Geophysical Research Abstracts
Vol. 19, EGU2017-10803, 2017
EGU General Assembly 2017

Hamiltonian approaches to spatial and temporal discretization of fully compressible equations

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The fully compressible Euler (FCE) equations are the most accurate for representing atmospheric motion, compared to approximate systems like the hydrostatic, anelastic or pseudo-incompressible systems. The price to pay for this accuracy is the presence of additional degrees of freedom and high-frequency acoustic waves that must be treated implicitly.

In this work we explore a Hamiltonian approach to the issue of stable spatial and temporal discretization of the FCE using a non-Eulerian vertical coordinate. For scalability, a horizontally-explicit, vertically-implicit (HEVI) time discretization is adopted. The Hamiltonian structure of the equations is used to obtain the spatial finite-difference discretization and also in order to identify those terms of the equations of motion that need to be treated implicitly. A novel treatment of the lower boundary condition in the presence of orography is introduced: rather than enforcing a no-normal-flow boundary condition, which couples the horizontal and vertical velocity components and interferes with the HEVI structure, the ground is treated as a flexible surface with arbitrarily large stiffness, resulting in a decoupling of the horizontal and vertical dynamics and yielding a simple implicit problem which can be solved efficiently. Standard test cases performed in a vertical slice configuration suggest that an effective horizontal acoustic Courant number close to 1 can be achieved.