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Interactive comment on "Impacts of the Horizontal and Vertical Grids on the Numerical Solutions of the Dynamical Equations. Part I: Nonhydrostatic Inertia-Gravity Modes" *by* Celal S. Konor and David A. Randall

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Comments on Konor and Randall

by Lucas Harris and Xi Chen

This manuscript makes broad conclusions regarding grid staggering (which is merely one characteristic out of the many of a modern dynamical core) based on the analysis of a simplified, linear, centered-difference, second-order discretization. We feel that the analysis presented in the manuscript is unrepresentative of the discretizations used in

modern dynamical cores, and that the conclusions may be misleading as to the actual behavior of a discretization in a comprehensive numerical model.

The authors did a remarkable job by acquiring analytical solutions or workably simple numerical solutions to the two-dimensional linearized analysis, but the mathematics is made tractable only by analyzing an oversimplified second-order centered-difference system that greatly exaggerates the difference between the staggerings. Few modern dynamical cores use such a primitive method; most use at least third or fourth-order, and many finite-volume schemes use a physically-based upwinding method. The analysis method also necessarily neglects many important fluid phenomena, especially nonlinear vorticity advection, crucial to many of the uses of numerical models.

Further, the analysis is entirely inviscid, while all numerical models require either implicit or explicit diffusion to remove grid-scale noise, created by improper handling of sharp gradients or errors in the parameterizations, boundaries, and data. Indeed, at $2\Delta x$ it is nearly impossible to distinguish computational noise from physical signals, so these modes should be filtered out (Skamarock et al. 2014). To this end, the behavior of the staggerings at $2\Delta x$ and $3\Delta x$—which the authors' conclusions lie heavily upon—is of little consequence. We can also conclude that the numerical diffusion, whether implicit or explicit, will always be an intrinsic part of any dynamical core, and a thorough analysis of any discretization must also consider the effects of dissipation.

Finally, the C-D grid analyzed in the manuscript has little resemblance to that in the FV3 dynamical core. The discretization is described in detail in Lin and Rood (1997), Lin (2004), and Harris and Lin (2013), and which can also be seen in the FV and FV3 source code that has been openly available for many years in GEOS, CESM, and the GFDL modeling suite. In FV3 none of the time-advanced C-grid quantities, other than the winds, are used for the full forward timestep. The C-grid vorticity, temperature, and mass are discarded, in contradiction to eqns. (39) through (42); this incorrect procedure, which then necessitates additional averaging of the vorticity to cell-centers, introduces significant error. FV3 also implements a fourth-order accurate transport scheme and uses upwinding based on the Lin and Rood (1996) advection scheme, and so would have behavior greatly different than that of the second-order method used in the manuscript, even if the analysis was done consistently with the FV3 algorithm.

References

Harris, L.M. and S. Lin, 2013: A Two-Way Nested Global-Regional Dynamical Core on the Cubed-Sphere Grid. Mon. Wea. Rev., 141, 283–306

Lin, S., 2004: A "Vertically Lagrangian" Finite-Volume Dynamical Core for Global Models. Mon. Wea. Rev., 132, 2293–2307

Lin, S. and R.B. Rood, 1996: Multidimensional Flux-Form Semi-Lagrangian Transport Schemes. Mon. Wea. Rev., 124, 2046–2070

Lin, S.-J. and R.B. Rood, 1997: An explicit flux-form semi-lagrangian shallow-water model on the sphere. Q.J.R. Meteorol. Soc., 123, 2477–2498.

Skamarock, W.C., S. Park, J.B. Klemp, and C. Snyder, 2014: Atmospheric Kinetic Energy Spectra from Global High-Resolution Nonhydrostatic Simulations. J. Atmos. Sci., 71, 4369–4381

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