A Standard Test Set for Nonhydrostatic Dynamical Cores of NWP Models

Objective: Compile a set of test cases to verify the correctness and examine the robustness of nonhydrostatic solvers (not ful NWP models). Publish this test set (journal paper, web page, etc.) to facilitate commmunity use.

Philosophy: Our foremost needs are for tests encompassing important linear and nonlinear nonhydrostatic flows encountered as NWP models increase resolution from hydrostatic regime (dx ~ 10 km) to nonhydrostatic regime (dx ~ 1 km), e.g. terrain-forced flows, gravity waves and convection (strongly nonlinear flows). The primary purpose of these tests are for testing coding correctness and the appropriateness of approximations, and to test model robustness, accuracy and efficiency.

Background: At the SRWNP (Short Range Numerical Weather Prediction) workshop in Bad Orb, Germany, 27-29 October 2003, we presented the following proposed test set. The 80+ participants at the workshop strongly endorsed the proposal. In this paper we invite the input of the wider community in the development of this test set.

A Proposal

Proposed Initial Test Set

(1) Inertia gravity waves in a periodic channel (Skamarock and Klemp, 1994, MWR, 2623-2630)

(2) Density Current (Straka et al, 1993, Int. J Numer. Meth. Fl., 1-22)

(3) Resting atmosphere

(4) Potential flow over a mountain

(5) 2-D mountain waves (hydrostatic and nonhydrostatic, linear and nonlinear)
(e.g. Klemp and Lilly, 1978, JAS, 78 - 107; Durran and Klemp, 1982, JAS, 2490 - 2506)

(6) 3-D mountain waves

(7) Schaer test case (Schaer et al, 2002, MWR, 2459-2480, Klemp et al, 2003, MWR, 1229-1239)

(8) Squall lines and/or supercells?

Guiding Principles

(1) Tests should be easy to configure.

(2) Tests should be easy to evaluate.

(3) Tests should require only minimal physics (dissipation, very simple moist physics).

(4) Tests should test something in the solver.

(5) Test set should be a minimal set.

Test Documentation: the crucial component

Existing test cases are scattered in the literature, and tend to be poorly documented, especially for the uninitiated, hence we will strive to provide complete documentation of

(1) setup of tests and interpretation of results.

(2) solution (analytic, numericall converged, subjective).

(3) identification of solver components tested by test, and interpretation of results with respect to solver components.

Implementation

Primary implementation will be on a web page that will be maintained and updated as need - it will evolve over time. It is expected that new tests will be added. Additionally, test results from models may be posted and discussion of tests and test results could also be posted. Finally, in the future, test cases or other aspects of NWP models (such as physics) could also be accomodated here.

FURTHER INFORMATION

Contact W. Skamarock at skamaroc@ucar.edu or (303)-497-8161
The test case website is http://mmm.ucar.edu/individual/skamarock/test_cases/test_cases.html
Comments, suggestions and help with the test cases are welcome.

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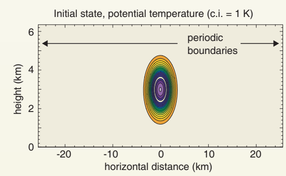
Proposed Test Case Examples

Density Current

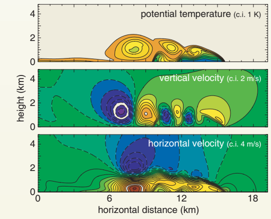
Verification: speed, u, w, q min/max eddy structure, symmetry (trans. soln)

Model compnents tested: coding, nonlinear behavior, model efficiency and robustness (using different timesteps and spatial resolutions, translation vel).

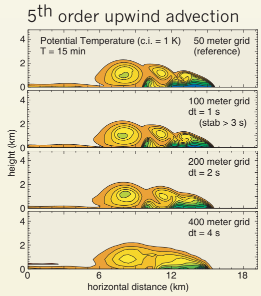
WRF-mass reference solution
5^{th} order upwind advection →



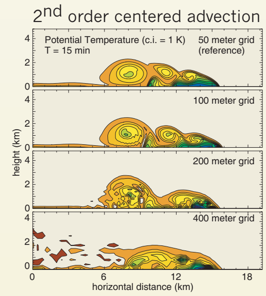
Density Current Solution
50 meter grid, T=15 minutes



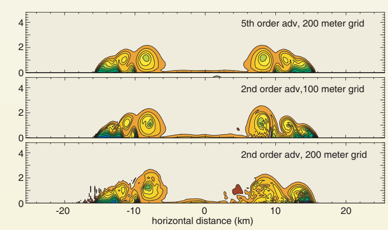
5^{th} order upwind advection



2^{nd} order centered advection



Translating Density Current, U_m = 20 m/s
Potential Temperature (c.i. = 1 K), T = 15 min



Schaer Test Case

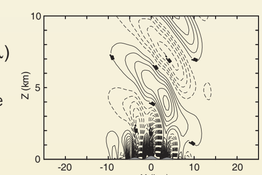
Verification: Solution, structure and amplitude

Model components tested: metric terms, divergence operators and advection (computation of ω).

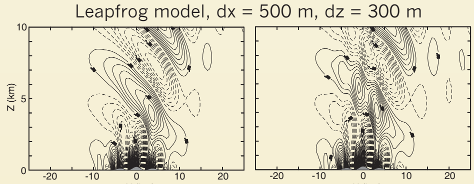
Steady-state solution: not a test of time integration (except in SL models).

$h(x) = H \exp(x^2/a^2)\ \cos^2(\pi x/\lambda)$
H = 250 m
λ = 4000 m
a = 5000 m
N = 0.01 s^{-1}
U = 10 ms^{-1}

Reference linear analytic solution



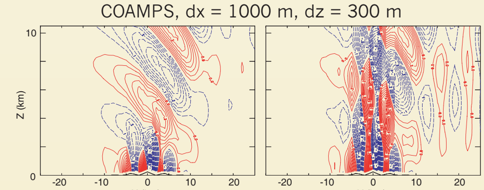
Leapfrog model, dx = 500 m, dz = 300 m



4^{th} order advection, ω comp.

4^{th} order advection, 2^{nd} order ω comp.

COAMPS, dx = 1000 m, dz = 300 m



4^{th} order advection, ω comp.

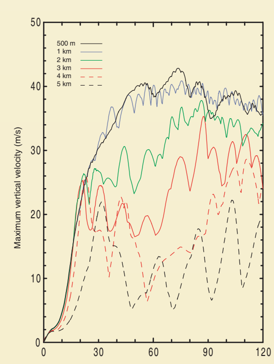
4^{th} order advection, 2^{nd} order ω comp.

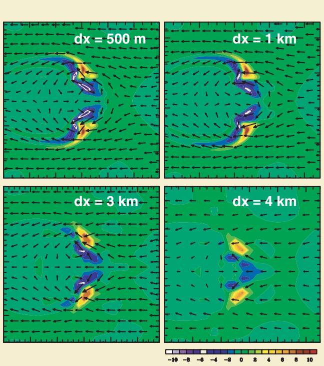
Moist Convection

Supercell test case: fixed viscosity (500 m^2/s), Kessler Microphysics, periodic x.y boundaries, (X,Y,Z = 90,90,20 km), unidirectional shear.

Verification: structure, amplitude, cell propagation.

Model Components tested: everything except terrain .





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