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Shear, Stability and Mixing within the Ice-Shelf-Ocean Boundary Layer

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Ocean-forced basal melting has been implicated in the widespread thinning of Antarctic ice shelves that has been causally linked with acceleration in the outflow of grounded ice. What determines the distribution and rates of basal melting and freezing beneath an ice shelf and how these respond to changes in the ocean temperature or circulation are therefore key questions.

Recent years have seen major progress in our ability to observe basal melting and the ocean conditions that drive it, but data on the latter remain sparse, limiting our understanding of the key processes of ice-ocean heat transfer. In particular, we have no observations of current profiles through the buoyancy- and frictionally-controlled flows along the ice shelf base that drive mixing through the ice-ocean boundary layer. This presentation represents an attempt to address this gap in our knowledge through application of a very simple model of such boundary flows that considers only the spatial dimension perpendicular to the boundary.

Initial results obtained with an unrealistic assumuption of constant eddy viscosity/diffusivity are nevertheless informative. For the buoyancy-driven flow two possible regimes exist: a weakly-stratified, geostrophic cross-slope current with an embedded Ekman layer, somewhat analogous to a conventional density current on a slope; or a strongly-stratified upslope jet with weak cross-slope flow, more analogous to an inverted katabatic wind. The latter is most appropriate when the ice-ocean interface is very steep, while for the gentle slopes typical of ice shelves the buoyant Ekman regime prevails.

Introduction of a variable eddy viscosity/diffusivity derived from a local turbulence closure scheme modifies the current structure and stratification. There is a sharp step in properties across the surface layer, where the viscosity/diffusivity is low, weak gradients across the outer part of the boundary layer, where shear-driven mixing is strong, and a relatively strong pycnocline below, where current shear is closely linked with stratification. For the purely one-dimensional diffusion problem, the low viscosity/diffusivity through the surface layer and pycnocline mean that the remainder of the boundary layer must be well-mixed. With the addition of along-slope advection, the lateral supply of heat can maintain stratification across the boundary layer, implying that observations, which typically do not show a well-mixed boundary layer, are inexplicable in terms of one-dimensional mixing processes.