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A Split-Explicit Runge-Kutta methods for 3D hydrodynamic equations for coastal applications

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Numerical models of marine hydrodynamics have to deal with processes exhibiting a wide range of timescales. These processes include fast external gravity waves and slower internal fully three-dimensional motions. In order to be both time-efficient and numerically stable, the temporal scheme has to be chosen carefully to cope with the characteristic time scale of each phenomenon. An usual approach is to split the fast and slow dynamics into separate modes. The fast waves are modeled with a two-dimensional system through depth averaging while the other motions, where characteristic times are much longer, are solved in a three-dimensional. However, if the splitting is inexact, for instance in projecting the fields in a new 3D mesh, this procedure can lead to improper results in regards to the physical properties such as mass conservation and tracer consistency. In this work, a new split-explicit Runge-Kutta scheme is adapted and developed for the Discontinuous-Galerkin Finite Element method in order to obtain a new second-order time stepping, yielding more accurate results. This method combines a three-stage low-storage Runge-Kutta for the slow processes and a low-storage one of two-stage for the fast ones. The 3D iterations are not affecting the surface elevation, hence an Arbitrary Lagrangian Eulerian implementation is straightforward. Water volume and tracers are conserved. A set of test cases for baroclinic flows as well as a laboratory application demonstrate the performance of the scheme. They suggest that the new scheme has little numerical diffusion.