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Modelling biogeochemical tracer transport in sea ice due to gravity drainage

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Sea ice is a porous material, formed of an evolving array of solid ice crystals bathed in liquid brine. The liquid-filled pore space provides a habitat for life within the ice, and, when the ice is permeable, provides a pathway for exchange of gases and other chemicals between the ice, ocean, and atmosphere. This coupling between the physical, chemical, and biological evolution of sea ice has poorly constrained implications for biogeochemical processes, such as the impact of sea ice on the carbon cycle. During winter ice growth, so-called gravity drainage drives a convective exchange of brine between the ocean and the porous interior of sea ice. Here, we use two-dimensional mushy-layer simulations of convective flow to provide insight into the resulting transport of passive biogeochemical tracers through the ice. We quantify the chemical concentration in the liquid during periods of quasi-steady growth rate, and determine a scaling law for the total chemical tracer fluxes through the region of active convection inside the ice. Chemical concentrations show spatial heterogeneity, and our results predict enhanced chemical concentrations in the pore space near to brine channels. These results may provide useful insight for interpreting studies of sea-ice biogeochemistry, and offer a framework to develop models of physical, chemical, and biological interactions.