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Onset of Double-Diffusive Convection in the Ice Shelf/Ocean Boundary Layer

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The interaction between Ice-Shelves and the Ocean is an important component of the response of ice sheets to future warming oceans. Observational data in the ocean boundary layer beneath ice shelves is limited and the turbulent flow in the boundary layer is not well characterised. Our work uses small scale (9m depth) direct numerical simulations (DNS) of the Ice-Shelf-Ocean Boundary Layer, inspired by field observations made beneath the George VI Ice Shelf. Here, warm water has been observed directly beneath the ice shelf, and yet the observed melt rates are modest. To study this scenario, we simulate a forced turbulent flow underlying an ice shelf where the ice base is represented by a dynamic melting boundary condition. As the ice melts, a pool of relatively cold, fresh water develops below the ice base. Thermal diffusion causes the underlying water to cool and can drive turbulent convection. At the same time, the salinity gradient in the halocline is stabilising, but develops over a longer time scale. As a result, two flow regimes exist: one with active turbulent convection driven by double-diffusion of heat and salt, and the other with stratified turbulence leading to mixing of the halocline. By varying control parameters, we identify the transition between the flow regimes in terms of the temperature contrast (thermal driving) and the level of turbulence in the far field. We consider the behaviour of the diapycnal buoyancy flux near the ice base, and it provides insight into the drivers of both the double-diffusive convection and its modification by ambient turbulence. Finally, we discuss how the double-diffusive process we have described applies to real-world ice-shelf ocean boundary layers, and how it may be quantified within observations.