Comparison of a moist idealized test case and aquaplanet simulations in an atmospheric general circulation model

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Introduction
Simplified test cases are important for testing the accuracy of the dynamical core, which computes the fluid flow in atmospheric general circulation models. Dynamical cores are coupled to complex subgrid-scale physical parameterization packages, resulting in nonlinear interactions between various components of the model. Idealized tests are a computationally efficient method for analyzing the underlying numerical techniques of dynamical cores. We present an idealized test case of intermediate complexity featuring moist feedbacks.

Test Case Design
• Based on the Held and Suarez (1994) dry test case
  • Newtonian temperature relaxation
  • Rayleigh damping of low-level winds
• Simplified moist physics modified from Reed and Jablonowski (2012)
  • Prescribed sea surface temperature profile
  • Large-scale condensation and precipitation
  • Boundary layer turbulence
  • Surface fluxes of latent and sensible heat
• Implemented on the spectral element dynamical core of the NSF/DoE Community Atmosphere Model
• Moist idealized test case compared to aquaplanet simulations, which use full physical parameterizations

Comparison with Aquaplanet
Dynamical motions across scales: Figure 1
• Both simulations follow the theoretical $k^{-3}$ slope

General circulation: Figure 2
• Similar magnitudes and structures for temperature ($a$, $b$) and zonal wind ($c$, $d$)
• Magnitudes of eddy variance of meridional heat transport ($e$, $f$) are similar
  • Structural differences are likely the result of different boundary layer turbulence schemes

Precipitation: Figures 3 and 4
• Precipitation rate (Fig. 3) differs significantly because aquaplanet has convective (PRECC) and large-scale (PRECL) precipitation
• Histogram of precipitation rate (Fig. 4) shows that moist idealized has fewer low rate events ($a$), but more high rate events ($b$)

Figures 1 and 2 show the kinetic energy spectrum and the general circulation for time-mean zonal-mean temperature ($a$, $b$), zonal wind ($c$, $d$), eddy variance of meridional flux of temperature $v^2$ ($e$, $f$). The red dashed line in ($a$, $b$) indicates the location of the tropopause.

Conclusions
• The new moist idealized test case provides a benchmark test of intermediate complexity
• The kinetic energy spectrum and the general circulation are successfully recreated when compared to aquaplanet simulations
• The latitudinal distribution of precipitation agrees with the large-scale precipitation of aquaplanet
• High-rate precipitation events, though more numerous than in aquaplanet, are a significantly smaller fraction of the total number of events compared to low-rate events, therefore the average precipitation rate is lower than aquaplanet

References