E-post: kerim@uib.no

Melting of Northern Greenland during the last interglacial

Kerim H. Nisancioglu[1,2,3] and Andreas Born[4,5]

[1]Bjerknes Centre for Climate Research [2]Department of Earth Sciences, Univeristy of Bergen [3]UNI Research AS, Bergen, Norway
[4]Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland [5]Oeschger Centre for Climate Change Research, Bern, Switzerland

ABSTRACT

The Greenland ice sheet (GrIS) is losing mass at an increasing rate, making it the primary contributor to global eustatic sea level rise. Large melting areas and rapid thinning at its margins has raised concerns about its stability. However, it is conceivable that these observations represent the transient adjustment of the fastest reacting parts of the ice sheet, masking slower processes that dominate the long term fate of the GrIS and its contribution to sea level rise.

Using simulated climate data from the comprehensive coupled climate model IPSL CM4, we simulate the Greenland ice sheet (GrIS) during the Eemian interglaciation with the three- dimensional ice sheet model SICOPOLIS. The Eemian is a period 126,000 years before present (126 ka) with Arctic temperatures comparable to projections for the end of this century. In our simulation, the northeastern part of the GrIS is unstable and retreats significantly, despite moderate melt rates. This result is found to be robust to the perturbation of five key parameters of the ice sheet model and the choice of initial ice temperature, and has been reproduced with climate forcing of a second coupled climate model, CCSM3. It is shown that the northeast is the most vulnerable part of the GrIS because even a small increase in melting potentially removes many years of ice accumulation, thus represents a large imbalance and triggers the potent ice-elevation feedback. Unlike the south and west, melting in the northeast is not compensated by high accumulation. The analogy with modern warming suggests that in coming decades, positive feedbacks could increase the rate of mass loss of the northeastern GrIS, exceeding the currently observed melting in the south.

OBSERVATIONS:

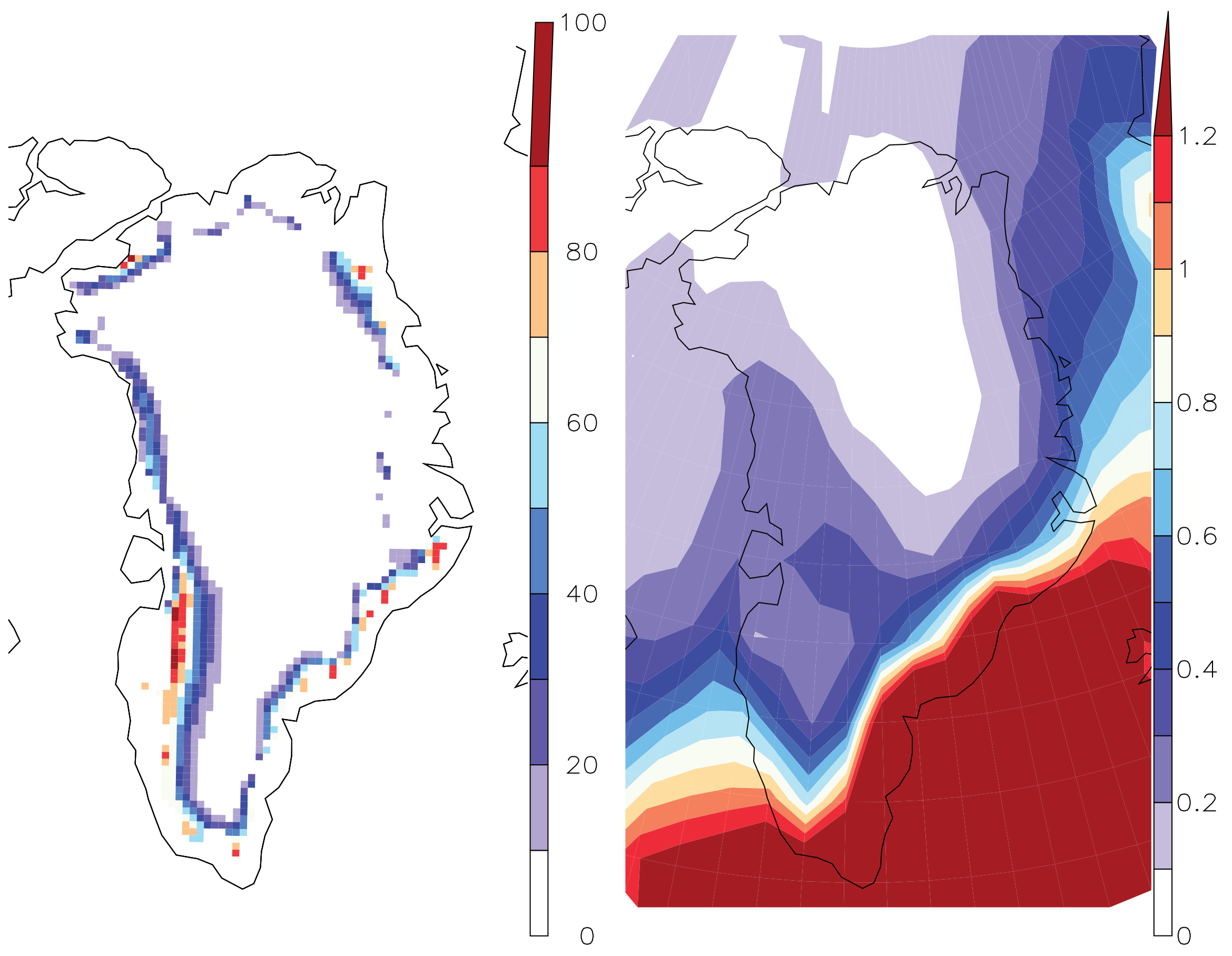

Figure 1. Observed average duration of melt season in 1979-2007 (left, in days) (Abdalati, 2007), and average winter (DJF) precipitation in 1958-2001 from ERA-40 (right, in m/yr). As in the south, the northeastern region of the ice sheet shows a long melt season. Unlike regions in the south, however, the northeast receives very little precipitation to balance the melting.

SIMULATED TEMPERATURE AND PRECIPITATION:

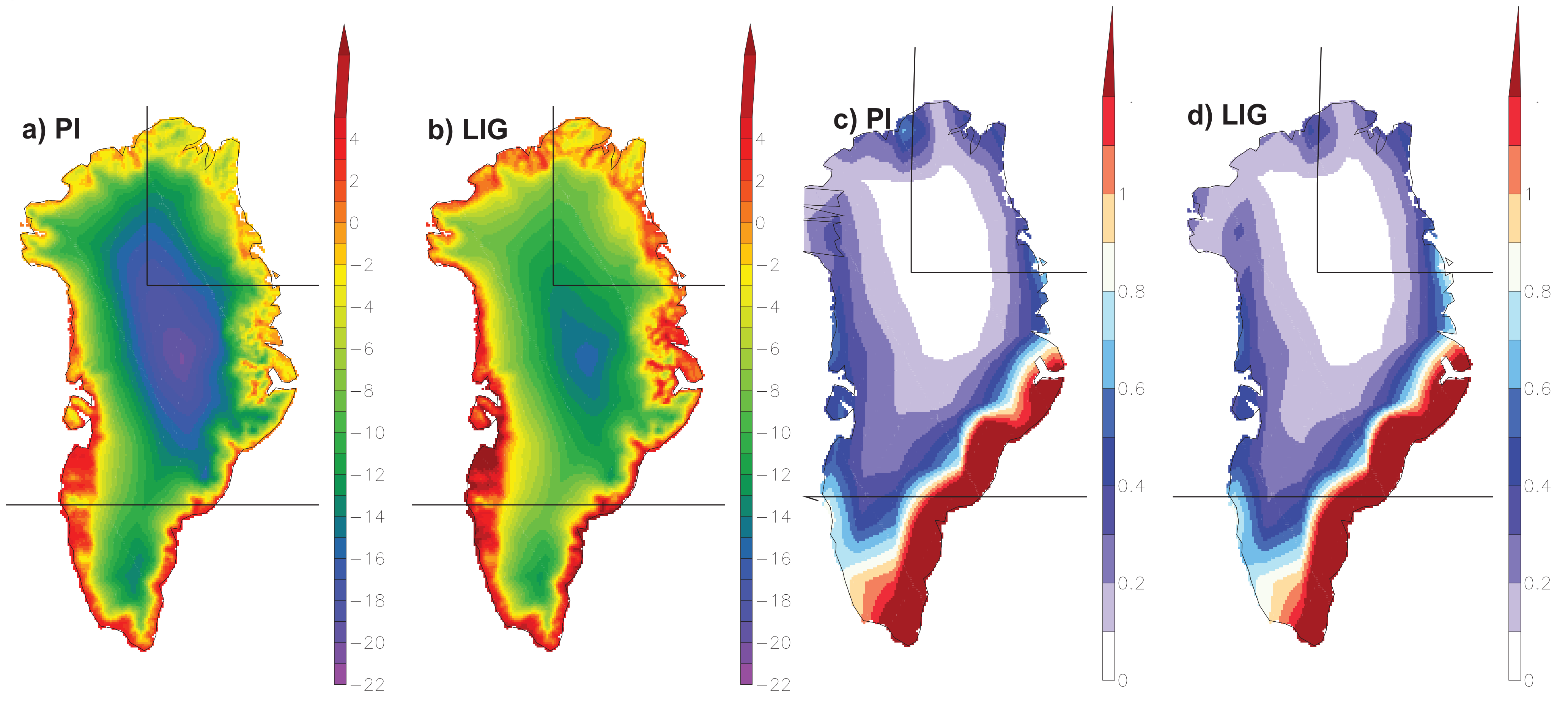

Figure 2. Seasonal averages of forcing fields from IPSL CM4, interpolated onto the ice sheet model grid. Temperature data has been corrected with a fixed lapse rate of -6.5 K/km to adjust for height differences between ice sheet and climate model. a) Summer (JJA) surface temperature for preindustrial climate (0 ka, in ◦C), b) JJA surface temperature for 126 ka (in ◦C), c) Winter (DJF) precipitation for 0 ka (in m/yr), d) DJF precipitation for 126 ka (in m/yr).

SIMULATED ICE THICKNESS:

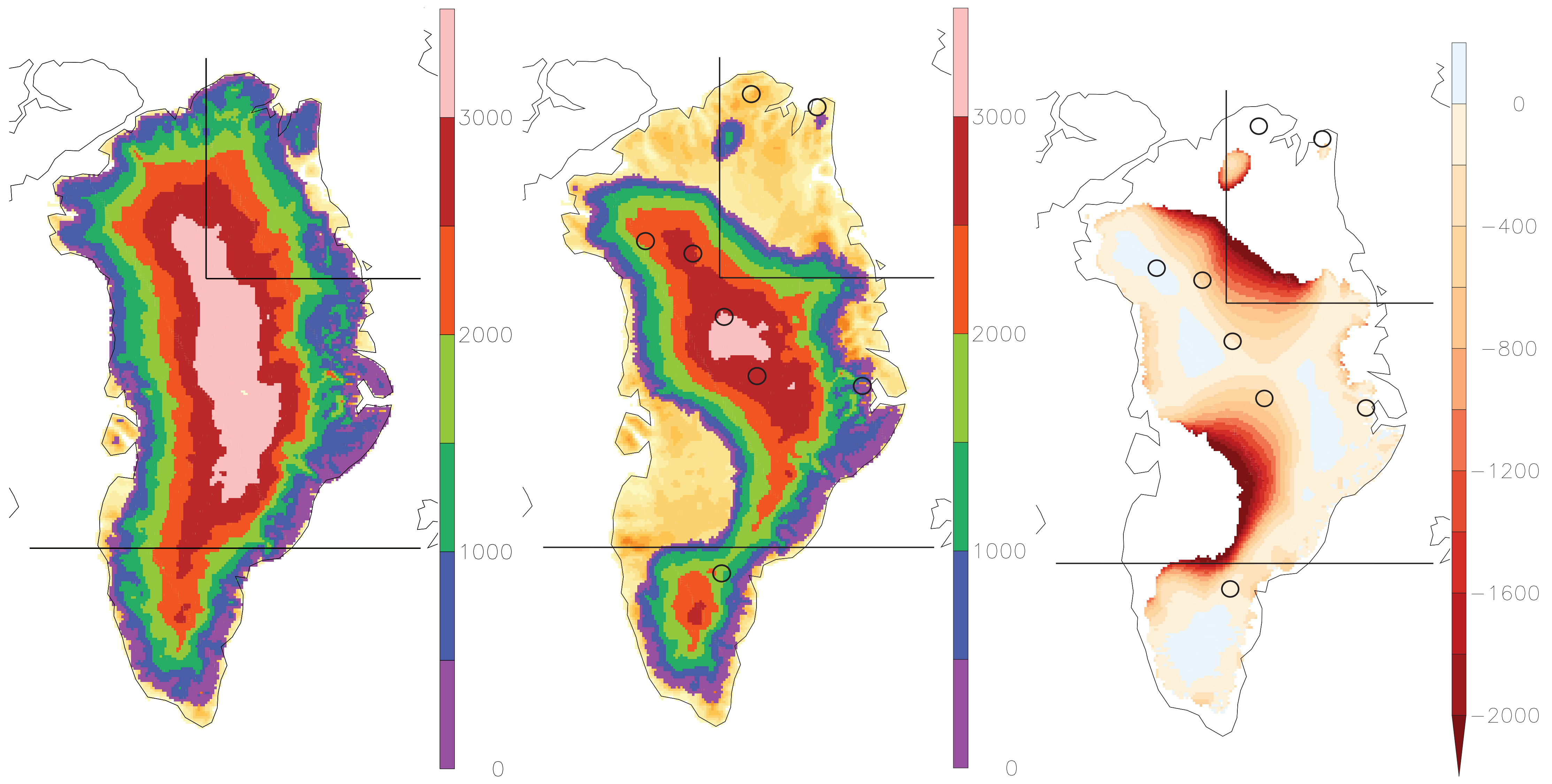

Figure 3. Modelled ice thickness (in m) after 10,000 years of simulation with preindustrial forcing (left) and after 6,000 years with 126 ka forcing (middle). Difference in ice thickness 126 ka - 0 ka right. Regions defined for this study are separated by bold black lines. Circles show locations of ice core sites (from north to south: Hans Tausen Iskappe, Flade Isblink, Camp Century, NEEM, NGRIP, GRIP, Renland, Dye-3). Preindustrial ice area and thickness are well reproduced. With 126 ka forcing, the Greenland ice sheet melts mostly from the northeast and southwest. The southern dome does not disappear.

SENSITIVITY STUDY:

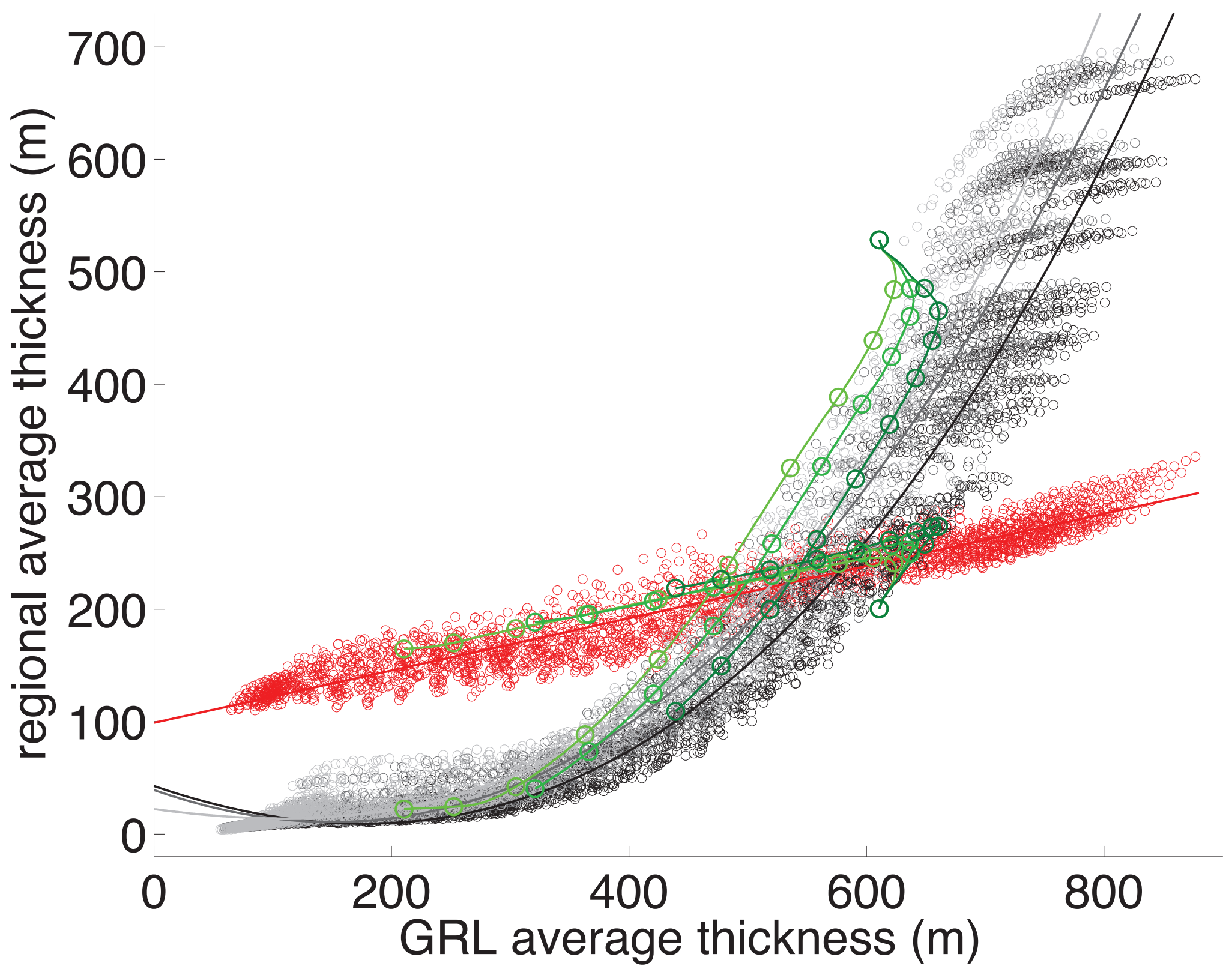

Figure 4. Simulated average ice thickness in northeastern (gray, black) and and southern (red) regions, as a function of the average ice thickness of the entire ice sheet, for 126 ka in IPSL CM4. Each data point corresponds to one of 15,552 ensemble members with a different set of parameters, run for 10,000 years. Different ice initial temperatures are highlighted for northeastern Greenland in light gray (-30◦C), gray (-40◦C) and black (-50◦C). Polynomial fits of first and third order are included for visibility. The transient evolution of the simulation of figure 5 is shown in green with circles spaced every 1000 years and ice initial temperature represented in color brightness as before. Ice thickness in northeastern Greenland responds rapidly to a reduction in total ice thickness, while ice in southern Greenland is more stable.

Acknowledgements. We gratefully acknowledge Ralf Greve for public availability and comprehensive documentation of SICOPOLIS, Pascale Braconnot for providing data of IPSL CM4. Our work greatly benefited from discussions with Sigfus Johnsen and Bette Otto-Bliesner,