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Turbulent heat flux to the ice shelf base: Microstructure measurements in the oceanic boundary layer

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Basal melting of Antarctic ice shelves plays an important role in ice sheet dynamics, as ice shelf loss allows the flow of inland glaciers to accelerate. Observed ice shelf thinning leads to suggestions of an increasing basal melt rate, yet given the inaccessibility of the ice shelf-ocean interface, the melt rate, vertical heat flux and processes that drive them are rarely quantified directly.

Microstructure shear and conductivity observations from a tethered profiler were made beneath Larsen C Ice Shelf in December 2011 and repeated along with microstructure temperature beneath George VI Ice Shelf in January 2012. Such measurements at the ice-ocean interface within the cavity of an ice shelf are unprecedented. CTD and 3D current velocity measurements were also made at both sites, and radar measurements showed that the ice base was melting.

Mean potential temperature in the upper ocean beneath Larsen C Ice Shelf was 77m˚C above the in situ freezing point. Eddy diffusivities immediately beneath the ice base of up to 10^{-4} m^2s^{-1} were calculated from shear derived dissipation rates of turbulent kinetic energy between 10^{-9} and 10^{-7} Wkg^{-1}. Associated mean heat flux of 0.7 Wm^{-2} leads to an underestimation of the observed melt rate by at least an order of magnitude.

Sharp interfaces dividing mixed layers of O(4m) thickness were detected in both CTD and microstructure measurements within a thermohaline staircase beneath George VI Ice Shelf. Temperature differences of ∼0.05˚C occurred across the steps and temperature at the ice base was 2˚C warmer than in situ freezing point. Stability calculations confirmed that this was a primarily double diffusive environment. Turbulent mixing was strong in some layers and weak in others, with shear and thermal variance-derived dissipation rates of turbulent kinetic energy varying between 10^{-10} (close to the shear probe noise limit) and 10^{-7} Wkg^{-1}. Vertical diffusion of heat is thought to provide the primary contribution to vertical heat flux where turbulent mixing is weak.

We use the first direct microstructure profiles taken through hot water-drilled access boreholes in these two different environments to gain insight into the processes involved in the transport of heat from the upper ocean to the ice shelf base.