POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

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Ice-load bedrock-uplift feedback leads to self-sustained oscillations in the Greenland Ice Sheet on long time scales

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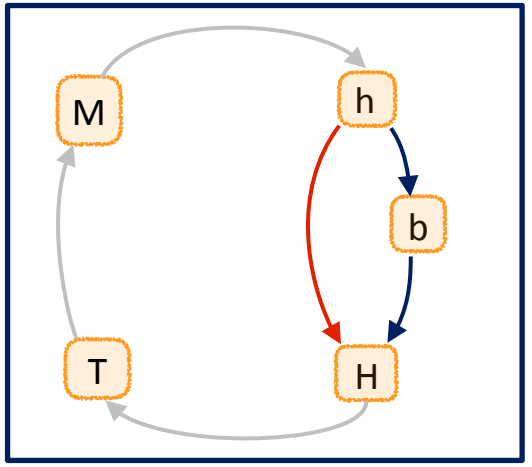
At a glance

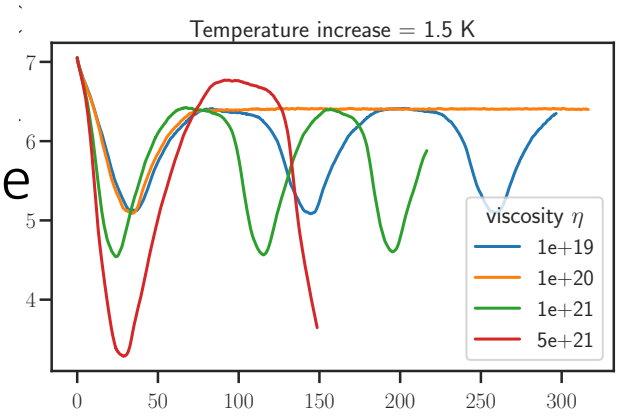
What?

» We explore the interplay of the ice-load bedrock-uplift feedback and warming air temperatures onto the dynamics of the Greenland Ice Sheet



Main finding

» We find self-sustained oscillations of the ice sheet volume on the time-scale of several millennia



How?

» Simulation of the Greenland Ice Sheet with the Parallel Ice Sheet Model (PISM) with a constant air temperature anomaly

PISM
Parallel Ice Sheet Model

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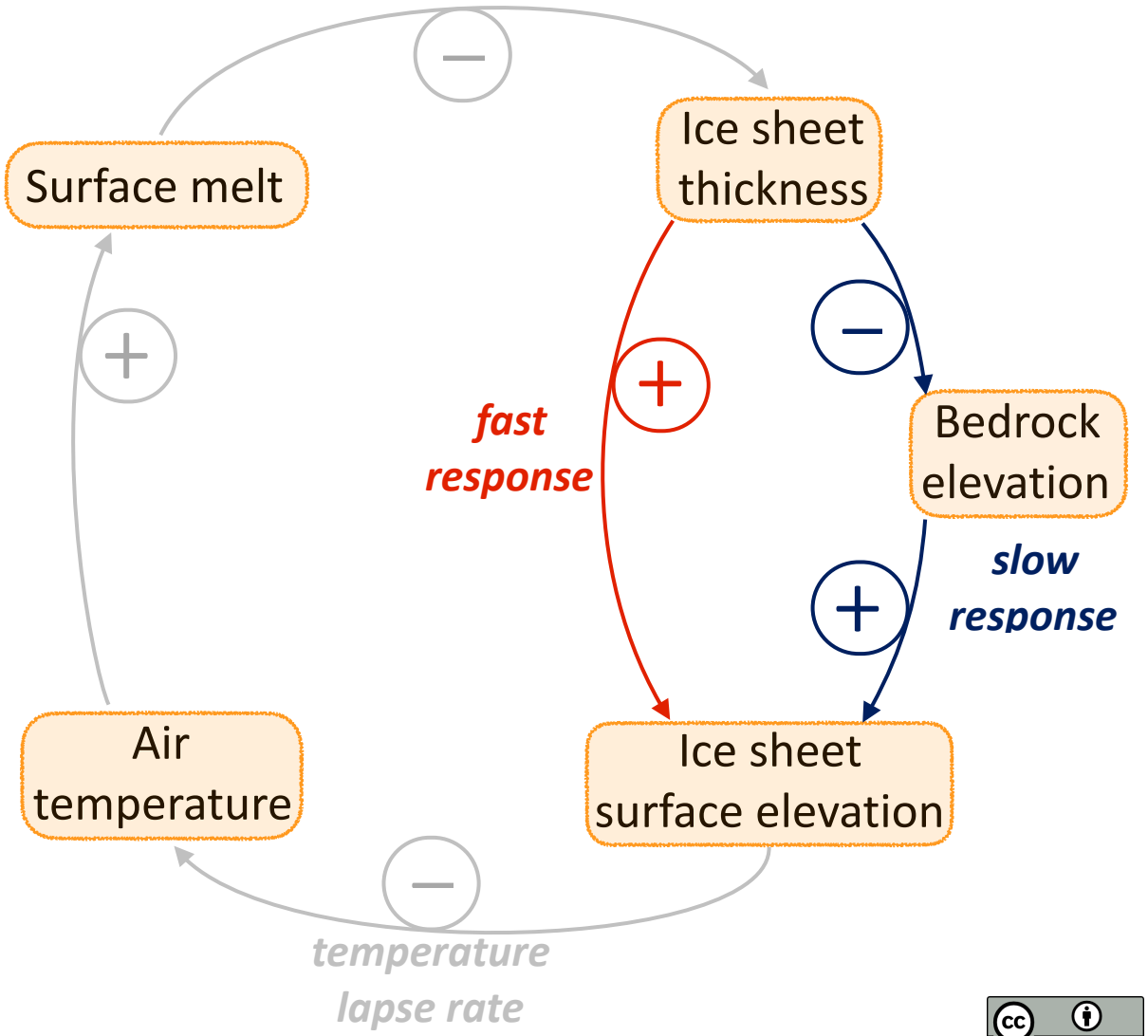
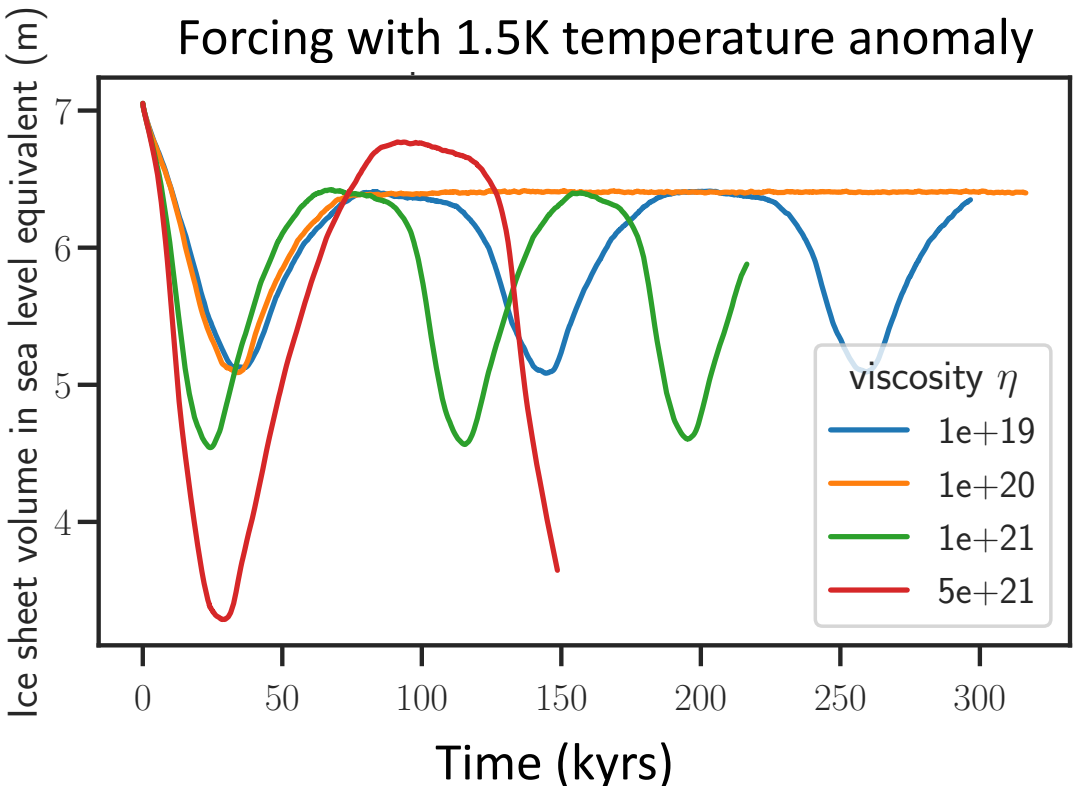
The ice-load bedrock-uplift feedback

- negative ice-load bedrock-uplift feedback mitigates positive melt-elevation feedback
- Ice-load bedrock-uplift feedback acts on long timescales, up to several millennia
- Interplay can create self sustained oscillations



Self-sustained oscillations of ice volume over many millennia

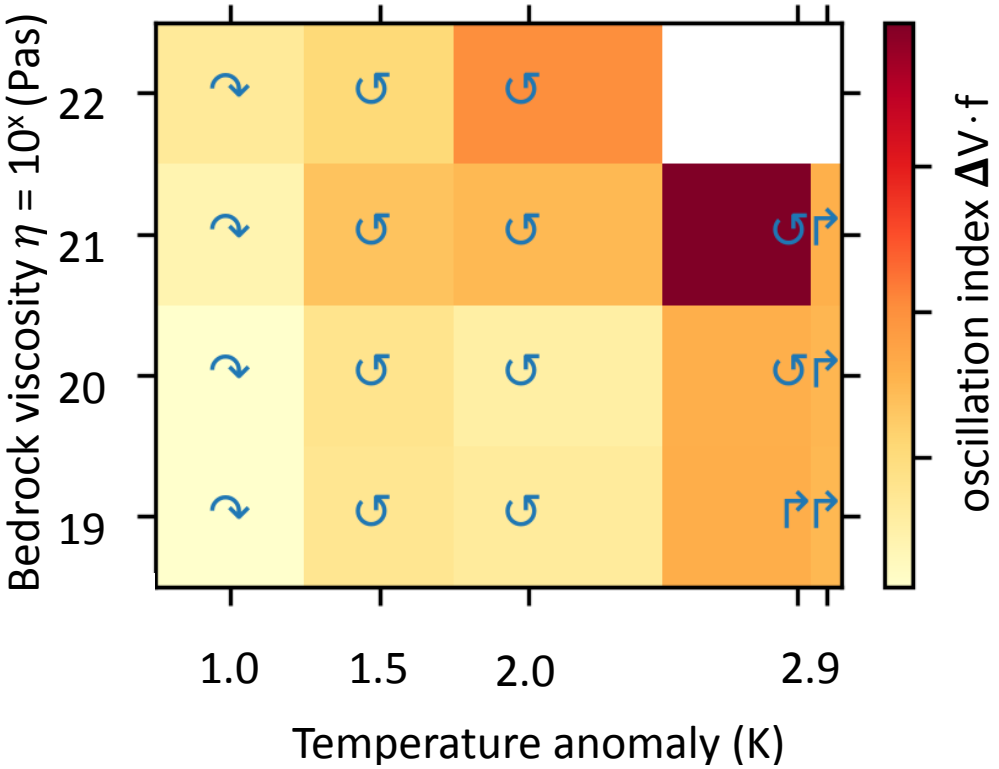
- Under constant warming on multi-millennial time scale volume of the ice sheet volume shows
  - retreat (at higher temperatures)
  - retreat and recovery (orange curve)
  - self-sustained oscillations
- bedrock viscosity η and warming temperature govern dynamics



Time evolution of the volume of the Greenland Ice Sheet in sea level equivalent with a temperature forcing of 1.5K and different bedrock viscosities η

Amplitude and period of oscillations depend on bedrock viscosity and warming temperature

- bedrock viscosity η and warming temperature govern ice-volume dynamics
- low forcing temperatures: retreat and recovery
- high forcing temperatures: permanent retreat



Oscillation behavior of the Greenland Ice Sheet. The oscillation index is measured as a product of amplitude (maximal - minimal ice volume) and oscillation frequency. Symbols indicate recovery, oscillation and permanent retreat of the ice sheet

Simulations with ice-sheet model PISM

- code version: PISM stable v1.1-6
- resolution: 15 km
- viscoelastic bedrock deformation: Lingle & Clark model
- temperature anomaly: step forcing, uniform in time and space
- lapse rate correction: 6 K/km
- melting: positive degree day melt module
- ice dynamics: shallow-ice and shallow-shelf approximation
- initialization: simulations start from a present-day like equilibrium state

C. S. Lingle and J. A. Clark. J., Geophys. Res., 1985.
Winkelmann, R. et al., The Cryosphere, 2011.

Conclusions

- The retreat of an ice sheet under temperature forcing can be mitigated by the bedrock uplift which reduces air temperatures and can initiate a re-advance of the ice
- Depending on the temperature anomaly and the viscosity of the bedrock the ice sheet volume can recover, show self-sustained oscillations or undergo permanent retreat
- The amplitude and frequency of oscillations in the ice volume depends on bedrock viscosity and temperature anomaly
- Oscillations only appear for forcing temperature anomalies between 1.5 and 2.9°C (in our setting), time scales of retreat may play an important role

Did you ever observe a similar behavior?

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