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Different present-day geothermal heat flux scenarios for the case of the Greenland Ice Sheet

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Heat entering large ice sheets and glaciers from the underlying bedrock controls the thermal regime of the basal ice layers in terms of basal melting, the formation of basal temperate ice layers and its influence on sliding processes. In this study, we estimate the effect of the uncertainties in geothermal heat flux (GHF) on the topography, dynamics and basal thermal conditions of simulations of the present-day Greenland Ice Sheet (GIS), using the dynamic polythermal ice-sheet model SICOPOLIS. Today's GHF at the base of the GIS has been measured at only the locations of the deepest ice cores. It should therefore be considered as highly uncertain forcing component for the dynamic modeling of the major part of the GIS.

Three GHF models are applied as lithosphere boundary conditions driving a series of paleoclimatic simulations. The first is based on a 3-D global seismic model of the crust and upper mantle, constrained in regions where heat-flow measurements are available. The other two models are based on tectonic regionalization and a combination of tectonic regionalization and deep ice-core measurements. Although the tectonic regionalization model was originally taken as a starting point for both the seismic mantle/crust and tectonic/ice-core GHF models, the resulting heat flow distributions across the extent of the GIS differ significantly, not only by the mean values but also by their spatial patterns. As a consequence, the present-day GIS driven by the seismic GHF model is 450 meters thicker in the northern and central parts of the GIS, and 450 meters thinner in the southern part relative to the GIS forced by the tectonic/ice-core GHF model. In addition, the horizontal ice transport simulated using the seismic GHF model is 10-50% higher in the northern and western GIS, and 10-30% lower in the southern and eastern GIS than the transport resulting from the simulation driven by the tectonic/ice-core GHF model. These alterations in the GIS topography and horizontal transport induced by the two latter simulations with respect to the simulation driven by the tectonic regionalization model have the opposite tendencies.

Finally, we discuss different scenarios of the evolution of the temperate base in the ice-sheet simulations driven by the seismic-based, tectonic regionalization and tectonic/ice-core GHF models. The modeled present-day temperate ice areas with non-zero basal melting cover 34%, 40.6% and 56.8% of the ice-covered area, respectively, for each of the GHF models examined. The minimum coverage of the temperate ice is reached shortly after the last glacial maximum and amounts to less than 20% of the ice-covered area, as determined using the seismic and tectonic GHF models, and about 40% when employing the tectonic/ice-core model. Although the response of the modeled ice-sheet to changing basal conditions may be influenced by the limitations in the classical polythermal approach used in SICOPOLIS (neglecting water diffusivity), we may conclude that the modeled present-day thermodynamical state of the GIS is largely sensitive to the GHF model employed.