Implicit-Explicit Runge-Kutta Time integration methods on a Spectral-Element-based Fully Compressible Non-hydrostatic Atmospheric Model

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For fully compressible non-hydrostatic systems, the presence of the vertically propagating acoustic waves combined with the large aspect ratio of the horizontal and vertical grid scale makes the use of purely explicit time integrators unattractive. In order to tackle this problem, horizontally explicit / vertically implicit (HEVI) or semi-implicit methods have been utilized. In this study, four different time integrators are compared on a spectral-element-based fully compressible non-hydrostatic vertical slice model. The four time integrators are: 1) the Strang carryover scheme and 2) the Ascher–Ruuth–Spiteri (2, 3, 3) scheme which are operator-split Runge-Kutta-Rosenbrock (RKR) methods (Ullrich and Jablonowski 2012), 3) 1D Implicit-Explicit Additive Runge-Kutta (ARK) method (Giraldo et al., 2013), and 4) explicit strong stability preserving Runge-Kutta method. The four methods' accuracy and efficiency are compared and analyzed for rising thermal bubble, density current, and inertia-gravity wave test cases.