A Moist Variant of the Held-Suarez Test for Atmospheric Model Dynamical Core Intercomparisons

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Atmospheric General Circulation Models (GCMs) consist of a dynamical core and a complex subgrid-scale physical parameterization package, which are intertwined in nonlinear ways. These nonlinear interactions can mask causes and effects of atmospheric phenomena, making the testing of the model or its individual model components difficult. Idealized test cases, like the Jablonowski-Williamson baroclinic wave or the Held-Suarez test for dry dynamical cores, give easier access to an improved understanding of the circulation, and are a computationally efficient method for analyzing the underlying numerical techniques. The original Held-Suarez test replaces the full physical parameterization package with a Newtonian temperature relaxation and Rayleigh damping of low-level winds. However, the impact of moisture, a crucial physics-dynamics coupling process, is not present.

Here, we introduce a moist extension of the Held-Suarez test case to create a test case of intermediate complexity with idealized moisture feedbacks. It uses simplified physical processes to model large-scale condensation, boundary layer turbulence, and surface fluxes of latent heat, and sensible heat between the atmosphere and an ocean-covered planet. We apply this test to four dynamical cores within NCAR's Community Atmosphere Model version 5.3, including the Finite Volume, Eulerian and semi-Lagrangian spectral transform, and Spectral Element dynamical cores. We analyze the kinetic energy spectra, general circulation, and precipitation of the new moist idealized test case across all four dynamical cores. These idealized simulations are compared to CAM 5.3 aqua-planet experiments with complex physical parameterizations. We show that the moist Held-Suarez test successfully reproduces many features of the general circulation seen in the aqua-planet simulations, such as the Hadley cell circulation and precipitation patterns, but does so in a much simpler setup. In addition, important model differences between aqua-planet simulations are successfully reproduced in the moist Held-Suarez test, so that it can serve as an idealized moist test bed for long-term simulations.