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# Applicability and limitations of large-scale ice-sheet modeling for constraining subglacial geothermal heat flux

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In recent years, a number of studies have addressed the problem of constraining subglacial geothermal heat flow (SGHF) patterns within the context of thermodynamic ice-sheet modeling. This study reports on the potential of today's ice-sheet modeling methods and, more importantly, their limitations, with respect to reproducing the thermal states of the present-day large-scale ice sheets. So far, SGHF-related ice-sheet studies have suggested two alternative approaches for obtaining the present-day ice-sheet temperature distribution: (i) paleoclimatic simulations driven by the past surface temperature reconstructions, and (ii) fixed-topography steady-state simulations driven by the present-day climate conditions. Both approaches suffer from a number of shortcomings that are not easily amended. Paleoclimatic simulations account for past climate variations and produce more realistic present-day ice temperature distribution. However, in some areas, our knowledge of past climate forcing is subject to larger uncertainties that exert a significant influence on both the modeled basal temperatures and ice thicknesses, as demonstrated by our sensitivity case study applied to the Greenland Ice Sheet (GIS). In some regions of the GIS, for example southern Greenland, the poorly known climate forcing causes a significant deviation of the modeled ice thickness from the measured values (up to 200 meters) and makes it impossible to fit the measured basal temperature and gradient unless the climate history forcing is improved. Since present-day ice thickness is a product of both climate history and SGHF forcing, uncertainties in either boundary condition integrated over the simulation time will lead to a misfit between the modeled and observed ice sheets. By contrast, the fixed-topography steady-state approach allows one to avoid the above-mentioned transient effects and fit perfectly the observed present-day ice surface topography. However, the temperature distribution resulting from steady-state simulations strongly depends on the choice of the present-day climate forcing. Thus, employing average temperature/precipitation forcings from either the end of the 20th century or the beginning of the 21st century leads to differences of 5-10 mW/m2 in the predicted SGHF values. Regardless of the climate forcing employed, a close match between the measured and modeled basal temperatures can be easily achieved by varying the SGHF forcing. Yet this approach fails to reproduce the shape of measured temperature profiles, nor the measured basal temperature gradients. We conclude that a use of steady-state simulations is unlikely to lead to correct estimations for SGHF values, whereas paleoclimatic simulations are potentially capable of producing quantitative estimations of the SGHF distribution, depending on the quality of the climate forcing.