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A dynamic-thermodynamic sea ice model on an Arakawa C-grid for coupled ocean and sea ice state estimation

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As part of an ongoing effort to obtain a best possible, time-evolving analysis of most available ocean and sea ice data, a dynamic and thermodynamic sea-ice model has been coupled to the Massachusetts Institute of Technology general circulation model (MITgcm). Ice mechanics follow a viscous-plastic rheology and the ice momentum equations are solved numerically using either line-successive-over-relaxation (LSOR) or elastic-viscous-plastic (EVP) dynamic models. Ice thermodynamics are represented using either a zero-heat-capacity formulation or a two-layer formulation that conserves enthalpy. The model includes prognostic variables for snow and for sea-ice salinity. The above sea ice model components were borrowed from current-generation climate models but they were reformulated on an Arakawa C grid in order to match the MITgcm oceanic grid and they were modified in many ways to permit efficient and accurate automatic differentiation. This paper describes the MITgcm sea ice model; it presents example Arctic and Antarctic results from a realistic, eddy-permitting, global ocean and sea-ice configuration; it compares B-grid and C-grid dynamic solvers and the effects of other numerical details of the parameterized dynamics and thermodynamics in a regional Arctic configuration; and it presents example results from coupled ocean and sea-ice adjoint-model integrations.