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Towards nonhydrostatic simulation of moist global flows

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High-resolution simulation of moist global flows for numerical weather prediction and climate research requires convection-permitting nonhydrostatic flow solvers valid across the entire range of spatial scales, from small-scale dynamics to planetary-scale flows. Fluid flow solvers based on compressible dynamics meet such a requirement, but they need special treatments of acoustic modes to make them computationally efficient. Soundproof (e.g., anelastic) solvers filter out acoustic modes, but their application to the large-scale dynamics has been questioned in the past. In addition, mesoscale and large-scale hydrostatic pressure perturbations are typically excluded from moist thermodynamics in standard anelastic models. This presentation will review these issues and report application of the explicit/implicit compressible and anelastic versions of the finite-difference non-oscillatory forward-in-time EULAG model to the idealized baroclinic instability problem and to the Held-Suarez climate benchmark. All model versions share a common numerical framework and allow confident assessment of the impacts of governing equations mathematical formulations on model solutions. The implicit compressible version allows time steps as large as the anelastic version, typically two orders of magnitude larger than required by the explicit compressible version. We will show an excellent agreement between solutions obtained with the explicit and implicit compressible versions. Systematic differences between compressible and anelastic solutions are present in the baroclinic test case. In contrast, the climate benchmark shows that the compressible and anelastic model versions simulate similar zonally averaged fields, and that the meridional transports of entropy, momentum and moisture agree well between the two model versions.