The 2012 Dynamical Core Model Intercomparison Project (DCMIP)

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What is DCMIP?

The poster presents snapshots of the Dynamical Core Model Intercomparison Project (DCMIP) that was launched in August 2012. The goal of DCMIP is to survey the advantages and trade-offs of the many numerical and computational design options in the dynamical cores of weather and climate models, with special emphasis on the newest non-hydrostatic General Circulation Models (GCMs). The GCM design options incorporate the choice of the equation set, numerical schemes, computational grids, grid staggering options and dissipative mechanisms. In addition, the coupling strategies to physical parameterizations and simple moisture feedbacks are assessed.

The GCM assessments utilize a suite of idealized dry and moist dynamical core test cases. The objectives of DCMIP are (1) to teach a large group of students how today's and future dynamical cores are or need to be built, (2) to invite over 18 dynamical core modeling groups to NCAR to launch the dynamical core intercomparison project, (3) to establish new dynamical core test cases in the community, and (4) introduce new cyberinfrastructure tools: http://www.earthsystemcog.org/projects/dcmip-2012/

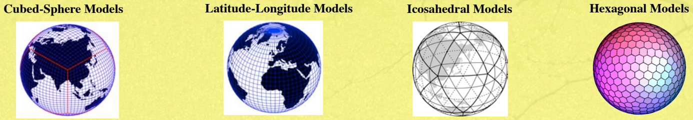
The DCMIP-2012 Dynamical Core Test Cases

The test suite consists of five 3D dynamical core test cases with multiple variants. The test case families in increasing order of complexity are:

- 3D advection tests with correlated tracers using prescribed deformational flow fields
- Non-rotating (reduced-size) planets: Orographic and non-orographic gravity waves, evaluation of steady-states, mountain waves, hydrostatic and non-hydrostatic responses
- Rotating (reduced-size) planets: Evolution of dry baroclinic waves with dynamic tracer fields (potential vorticity and potential temperature)
- Inclusion of simple moist interactions in a moist variant of the baroclinic wave test case
- Tropical cyclone test case with simplified physics parameterizations ("simple-physics")

All models were tested with identical resolutions and initial conditions that were analytically prescribed. The description of the test cases can be found at http://www.earthsystemcog.org/projects/dcmip-2012/test_cases

The 18 Dynamical Cores Participating in DCMIP-2012



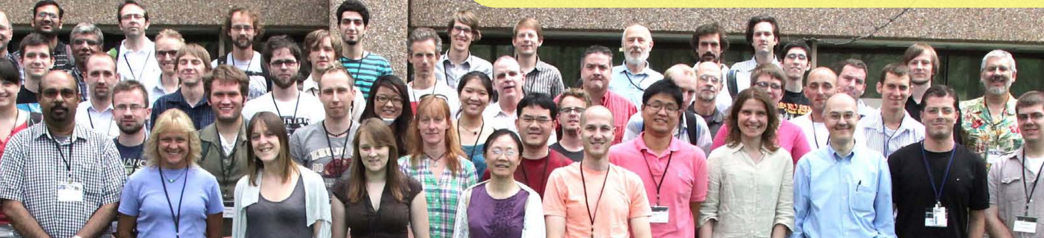
Cubed-Sphere Models
- CAM-SE (NCAR/Sandia Labs)
- FV3 (GFDL)
- Mcore (Uni. Michigan, UC Davis)

Latitude-Longitude Models
- CAM-FV (NCAR)
- PUMA (Uni. Hamburg)
- ENDGame (UK Met Office)
- IFS (ECMWF)
- GEM-latlon (Environment Canada)

Icosahedral Models
- ICON (MPI, DWD)
- DYNAMICO (IPSL, Paris)
- NIM (NOAA)
- OLAM (Uni. Miami)
- NICAM (RIKEN, JAMSTEC)

Hexagonal Models
- MPAS (NCAR)
- UZIM (CSU)
- FIM (NOAA)
- OLAM (Uni. Miami)
- ICON (IAP, Kühlungsborn)

Yin-Yang and Variable-Resolution Models
- GEM-YinYang (Environment Canada)
- FV3 (GFDL)
- MPAS (NCAR)
- CAM-SE (NCAR/Sandia Labs)
- OLAM (Uni. of Miami)
- ICON (MPI/DWD)



Background: Group photo of the participants of DCMIP and its associated summer school taken at the Foothills Lab of the National Center for Atmospheric Research (NCAR) in Boulder, CO, on Aug/1/2012. Over 18 dynamical core modeling groups, 37 graduate students, postdocs and researchers from the U.S. and international institutions, and 19 lecturers participated in the 2-week DCMIP summer school.

3D Advection with Correlated Tracers (Test 1-1)

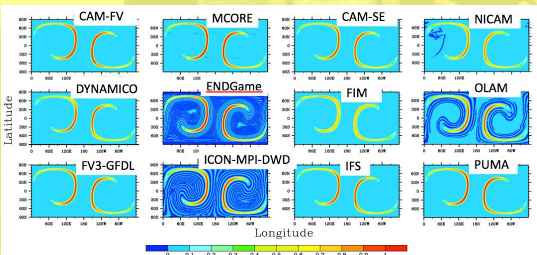
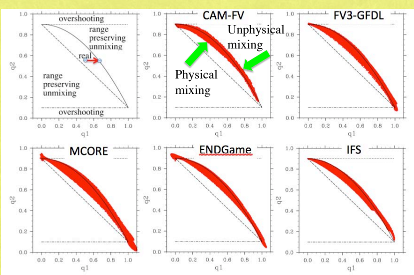


Fig. 1, top: Examples of latitude-longitude cross sections of the advected tracer *q1* at the height position z = 4900 m after 6 days. The tracer has reached its maximum deformation and will return to its initial position at day 12. The test evaluates the diffusion and dispersion characteristics of the advection schemes. Dark blue areas indicate numerical undershoots. The grid spacing is 1°x1° (≈110 km) with Δz=200 m.

Fig. 2, bottom: The figures show how well the initial functional correlation (labeled 'real') between tracer *q1* and *q2* is maintained after 6 days. The scatter plots reveal over- and undershoot errors, and whether the mixing is physical, as explained in the top left diagram.



Mountain Waves on a Small Planet (Test 2-1)

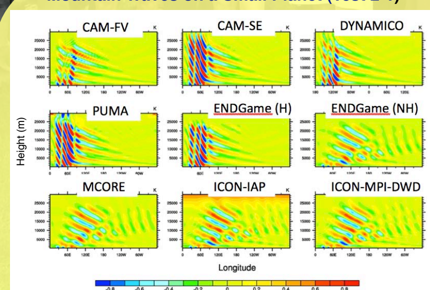


Fig. 3: Longitude-height cross sections of the temperature perturbation T' along the equator after 3600 s. The radius of the non-rotating planet is reduced by the factor X=500 to expose non-hydrostatic effects. The grid spacing is 1.5°x1.5° (≈334 m) with Δz=500 m. The Schär-type mountain is centered at 0°N,90°E with a 250 m peak amplitude. We see distinct differences in the gravity wave response in the non-hydrostatic models (Mcore, ICON, ENDGame (NH)) and the other hydrostatic models. There is a sponge layer above 20 km.

Gravity Waves on a Small Planet (Test 3-1)

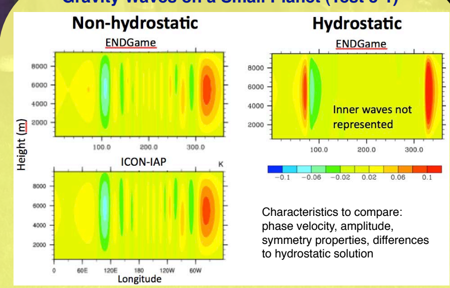
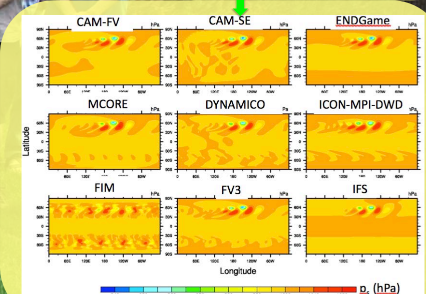


Fig. 4: Longitude-height cross sections of the potential temperature perturbation Θ' along the equator after 3600 s. The radius of the non-rotating planet is reduced by the factor X=125 to expose non-hydrostatic effects. The grid spacing is 1.125°x1.125° (≈1 km) with Δz=1 km. The propagating gravity wave is transported by a westerly wind field with a maximum speed of 20 m/s. The gravity wave response is very different in the non-hydrostatic and hydrostatic models. Hydrostatic models do not represent the inner wave train, and only capture the leading waves.

Baroclinic Waves (Test 4-1-1)

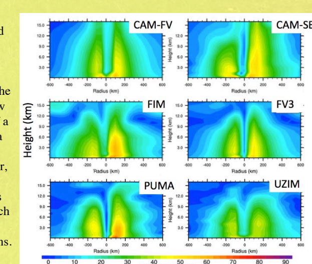
Fig. 5: Surface pressure at day 9. The test starts with balanced initial conditions that are overlaid by a Gaussian hill perturbation. The perturbation grows into a baroclinic wave. The grid imprinting of some cubed-sphere and icosahedral/hexagonal grids can be seen in the Southern Hemisphere (e.g. in FV3, ICON, FIM, DYNAMICO, Mcore). Slight spectral ringing is apparent in CAM-SE.



Grid spacing: 1°x1° (≈110 km) with 30 levels.

Tropical Cyclone with 'Simple-Physics' (Test 5-1)

Fig. 6: Longitude-height cross sections of the wind speed at day 10, plotted with respect to the longitudinal distance (radius) to the center of the storm. The cyclones show distinct characteristics of a tropical system, such as a relatively calm eye and a slanted eyewall. However, there is a wide spread in the shapes and intensities among the 6 models which were driven by identical physical parameterizations. It sheds light on the physics-dynamics coupling and its uncertainties.



Grid spacing: 0.5°x0.5° (≈55 km) with 30 levels.

Summary

18 atmospheric model dynamical cores were tested with an identical test suite during DCMIP-2012. The results give insight into the numerical characteristics of the dynamical cores. In particular, the tests allow an assessment of the accuracy of the numerical schemes, shed light on diffusion and damping mechanisms, reveal grid imprinting issues for models on cubed-sphere, triangular or hexagonal grids and have the potential to challenge the numerical stability of the scheme. The test suite is suggested as a standard test suite for dynamical core intercomparisons.
DCMIP is a long-term community-wide effort that is supported by a Wiki-based shared workspace with searchable database, metadata and visualization services: http://www.earthsystemcog.org/projects/dcmip-2012/. The DCMIP data are archived on an open-access Earth System Grid Federation (ESGF) node hosted by NOAA.
We invite all GCM modeling groups to participate in DCMIP and to contribute intercomparison data to the database. This establishes a community resource for model developments.