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The adaptive EVP method for solving the sea ice momentum equation

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Most dynamic sea ice models for climate-type simulations are based on the viscous-plastic (VP) rheology. The resulting stiff system of partial differential equations for the sea ice velocity is either solved implicitly at great computational cost, or explicitly with added pseudo-elasticity (elastic-viscous-plastic, EVP). Bouillon et al. (Ocean Modell., 2013) reinterpreted the EVP method for solving the sea ice momentum equation as an iterative pseudotime VP solver with improved convergence properties. In Kimmritz et al. (J. Comput. Physics, 2015) we showed that this modified EVP (mEVP) scheme should warrant converging solutions if its stability is maintained and the number of pseudotime iterations is sufficiently high.

Here, we focus on the role of spatial discretizations. We analyze stability and convergence of mEVP on B- and C-grids. We show that the implementation on B-grids is less restrictive with respect to stability constraints than on C-grids. Additionally, convergence on C-grids is sensitive to the discretization of the viscosities and can be lost for some variants of discretization.

Building on these findings we present an adaptive version of the mEVP scheme, which satisfies local stability constraints and aims to accelerate convergence where possible. This is achieved by local adaptation of the parameters governing the pseudotime subcycling of the scheme. We analyze the performance of this new “adaptive EVP” approach in a series of experiments with the sea ice component of the general circulation model MITgcm, which is formulated on a C-grid. We show that convergence in realistic settings is sensitive to the details of the implementation of the rheology. In particular, the use of the pressure replacement method deteriorates convergence.