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A Moist Variant of the Held-Suarez Test for the Assessment of Atmospheric Model Dynamical Cores

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Atmospheric General Circulation Models (GCMs) consist of a dynamical core, which describes the resolved fluid flow component, and a complex subgrid-scale physical parameterization package. They interact in nonlinear ways which masks causes and effects of atmospheric phenomena and makes the testing of the model or its individual model components difficult. Idealized test cases, like the widely used 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 on a flat planet. However, the impact of moisture, a crucial physics-dynamics coupling process, is missing.

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 horizontal momentum, 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. Simulations of the moist idealized test case are also compared to aqua-planet experiments with complex physical parameterizations. The moist idealized test case successfully reproduces many features of the general circulation seen in the aqua-planet simulations, such as the Hadley cell, precipitation patterns, and surface fluxes of latent and sensible heat, but does so in a much simpler setup.