Session: C30 Poster: W63B

Dependence of results from dynamic Greenland ice sheet models on subscale glacier bed topography and its representation

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Dynamic ice sheet models are used to estimate the contribution of mass loss from the Greenland ice sheet. Mass transfer from ice sheet to ocean is to a large part through outlet glaciers through calving and melt-water processes. Outlet glaciers have a higher velocity than the inland ice and are more sensitive to climatic change than other parts of the Greenland ice sheet. Bed topography plays an important role in ice dynamics, since the acceleration from the slow-moving inland ice to the formation of an ice stream is in many cases caused by the existence of a subglacial trough. A problem lies in the fact that subglacial troughs of most outlet glaciers are features of a scale that is not resolved in most ice sheet models. In this paper we investigate and compare algorithms that allow inclusion of subscale topographic features, especially troughs and generalized troughs, in spatial models of the Greenland bed topography. The problem relates to cartographic generalization, fractal geometry, mathematical morphology, topology and geostatistics. Radar measurements of bed topography collected by the Center of Remote Sensing of Ice Sheets as part of NASA's Operation IceBridge and other survey campaigns are used to improve the Greenland bed. Studies of the sensitivity of model variables, including surface velocity and strain rates, surface mass balance, surface elevation and basal temperature, to bed topographic models are presented for several dynamic ice sheet models. Results indicate that correct representation of bed topography is essential to modeling ice flow, elevation and mass changes, and hence to assess possible sea-level rise. More generally, this study helps to bridge the conceptual gap between data analysis and geophysical modeling approaches in an important question of ice-ocean interaction.