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The effects of the uncertainties in geothermal heat flux distribution on the present-day Greenland Ice Sheet

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The thermodynamic state of basal ice layers determines to a large extent the overall dynamic behavior of grounded ice masses, especially by (i) the formation of basal temperate ice that undergoes enhanced deformation, and (ii) by the process of basal melting, which controls sliding processes and most basal transport phenomena. One of major uncertainties in understanding the basal thermal conditions of the Greenland Ice Sheet (GIS) originates from our poor knowledge of the geothermal heat flux (GHF) that enters basal ice layers from the underlying bedrock. This study analyzes the range of results that arise from the models of the present-day GIS due to ill-constrained GHF distribution in the Greenland region. Within the context of dynamic GIS modeling, we consider the following questions: (i) What is the significance of the differences between the existing GHF models for thermomechanical ice-sheet modeling studies dealing with the past evolution and present-day state of the GIS? (ii) How well do paleoclimatic simulations controlled by each GHF model agree with the today's knowledge of the GIS's thermal state and thickness? (iii) What portion of the misfit between the ice-sheet model results and observations can be attributed to other source of uncertainties, namely the GIS history. In order to answer these questions, we consider three GHF models available in the published literature, based on the tectonic-regionalization model (Pollack et al. [1993]), seismic-tomography model (Shapiro and Ritzwoller [2004]) and magnetic-data model (Fox Maule et al. [2009]) and use these models to force paleoclimatic ice-sheet simulations throughout the last 150 thousand years of the GIS history. From the results of paleoclimatic simulations and sensitivity experiments, we conclude that differences in the GHF maps have a major effect on the history and present-day state of the GIS, exerting a strong influence on the evolution and current thermal regime of its basal layer. The ice-sheet model controlled by any of these GHF forcings reproduces the observed GIS thickness and measured temperature profiles to only a limited degree, and fails to reproduce either the topography or the low basal temperatures measured in southern Greenland. An extensive series of sensitivity tests reveals that the failure of the ice-sheet model in southern Greenland in fact originates to a large extent from the exaggerated GHF values suggested by all existing GHF models. Although the effects of uncertainties in the past climate forcing have non-negligible implications on the overall thermal state of the modeled present-day GIS, they can explain only a part of the misfit between the modeled and measured basal temperatures and basal temperature gradients.