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Floe-scale ocean / sea ice energy transfers in the marginal ice zone

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Marginal ice zones are regions where individual sea ice floes interact mechanically and thermodynamically with turbulent ocean currents at the (sub-)mesoscale. Fine scale exchanges of momentum, heat and salinity at the interface between the ocean and the sea ice floes have important effects on upper-ocean energetics, under-ice tracer mixing, and the ice-pack melt rates. The dynamics of these moving floes remain poorly constrained, notably due to the challenge of numerically resolving sub-mesoscale processes and modelling the discrete behavior of sea ice in traditional climate models.

Here, we use oceanic Large Eddy Simulations (LES), two-way coupled to a Discrete Element Model (DEM) of disk-shaped sea ice floes, to quantify the kinetic energy transfers between ocean and sea ice during summer-like conditions, varying sea ice concentration and floe size distribution. The damping of oceanic currents by floes is found to be important for a sea ice concentration as low as 40%, when the sizes of floes are comparable to the characteristic eddy size. This damping is largely compensated by the generation of kinetic energy due to melt-induced baroclinic instability at the edge of sea ice floes, leading to a net energy sink of approximately 15%, relative to a simulation with no floes. At higher sea ice concentrations, the oceanic kinetic energy production weakens, while energy loss due to ice/ocean damping and floe-floe collisions both increase. These energy fluxes are mediated by the spatial aggregation of sea ice floes that occurs within the high-strain regions surrounding ocean mesoscale eddies. Eddy-driven aggregation can also reduce the melt rate of small floes as they become shielded from warm waters by neighboring larger floes. These results highlight the need for scale-aware, and specifically floe-scale parameterizations of sea ice and its coupling to ocean turbulence, within global climate models.