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A model for ice-mélange based on particle and continuums mechanics

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Ice mélange (a mixture of sea ice, bergy bits and icebergs) can have a strong influence on the sea-ice-ocean interaction. So far, ice mélange is not represented in climate models as numerically efficient realizations are missing. This motivates the development of an ice-mélange model based on the viscous-plastic sea-ice rheology, which is currently the most commonly used material law for sea ice in climate models. Starting from the continuum mechanical formulation, we modify the rheology so that icebergs are represented by thick, highly compact pieces of sea ice. These compact pieces of sea ice are held together by a modified tensile strength in the material law. In this framework, the ice mélange is considered as one single fluid, where the icebergs are realised by particles.
Using idealized test cases, we demonstrate that the proposed changes in the material law are crucial to represent icebergs with the viscous-plastic rheology. Similar to the viscous-plastic sea-ice model, the ice-mélange model is highly nonlinear. Solving the model at the resolution needed to represent the typical size of icebergs in ice mélange (< 300m) is therefore challenging. We show that the ice-mélange formulation can be approximated efficiently with a modified Newton's method. Overall, the simple extension of the viscous-plastic sea-ice model is a promising path towards the integration of ice mélange into climate models.