Dynamical core intercomparison using a moist variant of the Held-Suarez test case in CAM5

Diana Thatcher\textsuperscript{1}, Christiane Jablonowski\textsuperscript{1}

\textsuperscript{1}Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI
E-mail: diatch@umich.edu

Background

Idealized test cases for dynamical cores are used to:
- Analyze the impacts of underlying numerical techniques without effects from physical parameterizations
- Compare different dynamical cores within the same modeling framework

Important features for an idealized test case:
- Limited or no physical parameterizations
- Able to recreate quasi-realistic climate conditions
- Computationally efficient

Modeling community needs moist dynamical core test cases of intermediate complexity:
- Moisture transport and latent heat release are important for physics-dynamics coupling processes
- Moist idealized test cases are needed to bridge the gap between dry dynamical core test cases and full physics simulations

Test Case Design

- Based on the Held and Suarez (1994) dry test case for dynamical cores
  - Modified Navier relaxation toward a prescribed equilibrium temperature profile
  - Rayleigh damping of low-level horizontal winds

- Simplified moist physics modified from Reed and Jablonowski (2012)
  - Prescribed sea surface temperature profile
  - Boundary layer turbulence for temperature and moisture
  - Latent and sensible heat fluxes at the surface
  - Large-scale precipitation

- Moist idealized test case compared to aquaplanet simulations on all four dynamical cores
  - Full physics with and without deep convection
  - Prescribed bulk aerosols

Kinetic Energy Spectrum

- Both the aquaplanet simulation and moist test case produce reasonable spectra
- Aquaplanet is slightly more diffusive for each dynamical core

References


Vertical Velocity

- As physical parameterization complexity increases, equatorial updrafts:
  - Widen across the equator and weaken
  - Become more uniform with height
- The moist idealized test (least complex) reveals differences attributed to the dynamical core:
  - Complex physics mask effects of the dynamical core in aquaplanet simulations (both with and without deep convection)

Precipitation Rate

- The inclusion of convective parameterizations reduces the frequency of extreme precipitation events:
  - Especially true for SE, which reaches nearly 600 mm/day in the moist idealized test
  - Aquaplanet with deep convection generates two distinct regimes for extreme precipitation events:
    - EUL and SLD: low precipitation rates (< 200 mm/day)
    - SE and FV: high precipitation rates (> 400 mm/day)

Conclusions

- Idealized test case with simplified moist physics are important tools for understanding dynamical cores
- In CAM5, replacing the full physical parameterizations with idealized moist physics reveals impacts of the dynamical core that are otherwise masked by the physical parameterizations
  - Updrafts over the equator are weaker in more recent dynamical cores (SE and FV) than older dynamical cores (EUL and SLD)
  - Stronger surface convergence and higher rainfall rates at the equator in SLD than SE
  - Average rainfall rates in the tropics are equivalent
    - SE has more precipitation at extreme rates, while SLD has more precipitation at low rates

- The new moist idealized test case recreates a quasi-realistic climate, but still shows features due to dynamical core formulation that would be hidden by complex physical parameterizations