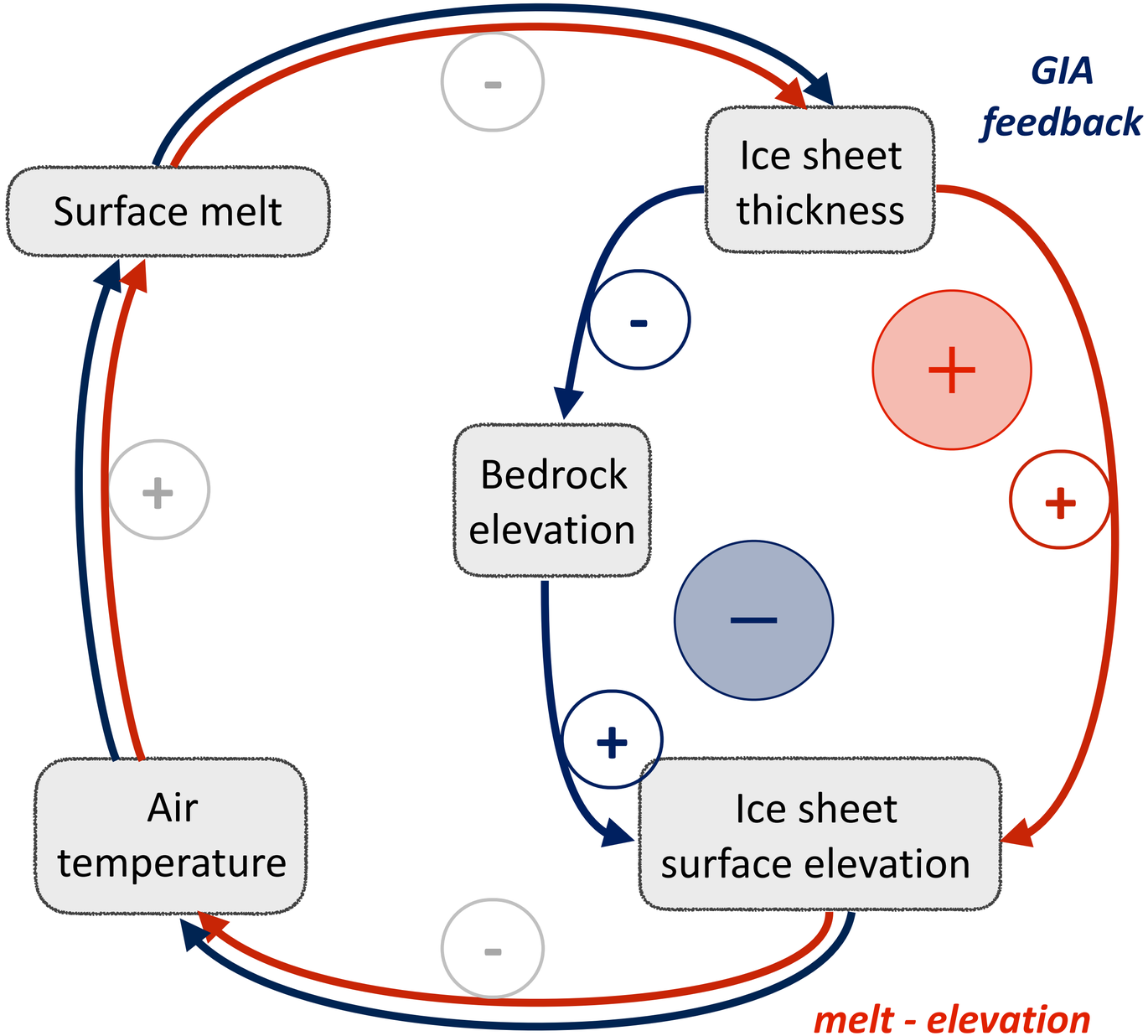


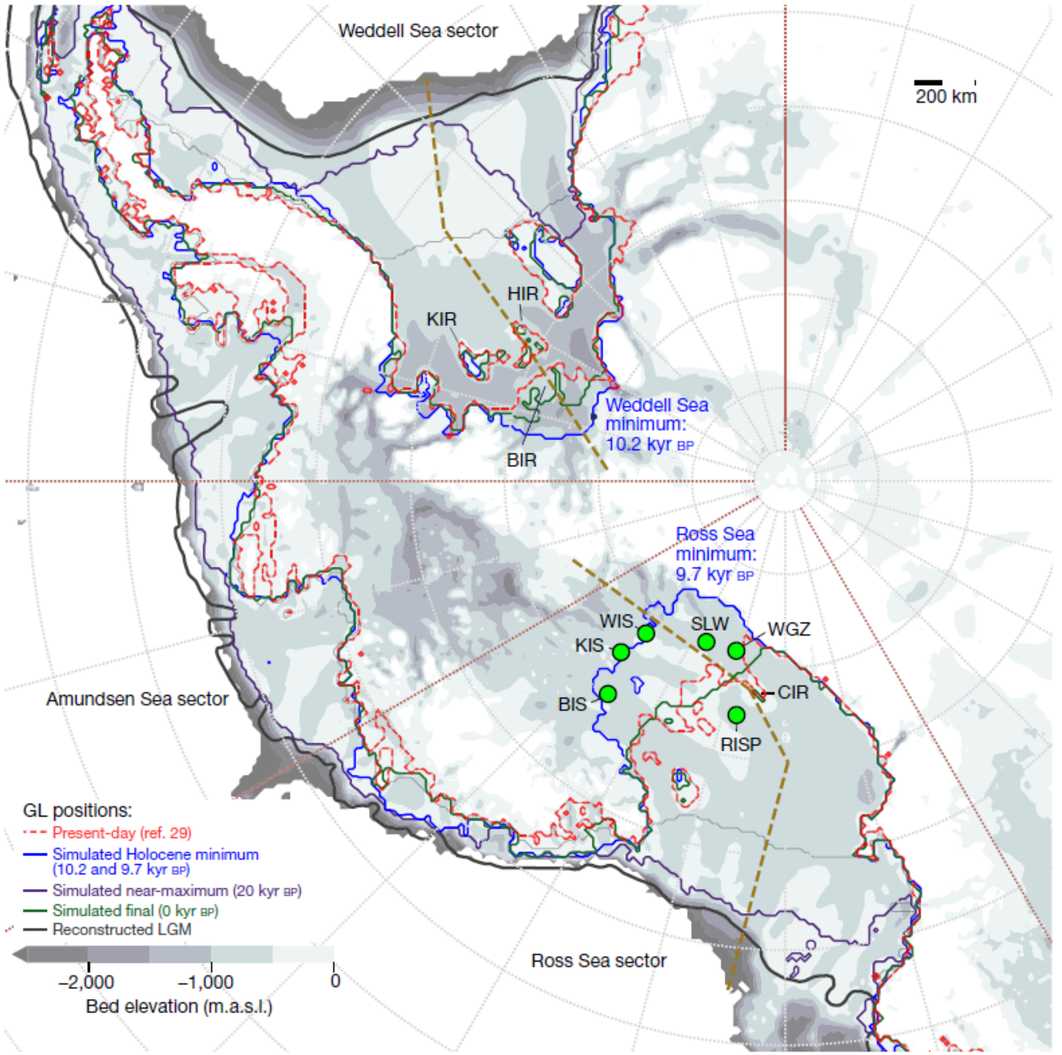
image: Volker Klemann, GFZ



Bedrock response is important for marine ice sheets

Bedrock response is important for marine ice sheets

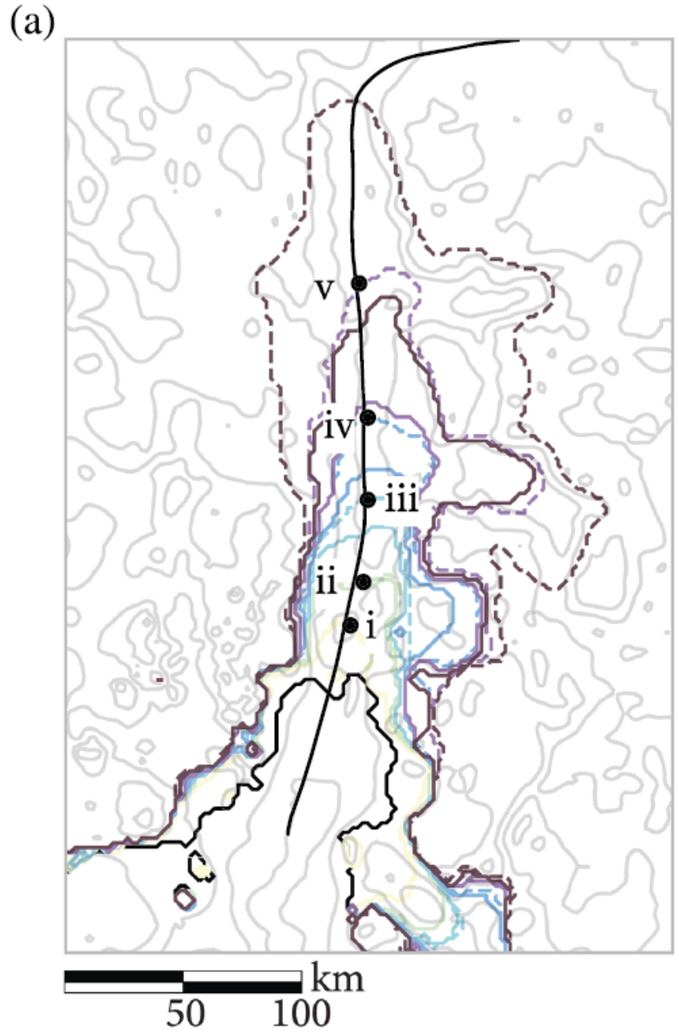
- Grounding line re-advance in Antarctica



Kingslake et al. 2018

Bedrock response is important for marine ice sheets

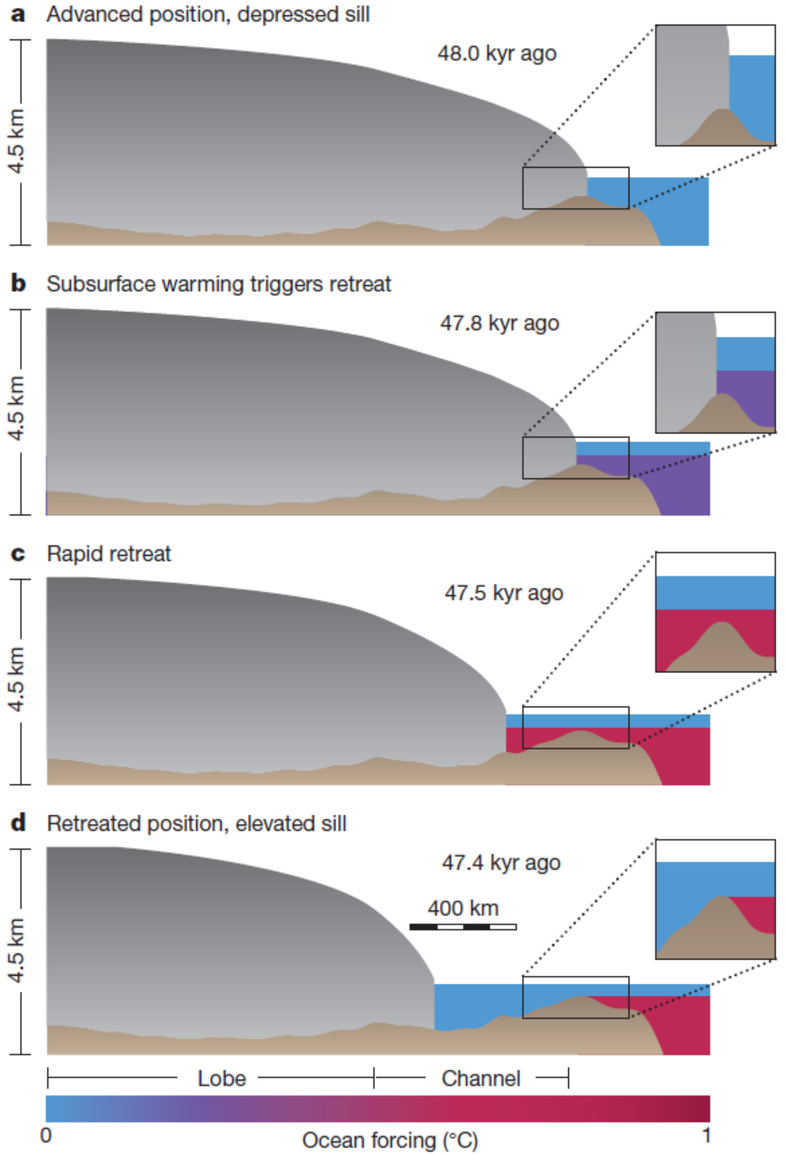
- Grounding line re-advance in Antarctica
- Slow down of marine ice sheet collapse of Pine Island Glacier



Kachuch et al. 2020

Bedrock response is important for marine ice sheets

- Grounding line re-advance in Antarctica
- Slow down of marine ice sheet collapse of Pine Island Glacier
- Heinrich events

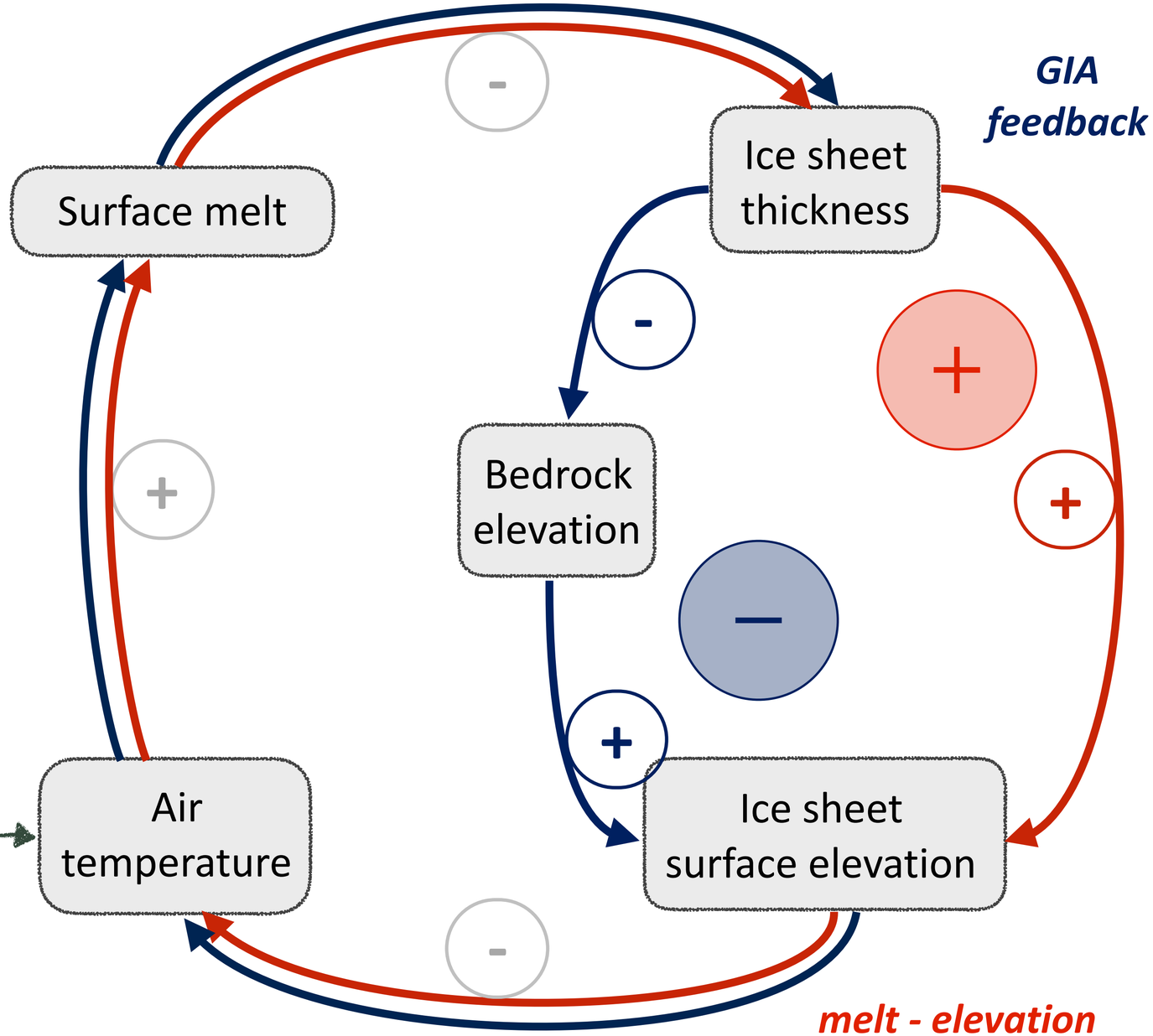


Bassis et al. 2017

PISM

PARALLEL ICE SHEET MODEL

- temperature lapse rate with PDD
- **upper mantle viscosity** in viscoelastic solid Earth module
- step forcing with scalar **temperature anomaly**



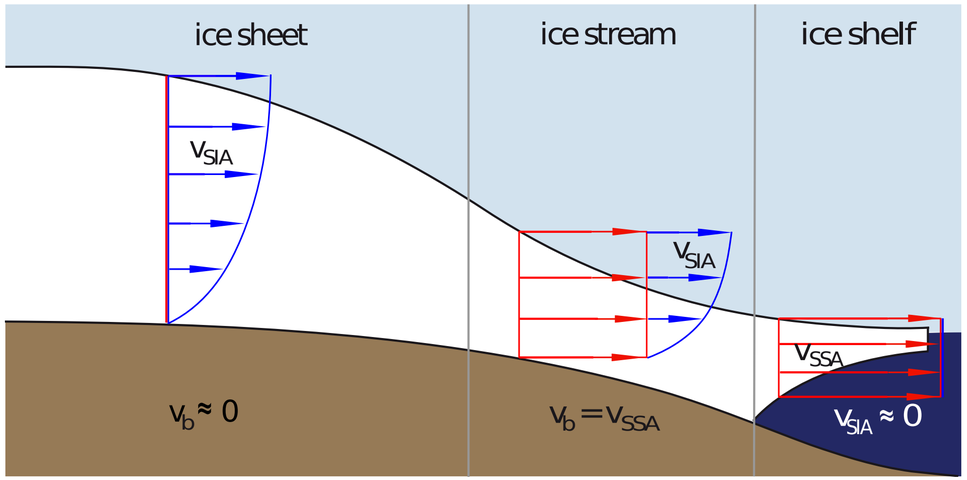
PISM simulations

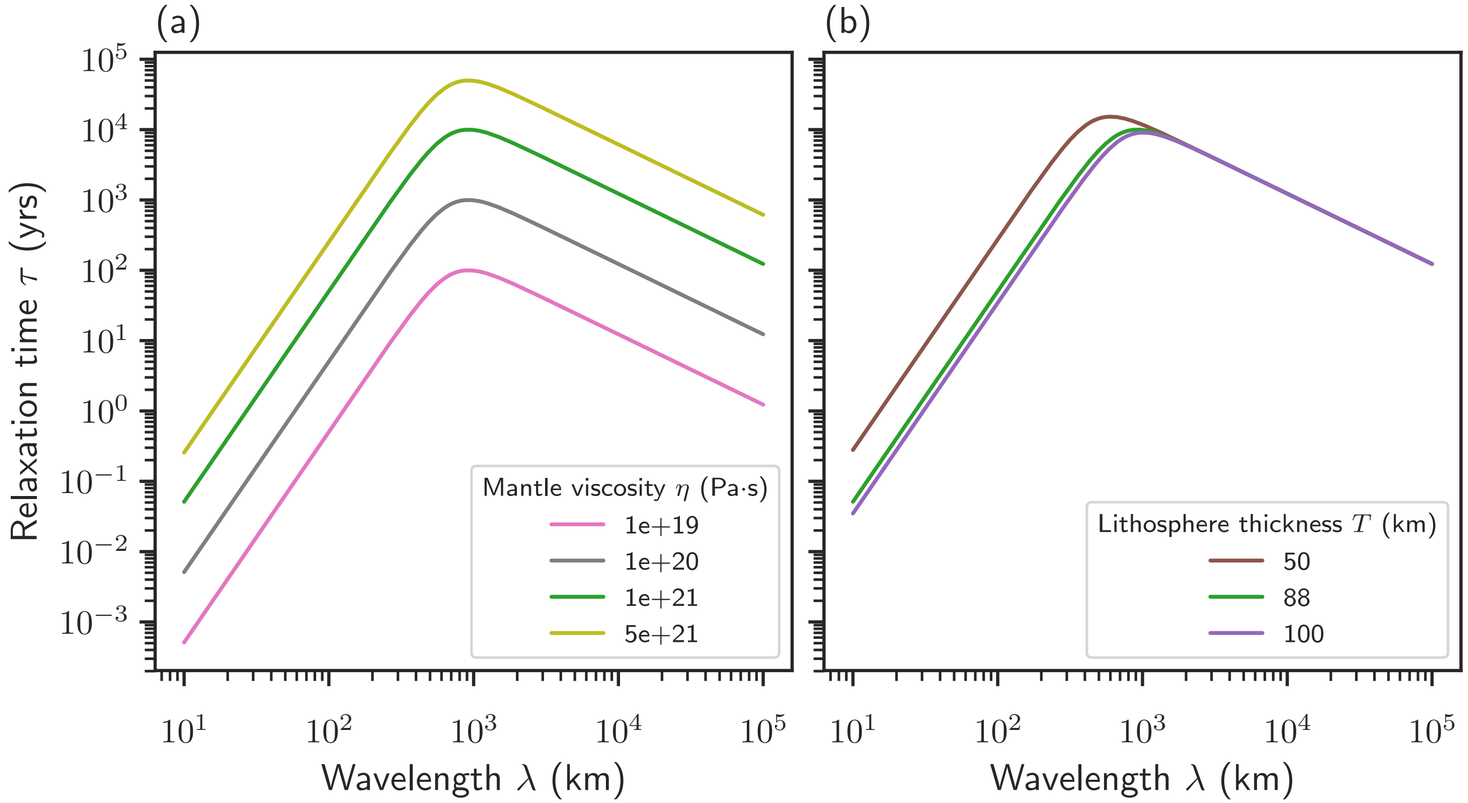
PISM
PARALLEL ICE SHEET MODEL

- thermo-mechanical coupling
- shallow ice approximation + shallow shelf approximation (for sliding)
- resolution: 15km
- surface model: positive degree day
- spin up: equilibrium state under present day climate
- forcing: step forcing with temperature anomaly
- **melt-elevation feedback**: temperature lapse rate
- solid Earth response and **GIA feedback**: Lingle-Clark model

Modeling the ice and the bedrock

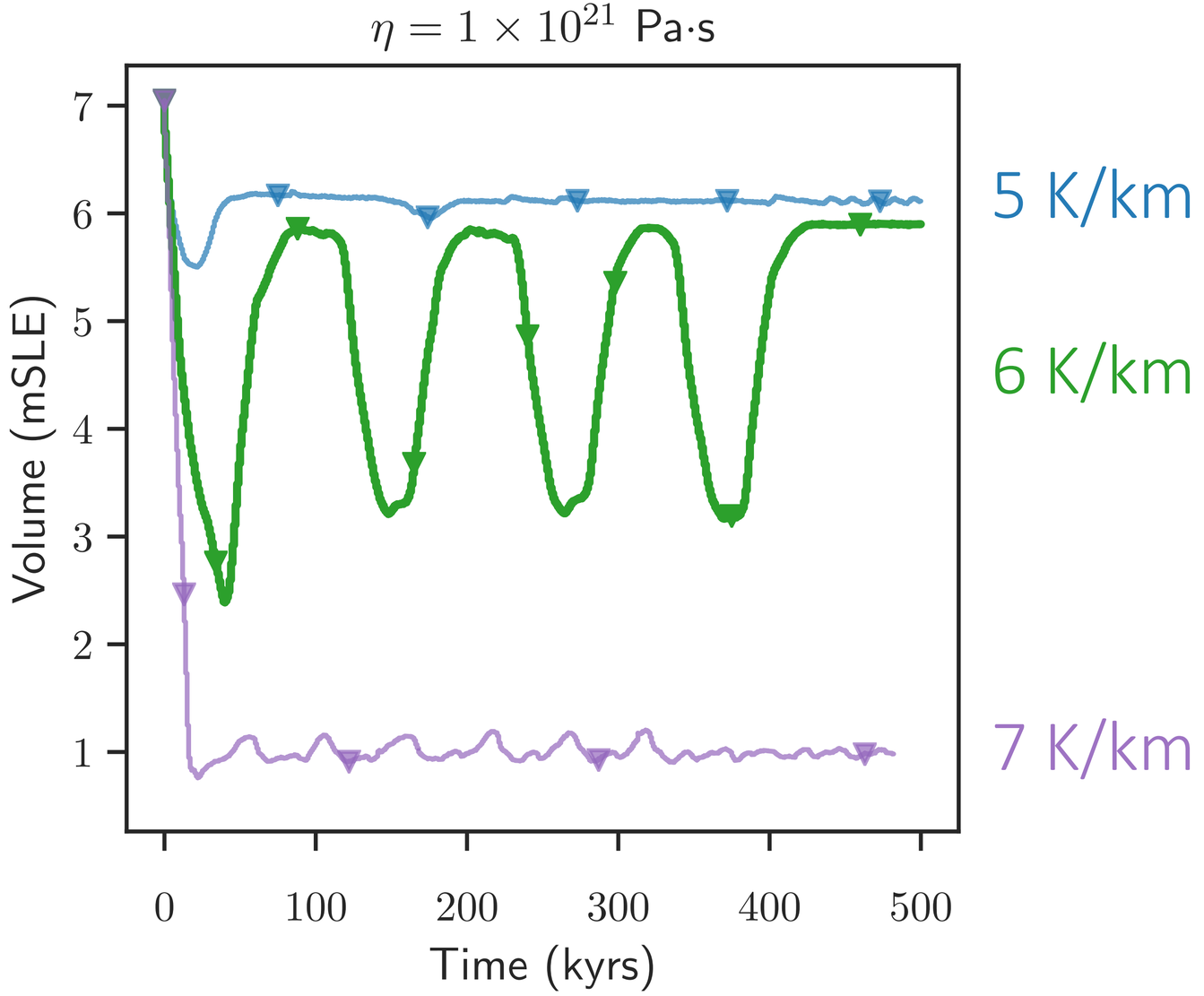
- ice: sliding via shallow shelf approximation
- bedrock: relaxation time of bedrock not constant





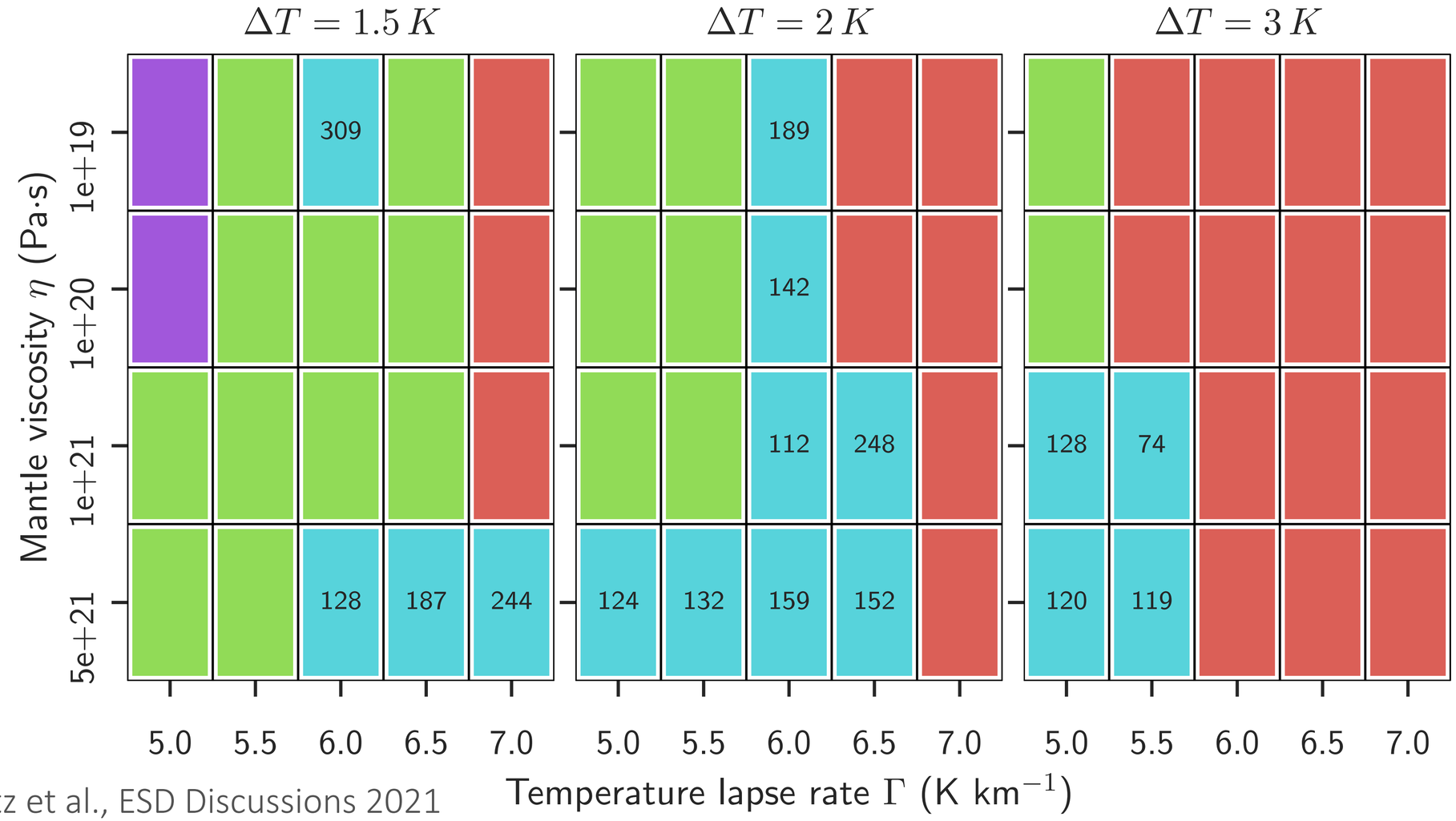
PISM simulations show four distinct types of GrIS dynamics

- stabilization
- incomplete recovery
- irreversible loss
- oscillations



Zeitz et al., ESD Discussions 2021

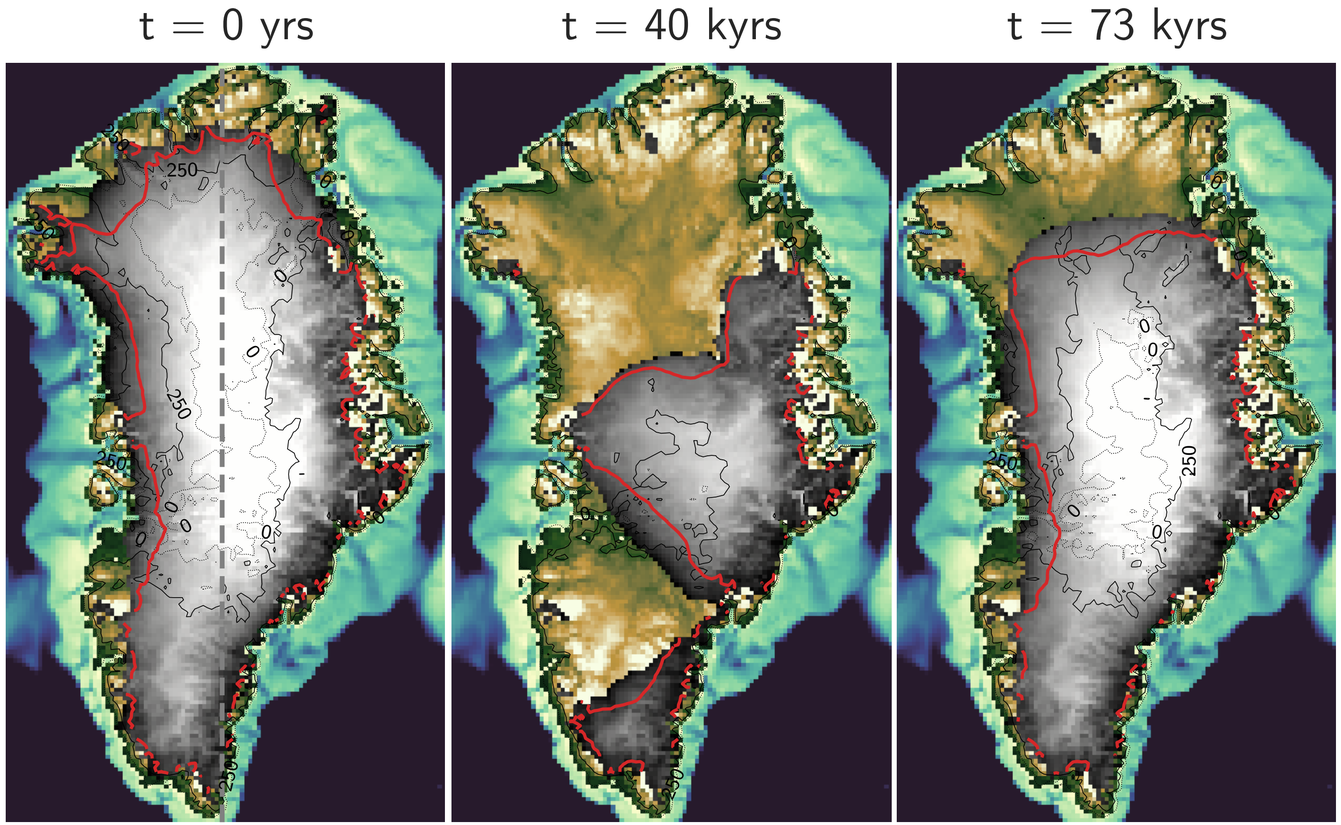
High lapse rates promote ice sheet collapse
High mantle viscosities promote oscillations

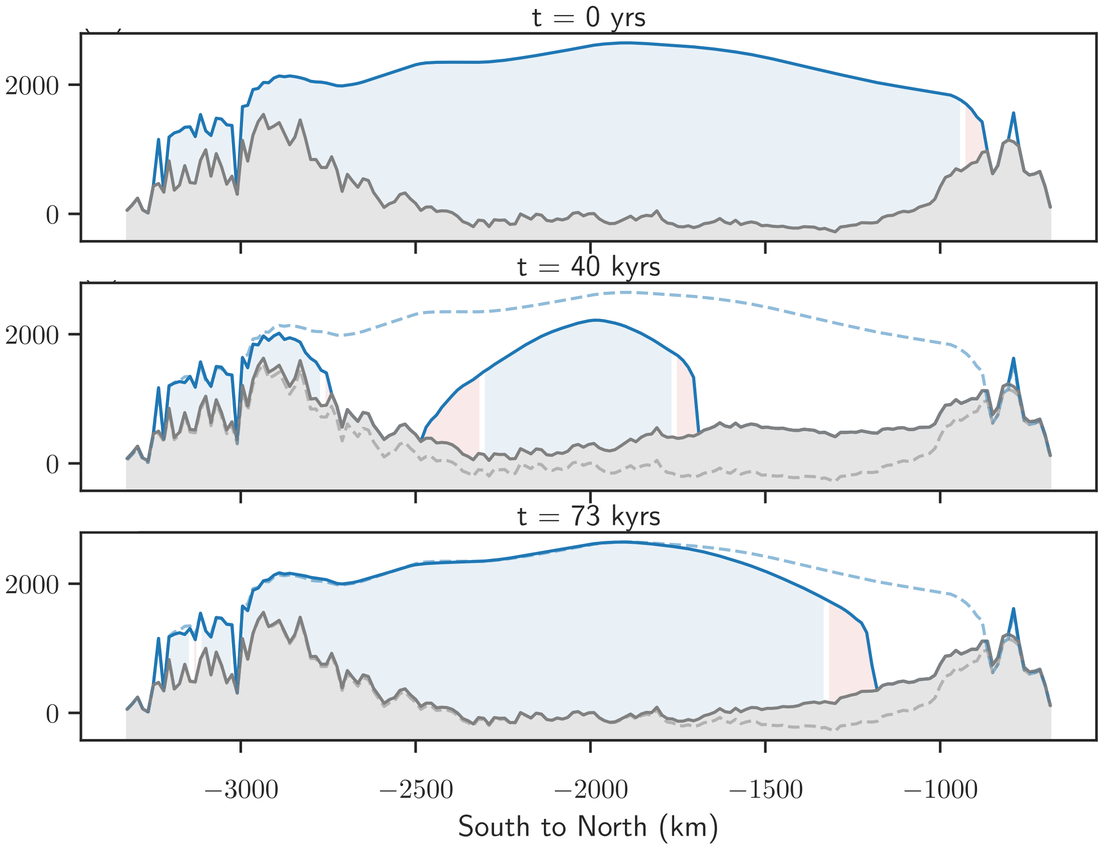


- stabilization
- incomplete recovery
- irreversible loss
- oscillations (numbers: oscillation period in kyrs)

Zeitz et al., ESD Discussions 2021

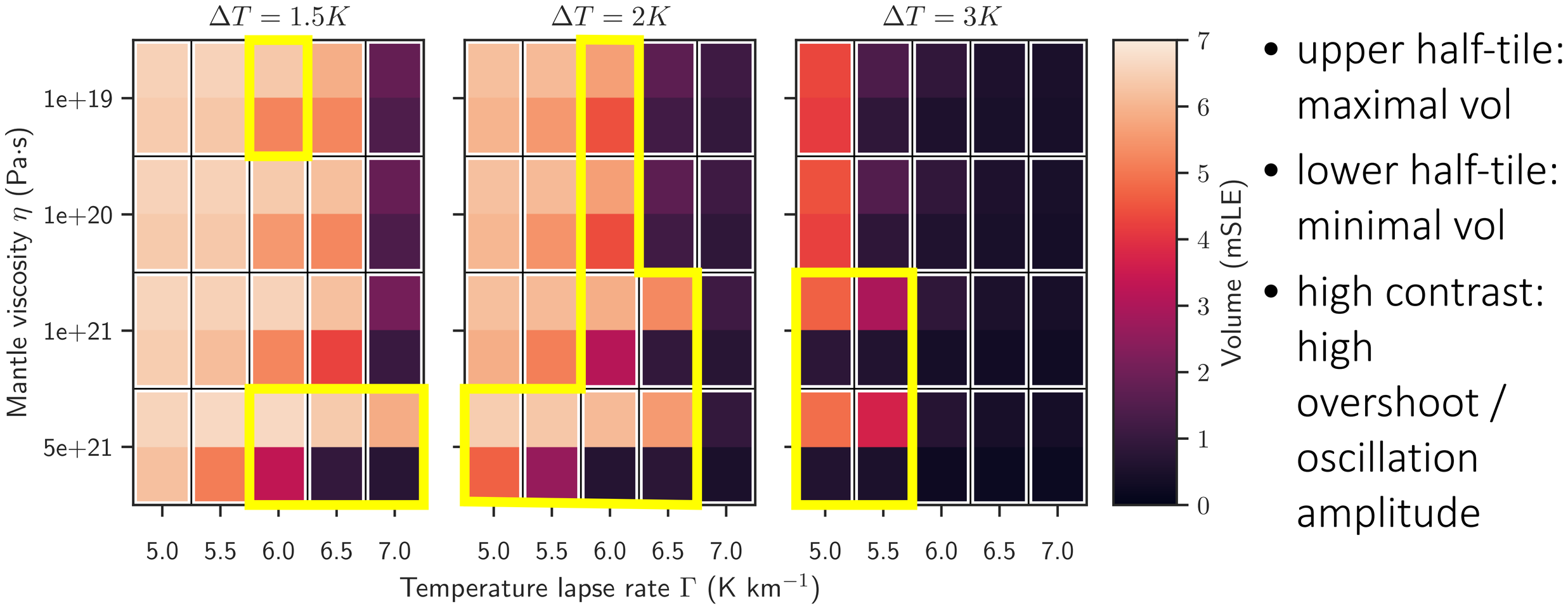
Oscillating regime of the Greenland Ice Sheet





Zeitz et al., ESD Discussions 2021

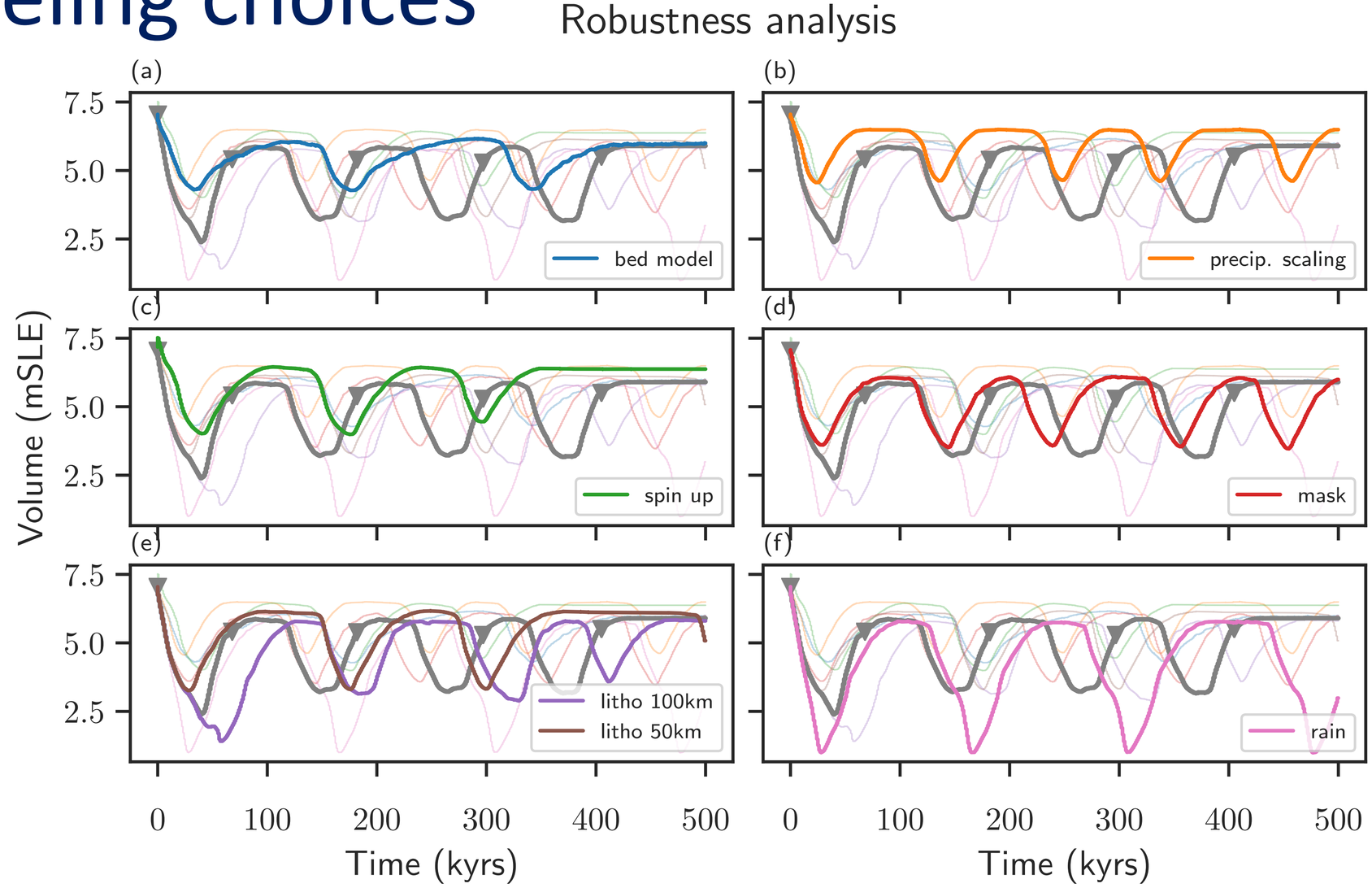
Amplitude of oscillation increases with high mantle viscosity



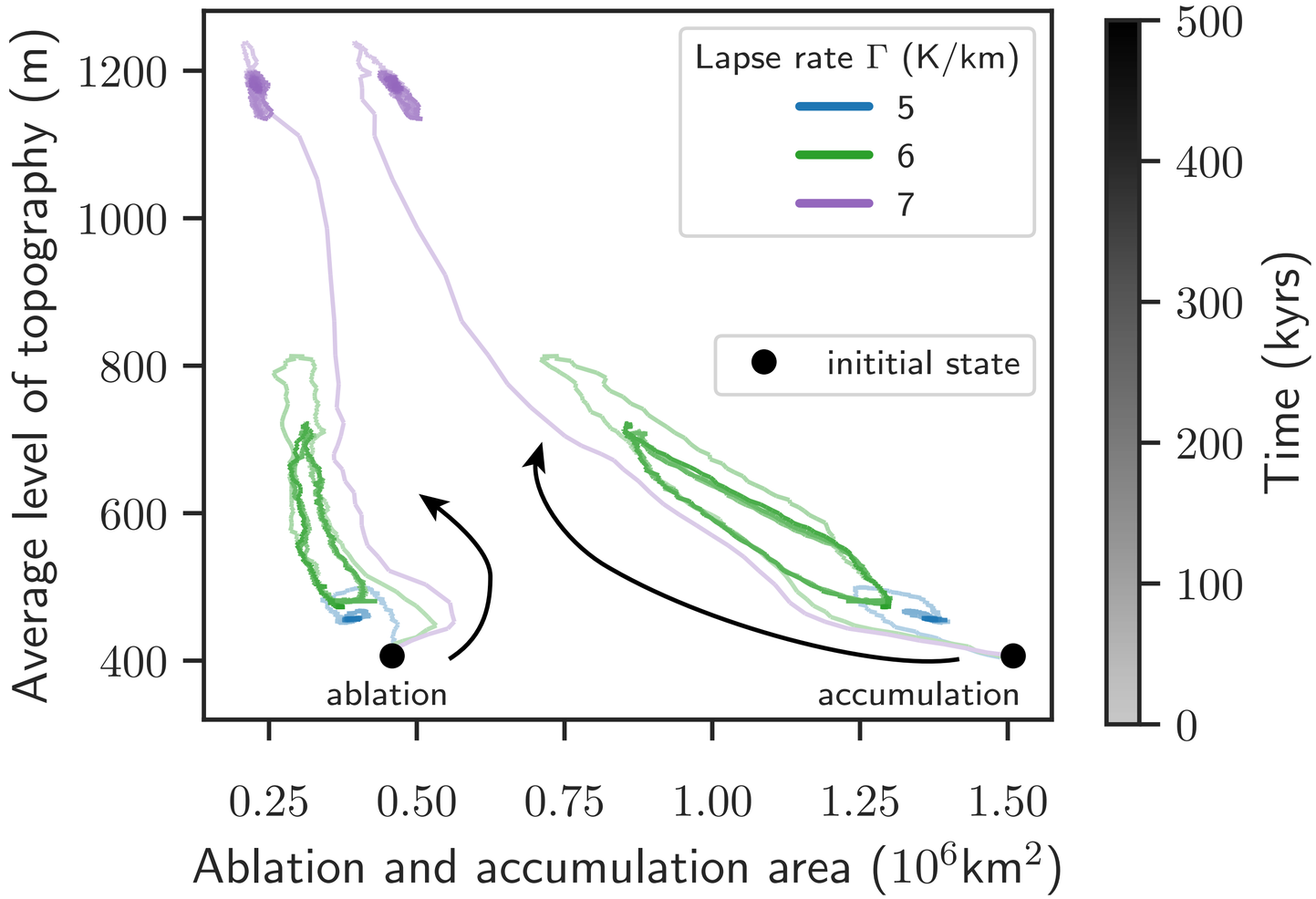
- upper half-tile: maximal vol
- lower half-tile: minimal vol
- high contrast: high overshoot / oscillation amplitude

Zeitz et al., ESD Discussions 2021

Oscillations are robust against variations in modeling choices



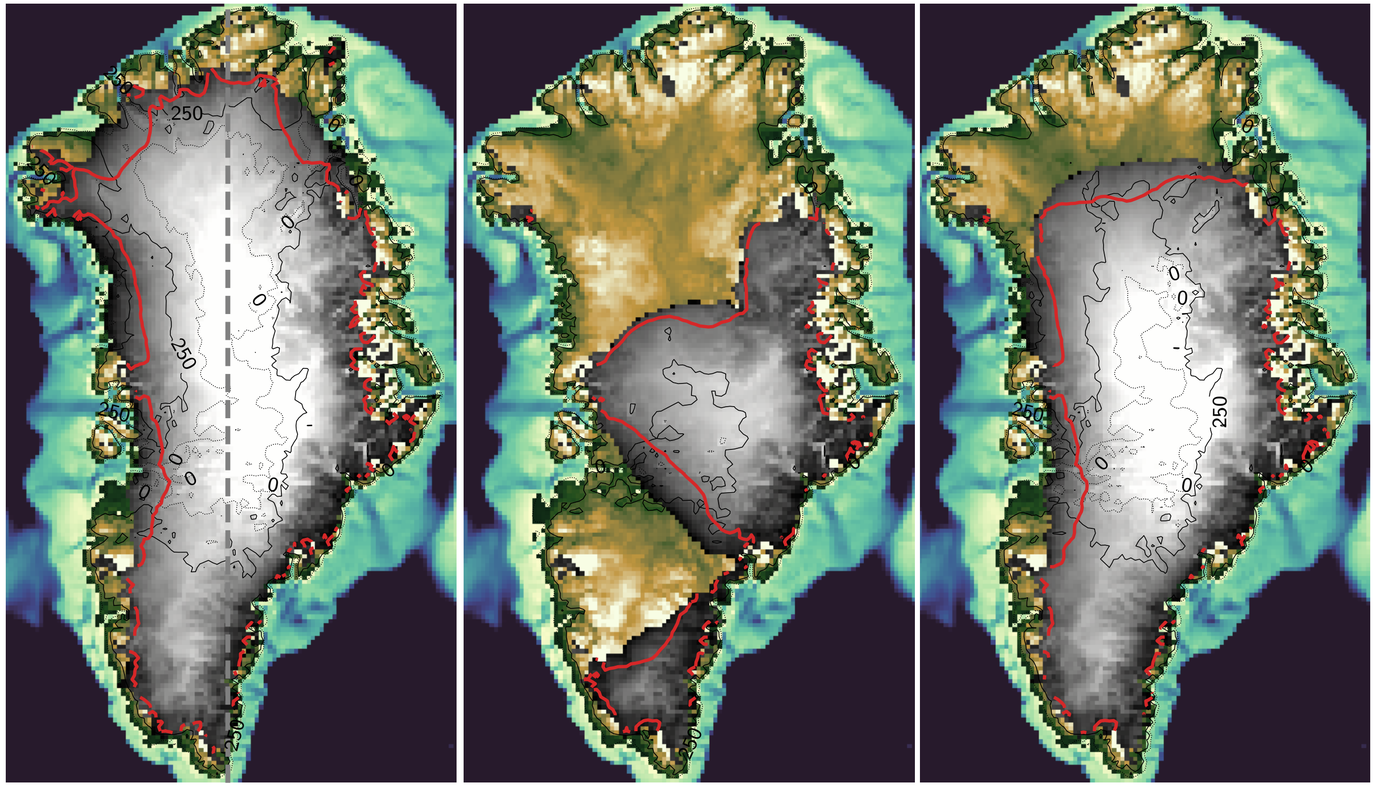
Trajectories in phase space



Zeitz et al., ESD Discussions 2021

Let’s discuss Greenland oscillations!

More details in
Zeitz et al., Earth System Dynamics Discussions (2021)



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