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Stability and accuracy of Runge-Kutta-based split-explicit time-stepping algorithms for free-surface ocean models

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Because of the Boussinesq assumption employed in the vast majority of oceanic models, the acoustic waves are filtered and the fast dynamics corresponds to the external gravity-wave propagation which is much faster than other (internal) processes.
The fast and slow dynamics are traditionally split into separate subproblems where the fast motions are nearly independent of depth. It is thus natural to model these motions with a two-dimensional (barotropic) system of equations while the slow processes are modeled with a three-dimensional (baroclinic) system.
However such splitting is inexact, the barotropic mode is not strictly depth-independent meaning that the separation of slow and fast modes is non-orthogonal, even in the linear case.
A consequence is that there are some fast components contained in the slow motions which induce instabilities controlled by time filtering of the fast mode.
In this talk we present an analysis of the stability and accuracy of the barotropic–baroclinic mode splitting in the case where the baroclinic mode is integrated using a Runge-Kutta scheme and the barotropic mode is integrated explicitly (i.e. the so-called split-explicit approach).
By referring to the theoretical framework developed by Demange et al. (2019), the analysis is based on an eigenvector decomposition using the true (depth-dependent) barotropic mode. We investigate several strategies to achieve stable integrations whose performance is assessed first on a theoretical ground and then by idealized linear and nonlinear numerical experiments.