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Melting beneath Greenland outlet glaciers and ice streams

David Alexander, Mahé Perrette, and Johanna Beckmann
Potsdam Institute for Climate Impact Research, Potsdam, Germany (David.Alexander@pik-potsdam.de)

Basal melting of fast-flowing Greenland outlet glaciers and ice streams due to frictional heating at the ice-bed interface contributes significantly to total glacier mass balance and subglacial meltwater flux, yet modelling this basal melt process in Greenland has received minimal research attention. A one-dimensional dynamic ice-flow model is calibrated to the present day longitudinal profiles of 10 major Greenland outlet glaciers and ice streams (including the Jakobshavn Isbrae, Petermann Glacier and Helheim Glacier) and is validated against published ice flow and surface elevation measurements. Along each longitudinal profile, basal melt is calculated as a function of ice flow velocity and basal shear stress. The basal shear stress is dependent on the effective pressure (difference between ice overburden pressure and water pressure), basal roughness and a sliding parametrization.

Model output indicates that where outlet glaciers and ice streams terminate into the ocean with either a small floating ice tongue or no floating tongue whatsoever, the proportion of basal melt to total melt (surface, basal and submarine melt) is 5–10% (e.g. Jakobshavn Isbrae; Daugaard-Jensen Glacier). This proportion is, however, negligible where larger ice tongues lose mass mostly by submarine melt (∼1%; e.g. Nioghalvfjerdsfjorden Glacier). Modelled basal melt is highest immediately upvalley of the grounding line, with contributions typically up to 20–40% of the total melt for slippery beds and up to 30–70% for resistant beds. Additionally, modelled grounding line and calving front migration inland for all outlet glaciers and ice streams of hundreds of metres to several kilometres occurs. Including basal melt due to frictional heating in outlet glacier and ice stream models is important for more accurately modelling mass balance and subglacial meltwater flux, and therefore, more accurately modelling outlet glacier and ice stream dynamics and responses to future climate change.