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Modelling mushy sea ice growth and brine convection

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More than 20 million square kilometres of the polar oceans freeze over each year to form sea ice. Sea ice is a mushy layer: a reactive, porous, multiphase material consisting of ice crystals bathed in liquid brine. The porosity of sea ice evolves in space and time, with important consequences for coupling to the oceans and sea ice ecosystems. Atmospheric cooling generates a density gradient in the interstitial brine, which can drive convection and rejection of dense brine from the sea ice to force ocean circulation and mixing. The resulting convective circulation also controls a nutrient supply to support biological activity, including sea-ice algae which grow within the liquid filled pores. This presentation will introduce the fundamentals of the multiphase behaviour of sea ice, with a particular focus on continuum phase-averaged models of sea ice thermodynamics using mushy-layer theory, and the generation of convective flows through the porous ice. I will present results from recent analysis of the transient growth of mushy layers. The cooling conditions provide a key control on the internal structure of the mushy layer during diffusive growth, with two regimes identified. A relatively porous mushy layer forms either for weak cooling, or early during growth when there are slow inefficient cooling rates. In contrast, strong and efficient cooling generates low porosity throughout much of the mushy layer, with a thin high-porosity boundary layer near to the mush-liquid interface. This localisation of porosity impacts the ice permeability, and provides a key control on the onset of convection in the mushy layer. I will conclude with a discussion of the nonlinear dynamics and the implications for the macroscopic ice structure, brine rejection and brine channel formation in growing sea ice.

Significance statement

The growth of sea ice and resulting brine rejection have key implications for climate and polar ecosystems. Using mushy layer theory, we characterise the impact of the cooling conditions on the multiphase structure of porous sea ice, and the onset of convective drainage of dense brine into the underlying ocean.

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