Implicit-explicit (IMEX) Runge-Kutta methods for non-hydrostatic atmospheric models

Objective

The DOE Energy Exascale Earth System Model (E3SM) project is developing a new nonhydrostatic dynamical core for modeling atmospheric fluid dynamics at high resolution. Nonhydrostatic motion includes fast waves in the vertical direction which strongly reduce the stable time step size for an explicit integration approach.

Approach + Results

- Implicit/explicit (IMEX) methods allow for stable implicit treatment of the vertical waves with explicit treatment of the horizontal dynamics
- Using the ARKode IMEX integration package in the Tempest nonhydrostatic dycore we ***tested 252 combinations of methods, splittings, and solvers***
- Highly efficient methods were identified
- We are ***now applying ARKode to test the most effective approaches in E3SM***

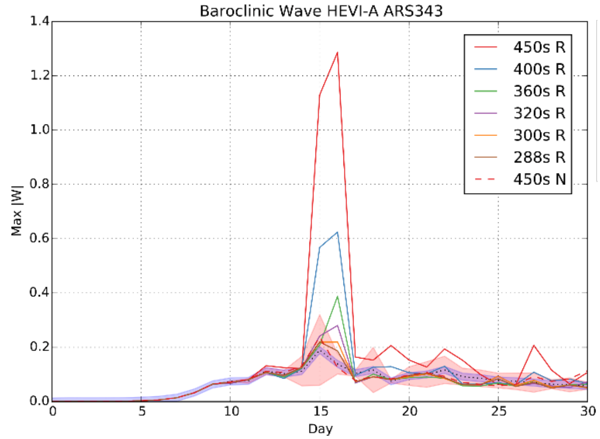

Figure: The maximum vertical velocity over 30 days with the fastest IMEX method using various step sizes and nonlinear solvers (solid is 1 iteration and dashed is iterated to a tolerance). The light red region defines an acceptable solution in terms of similar variation compared to explicit simulations with perturbed initial conditions. *Both solvers provided an acceptable solution with a step as high as 300s, and iterating the nonlinear solve could raise that to over 400s.*

Impact

Determination of most effective methods for nonhydrostatic dynamics leads us to streamlined method development and testing for the new E3SM nonhydrostatic dycore.

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