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The micro-physics of frazil-ice growth under ice shelves

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When buoyant meltwater plumes rise through sufficient depth of the ocean beneath a floating ice shelf, the pressure-dependence of the freezing temperature causes in-situ supercooling of this rising ice-shelf water. The growth of so-called frazil ice crystals from these supercooled ocean waters plays a significant role in the accretion of marine ice on the underside of floating ice shelves and in basal crevasses. Many different aspects of micro-physics are thought to affect frazil-ice formation, including the fluid dynamics of suspensions, nucleation, the collision and sintering of crystals, as well as heat and mass transfer. Here, we focus on the diffusive heat and mass transfer from an individual crystal, which is commonly used to parameterise thermodynamic growth in models of frazil ice accumulation under ice shelves. We model the growth of disk shaped frazil ice crystals accounting for anisotropic attachment kinetics, and show how the shape of a crystal affects its growth. Salt is rejected into the ocean as a crystal grows, which slows growth by reducing the local freezing temperature. We also analyse this effect, and show that polar seawater lies in an intermediate regime in which we must account for the diffusion of both heat and salt. Our results suggest that some previous scaling arguments, that are used in parameterisations, may substantially underestimate the growth rate of frazil ice crystals. The implications for models of frazil ice accumulation under ice shelves are considered.