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Horizontally Explicit Vertically Implicit (HEVI) Time-Integrators for a Non-Hydrostatic Whole Atmosphere Models

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The U.S. Navy is building a coupled thermosphere-ionosphere prediction system. As part of this project, we are developing a new dynamical core (DyCore) extending from the ground to the exobase (~500 km). The DyCore must be able to handle large variations in both temperature and composition, which motivates a new Horizontally Explicit Vertically Implicit (HEVI) time integrator. Unlike traditional linear Implicit-EXplicit (IMEX) methods commonly used in numerical weather prediction (NWP), HEVI does not require a fixed reference state. Our DyCore combines HEVI with a Specific Internal Energy Equation (SIEE) and a Spectral Element Method (SEM) spatial discretization to form a robust, whole-atmosphere model for the neutral atmosphere. We present results for two test cases using the proposed DyCore: an idealized heating/cooling test extending into the middle thermosphere and a perturbation experiment yielding nonhydrostatic baroclinic instability. The idealized heating/cooling test, which is compared to corresponding results from the hydrostatic Navy Global Environmental Model (NAVGEM), demonstrates that HEVI is more robust than traditional linear IMEX methods. The baroclinic instability test shows that HEVI, when combined with a banded lower-upper (LU) direct solve, is efficient and allows a large timestep. These numerical results suggest that our HEVI-enabled DyCore is a good candidate for the proposed thermosphere-ionosphere prediction system.

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