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Design of Runge-Kutta based split-explicit time integration algorithms for the NEMO ocean model

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The NEMO ocean model is currently based on the Leapfrog scheme that provides a good combination between simplicity and efficiency for low-resolution global simulations. However, this scheme is subject to difficulties that question its relevance at high-resolution : the necessary damping of its computational mode, e.g. via a Robert-Asselin filter, affect stability and increases amplitude and phase errors of the physical mode ; because it is unconditionally unstable for diffusive processes, monotonicity or positive-definiteness comes at a substantial cost and complication. The evolution toward a 2-level time stepping algorithm based on Runge-Kutta schemes is studied. Special attention is given to how to articulate a mode-splitting technique to handle the fast dynamics associated with the free surface. Linear stability analyses of several Runge-Kutta based, split-explicit algorithms are performed and the most promising ones are identified. They allow a good compromise between robustness, stability and accuracy for integration of internal gravity waves, Coriolis and advection processes. Idealized test-cases illustrate the benefits associated to the revised time-stepping compared to the original Leapfrog.