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Convection, phase change, and solute transport in mushy sea ice

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Sea ice is a porous material composed of ice crystals and interstitial brine; a mushy layer. The dense brine tends to sink through the ice, driving convection. Downwelling at the edge of convective cells leads to the development of narrow, entirely liquid channels, through which cold saline brine is efficiently rejected into the underlying ocean. This brine rejection provides an important buoyancy forcing on the ocean, and can have important consequences for the internal structure and properties of sea ice.

We consider numerical simulations of ice formation and convective brine rejection, that resolve flow through a reactive porous ice matrix with evolving porosity. Our simulations exploit Adaptive Mesh Refinement using the Chombo framework, which allows us to integrate over several months of ice growth, providing insights into mushy-layer dynamics throughout the winter season. The convective desalination of sea ice promotes increased internal solidification, and we find that convective brine drainage is restricted to a narrow porous layer at the ice-ocean interface, which evolves as the ice layer grows thicker over time. Away from this interface, stagnant sea ice consists of a network of previously active brine channels which retain higher solute concentrations than the surrounding ice. We investigate the response of these remnant brine channels to changes in atmospheric and oceanic conditions, and consider the potential implications for nutrient transport, sea ice ecology, and ice-ocean brine fluxes.