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The impact of ocean temperature and salinity stratification on buoyancy-driven meltwater flows next to ice shelves and glacier termini

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Melting of the undersides of floating ice shelves can impact the dynamics of ice flow, and this presents the challenge of modelling coupled ice-shelf and ocean interactions to achieve well-quantified predictions of sea level rise. Melting rates are controlled by the supply of heat and salt to the ice-ocean interface, which depend on both the details of turbulence and the temperature and salinity conditions in the underlying ocean. One such feedback on ice melting comes from the buoyancy-driven flow of fresh meltwater rising below the ice shelf, which shares dynamical similarities with meltwater flows rising along steep glacier termini. The strength of this flow and resulting melting rates are sensitive to the vertical stratification of temperature and salinity in the neighbouring ocean. To build theoretical insight into the role of ocean stratification, we apply a plume model to describe buoyancy-driven flow under a planar ice shelf lying above a stratified ocean. A range of background ocean temperature and salinity profiles are studied. Our plume model considers both persistent alongslope flows, or layered flows featuring multiple intrusions into the background ocean, with intrusions occurring after the plume density reaches a neutral buoyancy level compared to the background ocean density stratification. For flows with negligible subglacial discharge into a linear stratification, we develop approximate scaling laws for the dependence of melting rates on the temperature and salinity stratifications. The scaling laws are in good agreement with results from numerical simulations. Under appropriate conditions, these scaling laws may provide a computationally-efficient approximation to ice-shelf melting rates controlled by buoyancy-driven flows, in circumstances where the use of a more detailed ocean model proves impractical.