The sensitivity of the Greenland ice sheet to glacial-interglacial oceanic forcing

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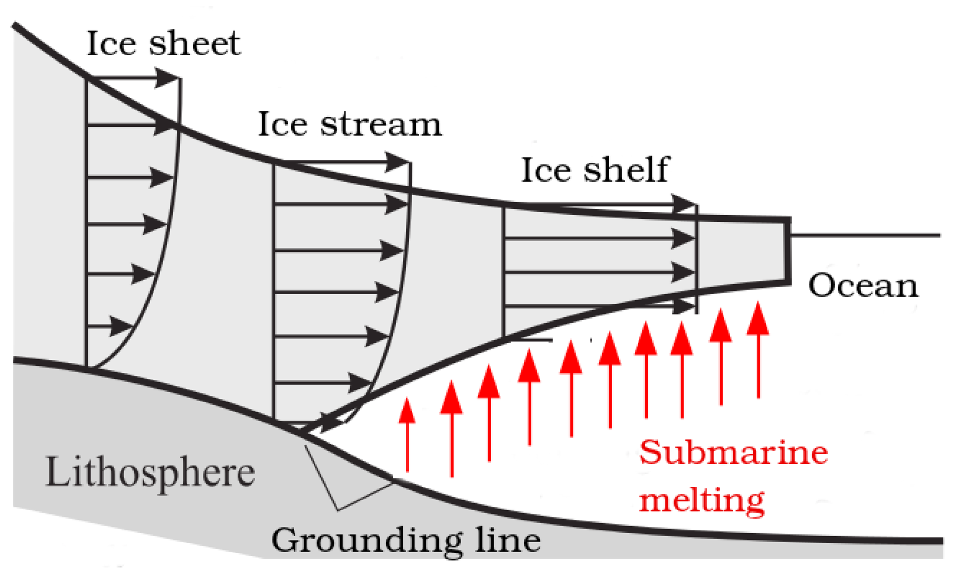
Introduction

Recent observations and reconstructions suggest that the ice-ocean interaction is a primary driver of the evolution of the Greenland Ice Sheet (GrIS). This is especially relevant in glacial periods, when the fully-marine based GrIS is more exposed to ocean changes. However, up to now, the scientific community has mainly focused on the sensitivity of the GrIS to atmospheric variations. Here, for the first time, we study the response of the GrIS to past oceanic changes over the last two glacial cycles using an ice-sheet-shelf model.

GRISLI-UCM model



- 3D hybrid ice-sheet-shelf model (based on GRISLI model) developed in our research group.
- Combination of SIA (ice sheet) and SSA (ice stream and ice shelf) approxim.

- Atmospheric forcing applied

$$T_{atm} = T_{ref} + \Delta T_{atm}$$
$$\Delta T_{atm} = (1-\alpha)\,(T_{LGM,atm} - T_{PD,atm})$$

- Oceanic forcing applied at the grounding line (***submarine melting rate parameterisation***)

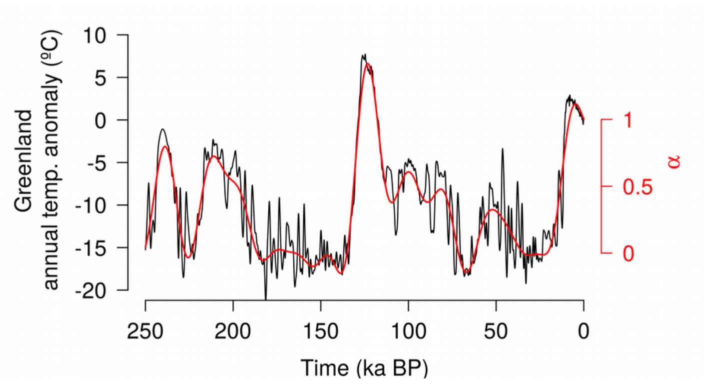
$$B_{gl} = B_{ref} + \kappa\, \Delta T_{ocn}$$
$$\Delta T_{ocn} = (1-\alpha)\,(T_{LGM,ocn} - T_{PD,ocn})$$

B_{ref} assumed present-day submarine melting rate around GrIS

κ heat-flux coefficient (sensitivity to oceanic forcing)

ΔT_{ocn} temporal evolution of the oceanic temperature

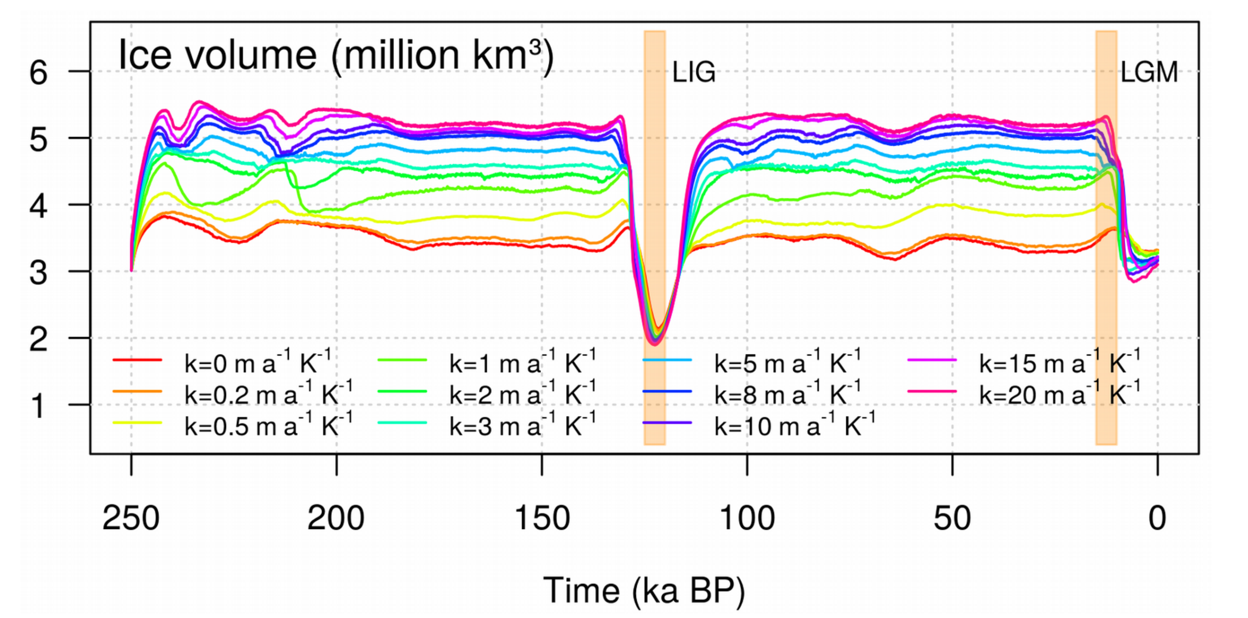
Climatic index α used for both atmosphere and ocean is built through a multi-proxy approach.



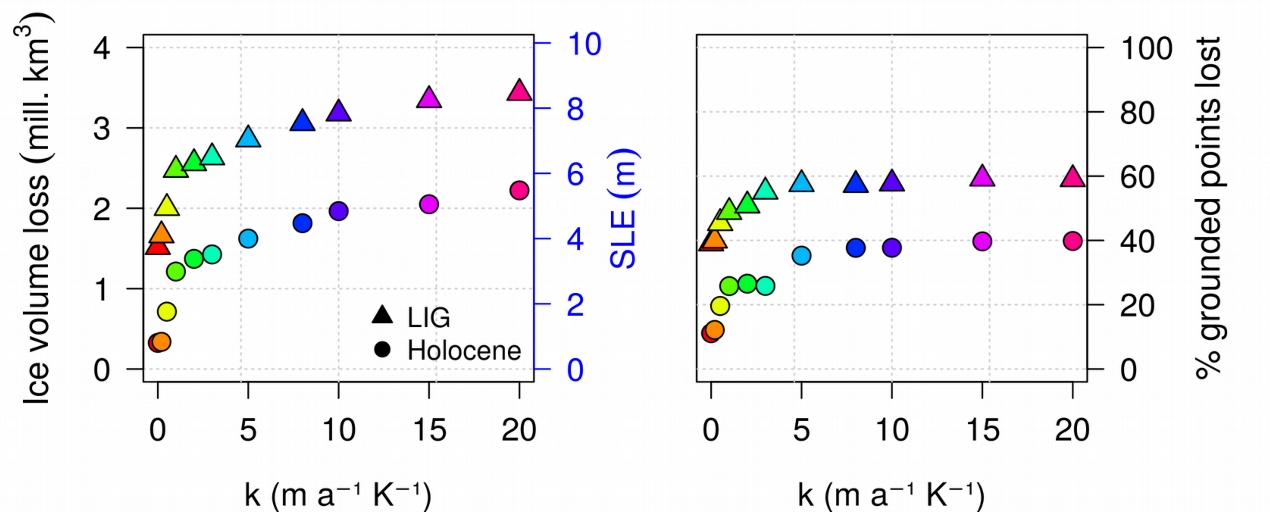
Experimental design

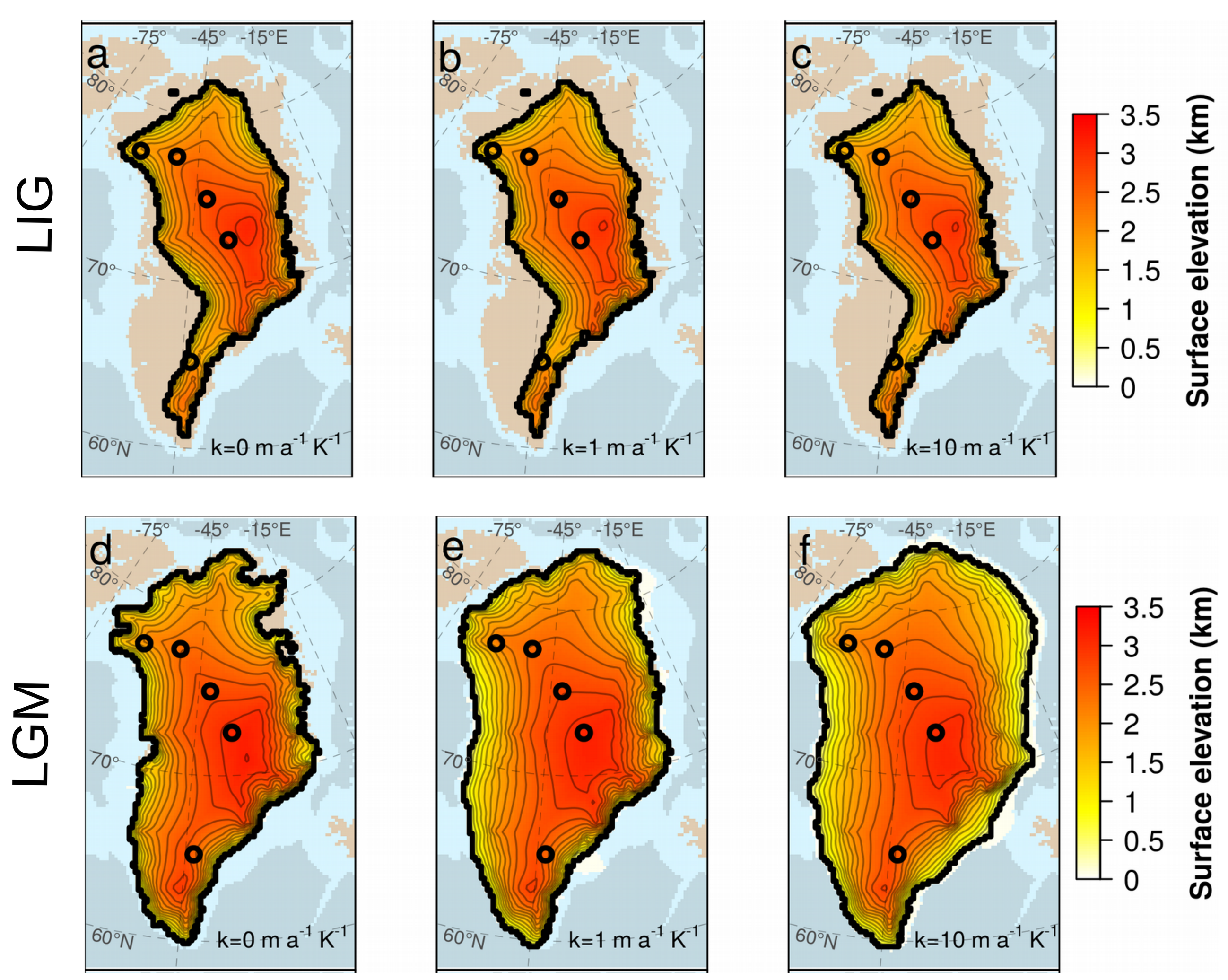
	Parameters	Values	Units
Atmospher. forcing	T_{ref}	RCM MAR v3.5	K
	$T_{LGM,atm}$	Climber 3α	K
	$T_{PD,atm}$	Climber 3α	K
Oceanic forcing	B_{ref}	1	$m\,a^{-1}$
	k	0, 0.2, 0.5, 1, 2, 3, 5, 8, 10, 15, 20	$m\,a^{-1}\,K^{-1}$
	$T_{LGM,ocn}$ - $T_{PD,ocn}$	-3	K

Results



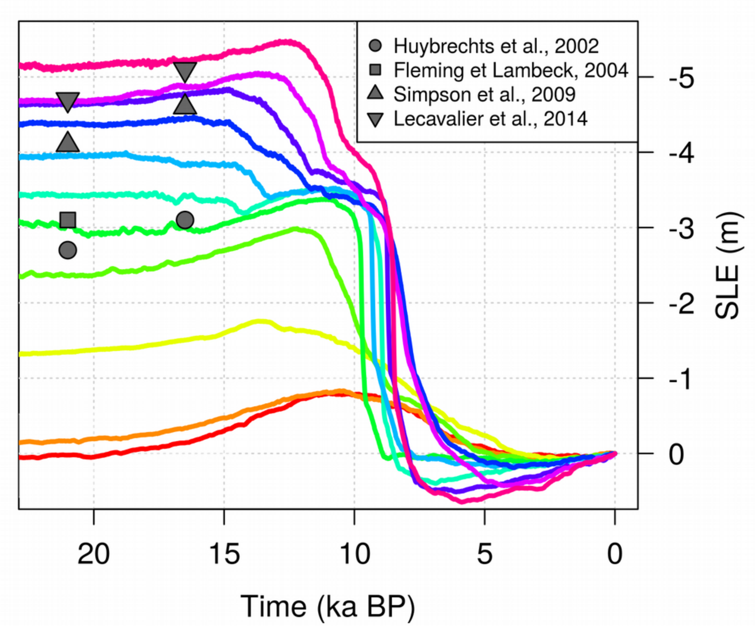
- Glacial ice volume increases for increasing k.
- The oceanic sensitivity affects the ice growth in glacials much more than the ice loss during deglaciations.
- The ice loss during the deglaciations monotonically increases with increasing κ.

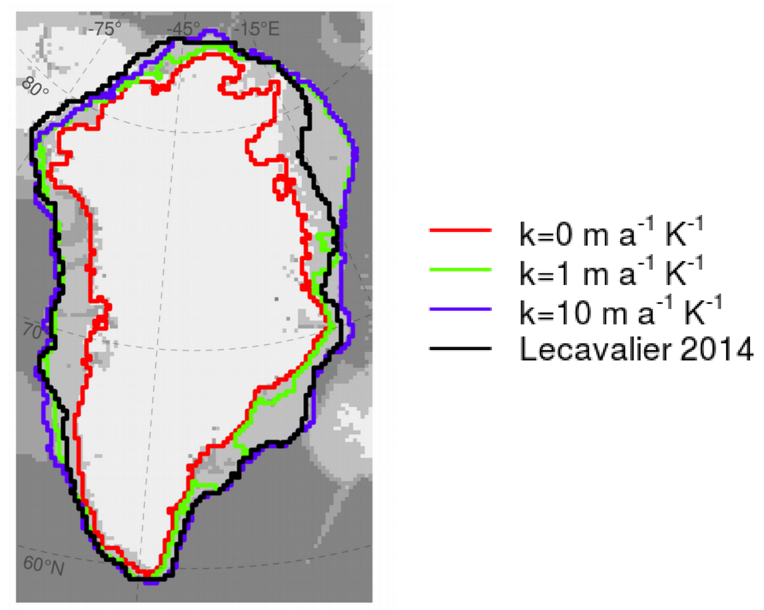




- The retreat in warm periods (LIG) is less sensitive to ocean changes.
- Shutting down the oceanic forcing (k=0), the glacial GrIS is constrained to the present-day coastlines.
- By increasing the magnitude of k, the GrIS is able to expand towards the continental shelf break.

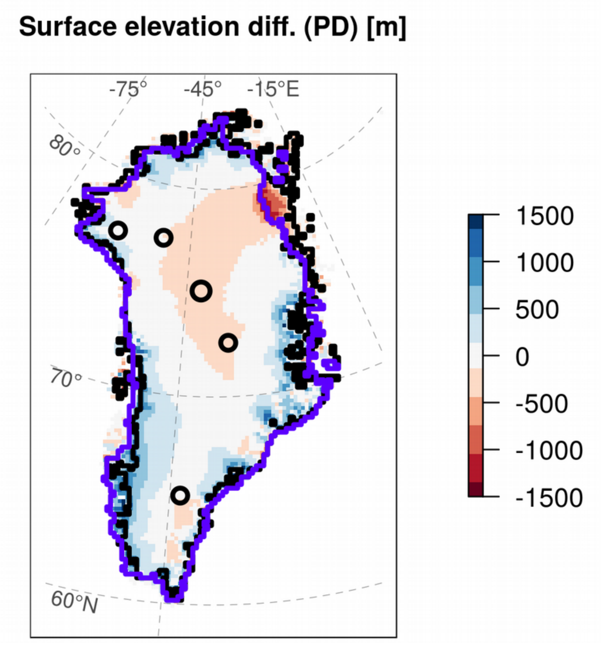
LGM GrIS





Our LGM simulations show GrIS volume and extent comparable to other ice-sheet model reconstructions only for high oceanic sensitivities.

Present-day GrIS



Good agreement between the simulated present-day ice volume and observations (Bamber et al., 2013)

Conclusions

- Oceanic sensitivity of the paleo GrIS is studied for the first time from a modeling perspective.
- Oceanic forcing primarily drives the GrIS glacial advance.
- Atmospheric forcing alone is not capable of accounting for the expected evolution of the GrIS.
- The oceanic component should be included as an active forcing in paleo ice sheet models.

References

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