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Solving the Momentum Equations of Dynamic Sea Ice Models with Implicit Solvers and the Elastic-Viscous-Plastic Technique

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The momentum equations that describe sea ice drift for a viscous-plastic (VP) ice rheology are difficult to solve numerically, because the associated bulk and shear viscosities can be very large. Traditionally, implicit solution techniques for the VP rheology are thought to be expensive; the explicit elastic-viscous-plastic (EVP) method was designed to be more efficient and accurate. In order to assess their relative performance, experiments with idealized geometry are used to compare model solutions of implicit VP- and explicit EVP-solvers in two very different ice-ocean codes: the regular-grid, finite-volume Massachusetts Institute of Technology general circulation model (MITgcm) and the Alfred Wegener Institute Finite Element Ocean Model (FEOM). For both codes the obtained solutions of implicit VP- and EVP-solvers can differ significantly, because the EVP solutions tend to have smaller ice viscosities ("weaker" ice). EVP solutions tend to converge to implicit VP solutions for very small sub-cycling time steps. A limiting scheme for EVP viscosities, that addresses a noise problem, reduces the viscosity even further and, especially in the case of the variable-resolution unstructured grids of FEOM, can lead to unexpected ice distributions that are dramatically different from solutions without this scheme. Implicit VP-solvers are found to be generally faster than the EVP-solvers, most likely because the ice distribution does not change much within the short time steps of this study. Short time steps are thought to be typical of present day high resolution ice-ocean models, so that previous timing results for long time steps may no longer be representative.