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Scalings for subglacial discharge driven circulation in Greenland's proglacial fjords

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Around Greenland, the transport of heat and fresh meltwater between the ocean and Greenland's Ice Sheet is mediated by circulation in several hundred proglacial fjords. These fjords are long and narrow, with circulation controlled by a variety of processes. This circulation, and the resultant heat transported to the ice sheet has global implications. However, the spatial scales of these fjords means that they cannot be directly represented in global scale climate models, as currently achievable horizontal resolutions are too coarse to resolve fjords directly. Therefore, a subgrid-scale parameterization scheme is required, to include the impact of fjord circulation on Greenland's Ice Sheet in these models. The development of such a scheme requires increased theoretical understanding, with the aim of capturing the circulation response simply, over a relevant range of the parameter space.

Current climate models add freshwater runoff from Greenland's Ice Sheet into the ocean model in the surface grid cell, and do not account for the impacts of fjord circulation on melt rates at glacial termini. Therefore, we focus on predicting the depth at which fresh meltwater enters the wider ocean, and the flow structure at the ice face itself, to understand the feedback on ice melt rates. We consider a subglacial discharge driven regime, with a localised source of subglacial discharge into the fjord at the glacial grounding line. We employ a combination of computational modelling using idealised configurations in MITgcm, and theoretical explorations, to capture this circulation as simply as possible. For fjords without sills, we find that the cross-fjord integrated velocity profile at the fjord mouth echoes that at the ice face. Further, we find that a horizontal recirculation cell develops at the ice face, as the fjord responds to horizontal velocities driven by the plume itself, generating flow across the entire ice face. We use scaling laws previously developed for turbulent plumes to provide a simple prediction of the cross-fjord integrated velocity structure at the fjord mouth, predicting the depth level at which meltwater enters the wider ocean. We develop theoretical predictions for the cross-fjord flow at the ice face, as a consequence of the flow directly induced by a buoyant plume and the circulation response in the fjord, allowing prediction of the pattern of melt across the ice face.