Sea Ice Level Set DEM: Effects of Lateral Melting and Breakage

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Understanding the temporal and spatial evolution of sea-ice across different scales is an urgent issue, given its vital role on the planetary energy balance and climate regulation. As part of forecasting the changes of sea-ice concentration, especially that of susceptible regions such as the Artic Ocean, different modeling approaches have been implemented to close the gap with discrepancies in predictions. Among the alternatives to enhance predictability are discrete element method (DEM) models, which can capture the behavior of individual ice floes. Consequently, emergent complex system or granular properties, such as jamming and interparticle collisions, can be better understood.

For this work several modifications to prior DEM simulations have been implemented to better capture the behavior of in-situ sea ice in 2D, using the Level Set DEM (LS-DEM). LS-DEM considers arbitrary shaped sea-ice floes, shape evolution by lateral melting and breakage of floes by interparticle contacts. Using Level Set functions to capture the geometry of floe shapes obtained from satellite pictures allows to replicate the influence of irregular shapes on floe-to-floe contact, rotations, effect of fluid forces for one-way coupling and contact with arbitrary-shaped coastal boundary conditions. Furthermore, the effect of shape is accentuated when floes are subject to melting and break due to contact loads.

Based on simulations presented, the effect of shape was found to affect sea-ice kinematics, mass loss over time, changes in floe size distribution, breakage of densely packed sea-ice and floe jamming at narrow locations with sufficient floe density and lack of other external loading. Hence, it is shown that considering the factors used by the methodology presented can help simulate the cyclic behavior of sea ice both at open ocean, straits and marginal ice zone (MIZ). Further developments such as fracture propagation and two-way fluid coupling can provide even better insight into the granular behavior of sea-ice and be valuable input for macro-scale models.