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Integrated investigation of subglacial hydrology and convective plume melting using a 3D full-Stokes model of Store Glacier, West Greenland

Samuel Cook (1), Poul Christoffersen (1), Joe Todd (2), Donald Slater (3), and Nolwenn Chauché (4)

(1) Scott Polar Research Institute, University of Cambridge, Cambridge, United Kingdom, (2) Department of Geography and Sustainable Development, University of St Andrews, (3) Scripps Institution of Oceanography, USA, (4) Access Arctic, Le Vieux Marigny 58160 Sauvigny les Bois, FRANCE

The structure of subglacial hydrological drainage systems beneath large Greenlandic tidewater glaciers influences ice velocity due to its effect on basal traction, and it may also influence calving by its control on melting at the ice-ocean interface. Understanding these systems is critical to being able to accurately predict the evolution of the Greenland Ice Sheet and the resulting sea-level rise, as the fifteen largest Greenland outlet glaciers are responsible for 77% of the additional mass loss from the ice sheet due to acceleration since 2000. In this study, we use numerical modelling and observations of Store Glacier in West Greenland to constrain the form of the subglacial drainage system and melt rates from the resulting plumes, both of which are poorly known.

We investigate the evolution of Store Glacier's subglacial hydrology using the open-source, full-Stokes model Elmer/Ice in a novel 3D application, the GlaDS hydrological module, which includes a distributed sheet and the ability to form concentrated channels when the sheet locally reaches sufficient thickness to initiate melting in cavities. At first, we produce a baseline winter scenario in which the hydrological system contains only basally derived meltwater produced primarily from friction at the bed. We then investigate the hydrological system during summer, focussing specifically on 2012 and 2017, which provide examples of high and low inputs of surface meltwater, respectively. When the model is forced with constant average runoff from summer (Jun-Aug) 2012, outputs show a hydrological system with significant sheet activity extending 55km inland and channels with a cross-sectional area higher than 1 m2 forming up to 45 km from the margin. However, we also find the hydrological system to be active in winter, when significant sheet flux is evident up to 35 km inland, and channels form as far as 25 km inland. The discharge of meltwater into the fjord produces convective plumes throughout the year, and these drive average submarine ice-front melt rates of up to 0.15 m d-1 in summer and 0.12 m d-1 in winter, rising to 1.6 m d-1 and 1.07 m d-1 , respectively, for average temporal maximum melt rates. When the model is forced with daily time-series of summer runoff, we find a higher intensity of plume melting, reaching 0.16 m d-1 on average (rising to 2.21 m d-1 for the average temporal maximum). Our study shows that plume-induced ice-front melting is substantial even in winter, and we hypothesise that the high spatial variability and intensity during summer may drive calving through plume-induced notches cutting into the ice front as well as by undercutting of the terminus as a whole.