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# A simple parameterisation of melting near the grounding lines of ice shelves and tidewater glaciers

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Both the Antarctic and Greenland ice sheets are experiencing rapid change, at least in part as a result of acceleration of some of their larger, marine-terminating outlet glaciers. It is generally assumed that the accelerations have been driven by the ocean, probably through changes in the submarine melt rate. However, the processes that drive melting, particularly in the region close to the grounding line are difficult to observer and quantify. The rapid flow of the outlet glaciers is almost always associated with an active sub-glacial hydrological system, so in the key regions where the glaciers either discharge into ice shelves or terminate in fjords there will be a flow of freshwater draining across the grounding line from the glacier bed. The input of freshwater to the ocean provides a source of buoyancy and drives convective motion alongside the ice-ocean interface. This process is modelled using the theory of buoyant plumes that has previously been applied to the study of the larger-scale circulation beneath ice shelves. The plume grows through entrainment of ocean waters, and the heat brought into the plume as a result drives melting at the ice-ocean interface. The equations are non-dimensionalised using scales appropriate for the region where the sub-glacial drainage, rather than the subsequent addition of meltwater, supplies the majority of the buoyancy forcing. It is found that the melt rate within this region can be approximated reasonably well by a simple expression that is linear in ocean temperature, has a cube root dependence on the flux of sub-glacial meltwater, and a more complex dependency on the slope of the ice-ocean interface. The model is used to investigate variability in melting induced by changes in both ocean temperature and sub-glacial discharge for a number of realistic examples of ice shelves and tidewater glaciers. The results show how warming ocean waters and increasing sub-glacial drainage both generate increases in melting near the grounding line. The model is particularly appropriate for the study of melting at the quasi-vertical calving face of a tidewater glacier, where conventional ocean models struggle to capture the appropriate scales and fundamentally non-hydrostatic dynamics.