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A 3D full-Stokes model of Store Glacier, Greenland, with coupling of ice flow, subglacial hydrology, submarine melting and calving

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Tidewater glaciers are complex systems, which present numerous modelling challenges with regards to integrating a multitude of environmental processes spanning different timescales. At the same time, an accurate representation of these systems in models is critical to being able to effectively predict the evolution of the Greenland Ice Sheet and the resulting sea-level rise. In this study, we present results from numerical simulations of Store Glacier in West Greenland that couple ice flow modelled by Elmer/Ice with subglacial hydrology modelled by GlaDS and submarine melting represented with a simple plume model forced by hydrographic observations. The simulations capture the seasonal evolution of the subglacial drainage system and the glacier's response, and also include the influence of plume-induced ice front melting on calving and buttressing from ice melange present in winter and spring.

Through running the model for a 6-year period from 2012 to 2017, covering both high- and low-melt years, we find inputs of surface meltwater to the subglacial system establishes channelised subglacial drainage with channels >1 m^2 extending 30-60 km inland depending on the amount of supraglacial runoff evacuated subglacially. The growth of channels is, however, not sufficiently fast to accommodate all inputs of meltwater from the surface, which means that basal water pressures are generally higher in warmer summers compared to cooler summers and lowest in winter months. As a result, the simulated flow of Store Glacier is such that velocities peak in warmer summers, though we suggest that higher surface melt levels may lead to sufficient channelisation for a widespread low-water-pressure system to evolve, which would reduce summer velocities. The results indicate that Greenland's contribution to sea-level rise is sensitive to the evolution of the subglacial drainage system and especially the ability of channels to grow and accommodate surface meltwater effectively. We also posit that the pattern of plume melting encourages further calving by creating an indented calving front with 'headlands' that are laterally unsupported and therefore more vulnerable to collapse. We validate our simulations with a three-week record of iceberg calving events gathered using a terrestrial radar interferometer installed near the calving terminus of Store Glacier.