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Numerical and dynamical assessment of a newly developed non-hydrostatic atmospheric dynamical core

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HOMME-NH is a variable-resolution, efficient and architecture-aware, non-hydrostatic dynamical core that is being developed under the United States DOE's earth system modeling initiative. Algorithmic improvements included in the model and the current availability of high-performance computing resources, allow to perform idealized global atmospheric simulations at resolutions at which non-hydrostatic effects become significant. We consider high-resolution simulations of prototypical atmospheric flows with an aim of quantifying and characterizing non-hydrostatic effects. In particular, we consider the nonlinear evolution of an unstable baroclinic wave to evaluate both numerical and dynamical aspects of model simulations. We find that the choice of a vertically-collocated computational grid can trigger spurious modes of instability—modes that resemble the physical symmetric instability; these instabilities are eliminated by the use of a (Lorenz) staggering in the vertical. We also verify that the Hollingsworth instability that plagues numerous dycores and is exacerbated at high horizontal resolutions is absent in HOMME-NH. We also conduct a suite of experiments that combine different vertical to horizontal resolution aspect ratios and small-earth configurations to (a) examine spurious NH effects introduced by poorly resolving vertical scales, and (b) accentuate non-hydrostatic effects by reducing the Earth's radius, respectively. We are able to determine scales at which hydrostatic and non-hydrostatic integrations begin to depart significantly from each other with respect to symmetric instabilities, dynamical interactions across scales, and restratification effects.