Status of the Dynamical Core Model Intercomparison Project (DCMIP)

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DCMIP

2nd IS-ENES Workshop, Toulouse, Jan/31/2013

The Ideas behind DCMIP

- The 2-week summer school and model intercomparison project DCMIP-2012 highlighted the newest modeling techniques for global climate and weather models
- Took place at NCAR from July/30-August/10/2012
- Brought together over 26 modeling mentors and organizers, 37 students, and 19 speakers
- DCMIP-2012 paid special attention to non-hydrostatic global models and their dynamical cores that now emerge in the GCM community
- Hosted 18 participating dynamical cores (3 participated remotely)

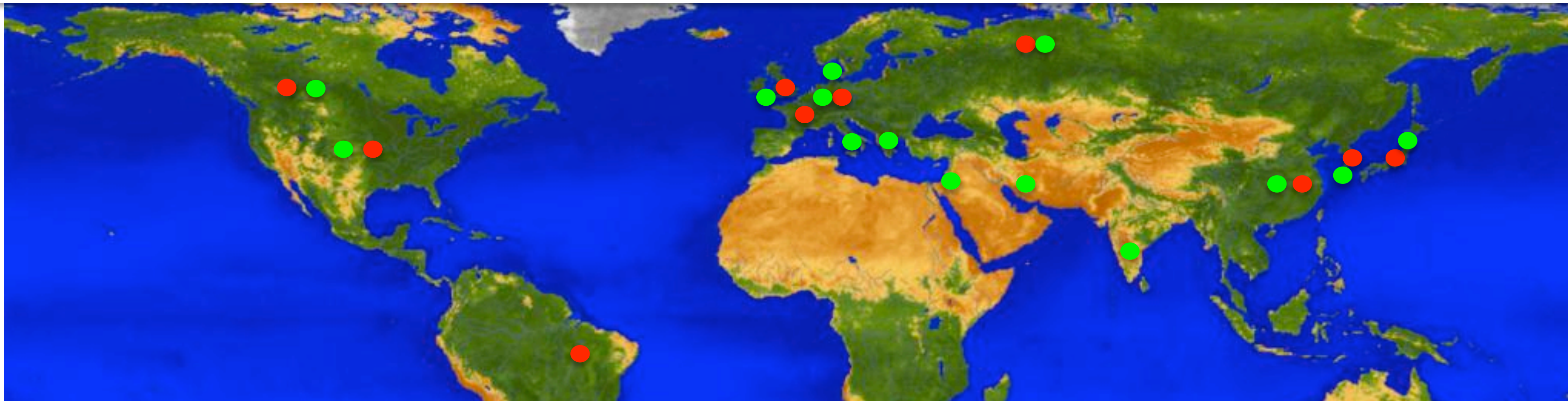
The Ideas behind DCMIP

- DCMIP-2012
  - Taught students, postdocs and the GCM community, both via lectures and hands-on sessions, at NCAR and elsewhere in the world (via the webcast and recordings): http://earthsystemcog.org/projects/dcmip-2012/lectures
  - Conducted an international dynamical core model intercomparison
  - Defined, tested and probably establishes new dynamical core tests
- Our vision: establish DCMIP as a long-term virtual community via the cyberinfrastructure-supported workspace
- Gateway to the virtual community, and open invitation to become a member and participate: http://earthsystemcog.org/projects/dcmip-2012/

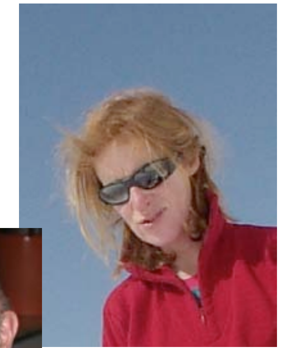
Meet the DCMIP Participants

Countries where the participants traveled from

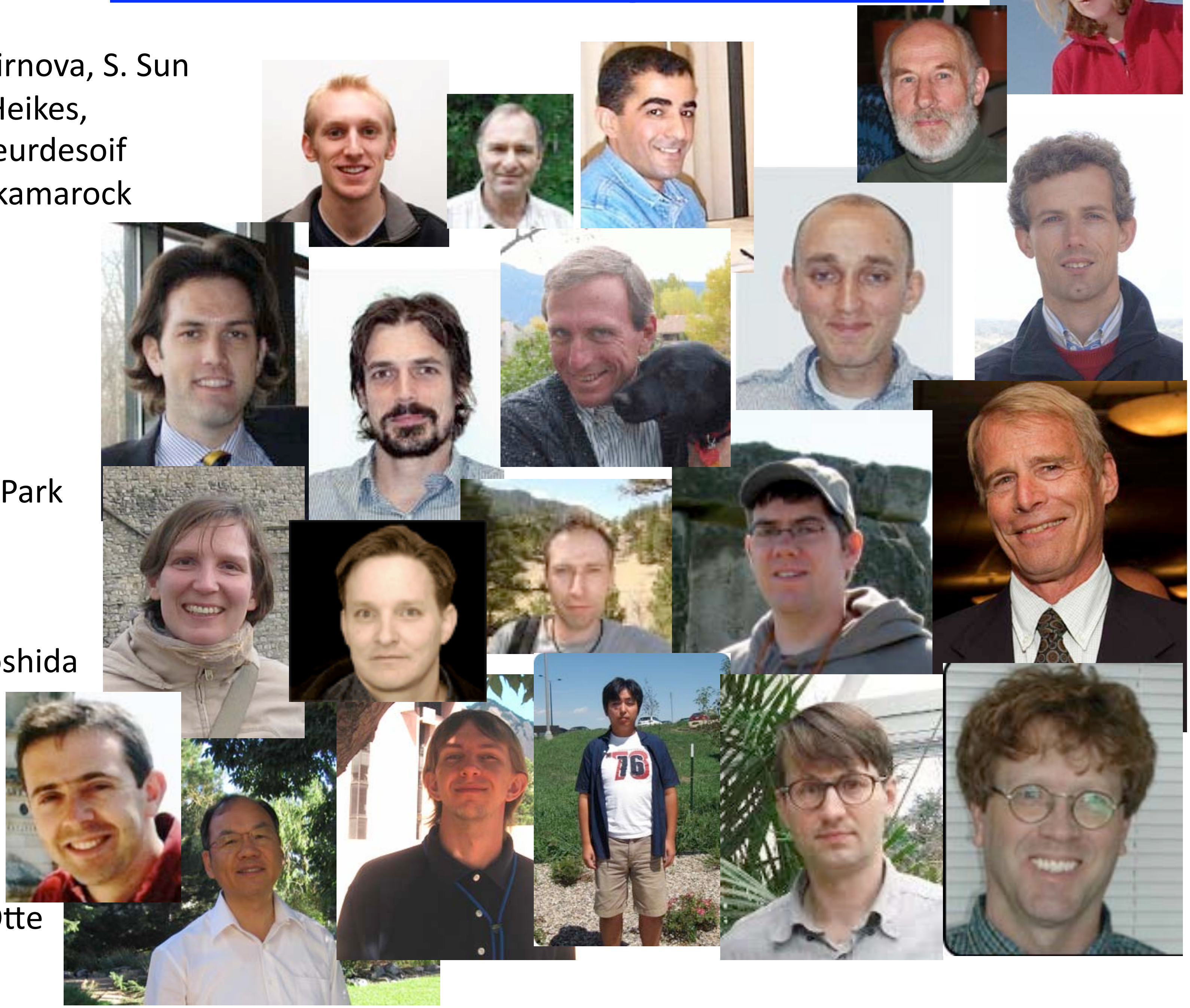
Countries where the participants came from



Meet the DCMIP Modeling Mentors



R. Bleck, T. Smirnova, S. Sun
D. Dazlich, R. Heikes,
T. Dubos, Y. Meurdesoif
M. Duda, W. Skamarock
T. Frisius
A. Gassmann
M. Giorgetta
M. Gross
L. Harris
J. Kent
J. Klemp, S.-H. Park
J. Lee
S. Malardel
T. Melvin
H. Miura, R. Yoshida
A. Qaddouri
K. Reed
D. Reinert
L. Silvers
M. Taylor
R. Walko, M. Otte

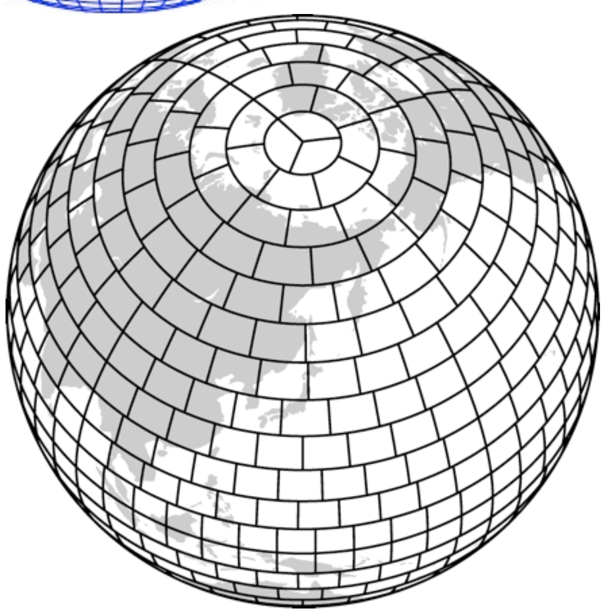


DCMIP Models: Cubed-Sphere Grids

Cubed-sphere grids

- CAM-SE
  (NCAR & Sandia Labs)
- FV3-GFDL
  (GFDL & NASA)
- MCORE
  (University of Michigan & University of California, Davis)

DCMIP Models: Latitude-Longitude



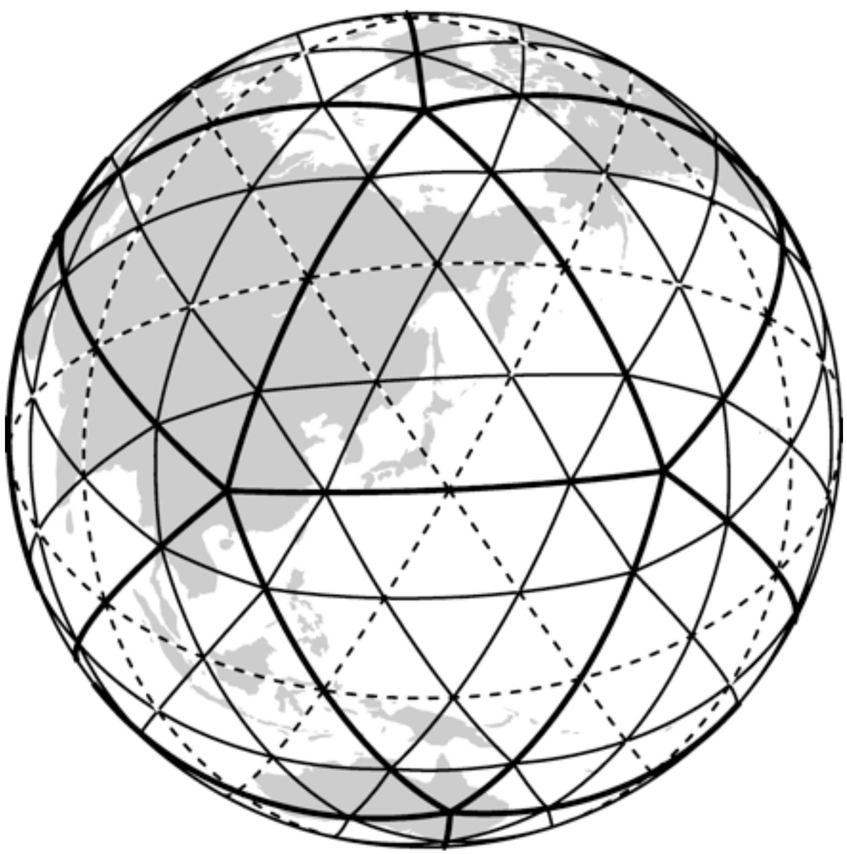
Latitude-longitude or Gaussian grids

- CAM-FV (NCAR)
- PUMA (University of Hamburg)
- GEM-latlon (Environment Canada)
- ENDGame (U.K. Met Office)

Reduced Gaussian grid

- IFS (ECMWF)

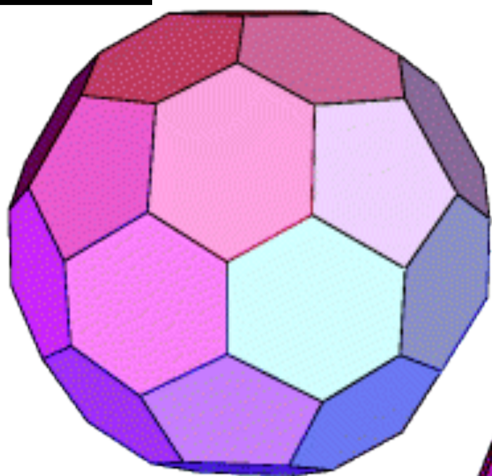
DCMIP Models: Triangular Grids

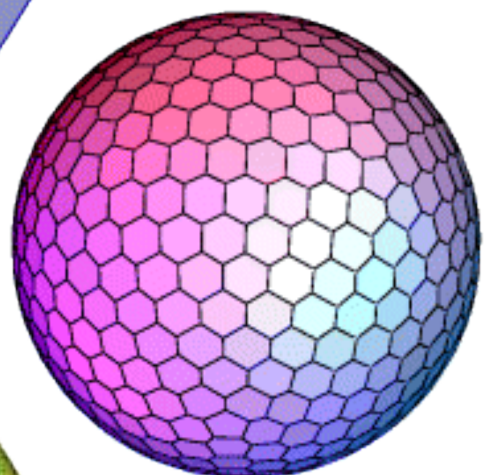


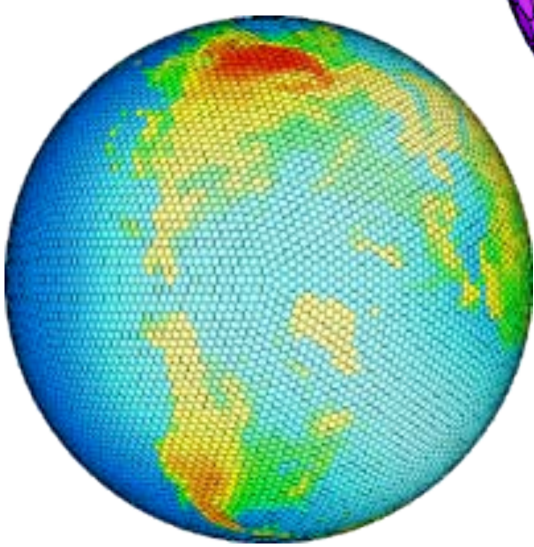
Spherical geodesic or icosahedral-based grids

- ICON-MPI-DWD (Max-Planck Institute, German Weather Service)
- DYNAMICO (IPSL, Paris)
- NIM (NOAA)
- NICAM (RIKEN, JAMSTEC)
- OLAM (University of Miami)

DCMIP Models: Hexagonal Grids



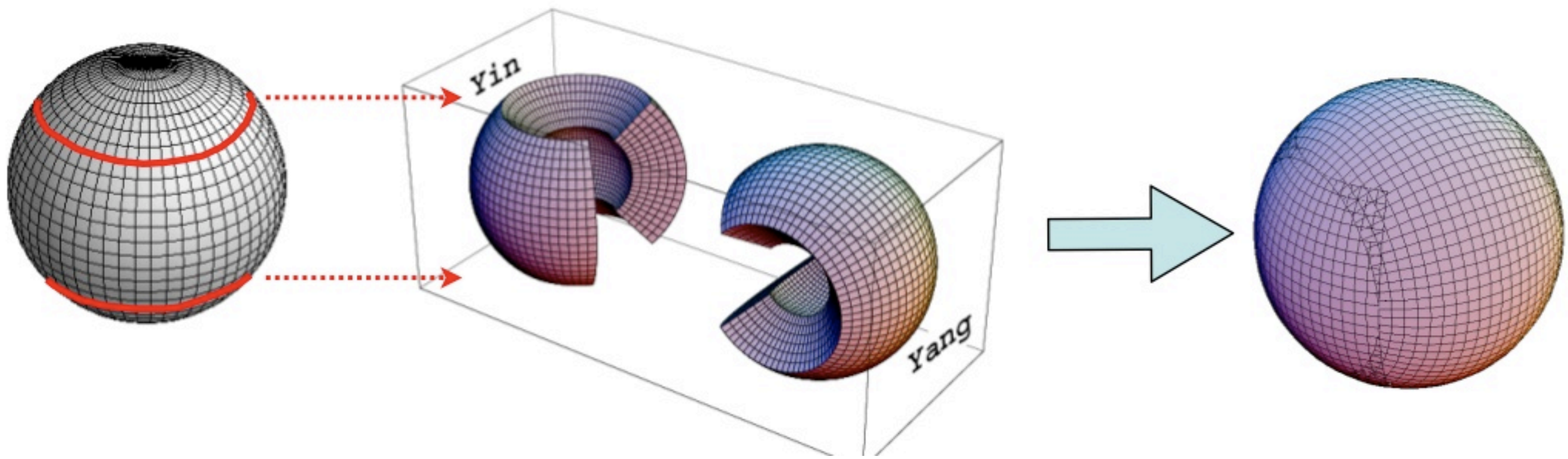




Hexagonal or spherical Voronoi grids

- FIM (NOAA)
- ICON-IAP (IAP Kühlungsborn)
- MPAS (NCAR)
- OLAM (University of Miami)
- UZIM (Colorado State University)

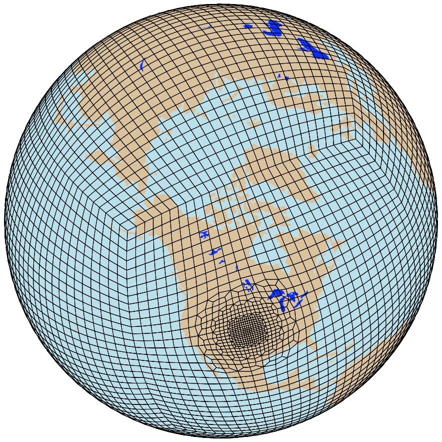
DCMIP Models: Yin-Yang Grid

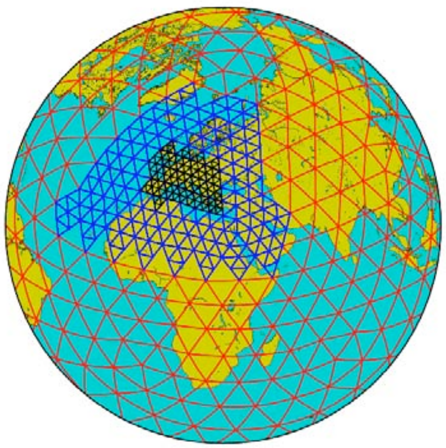


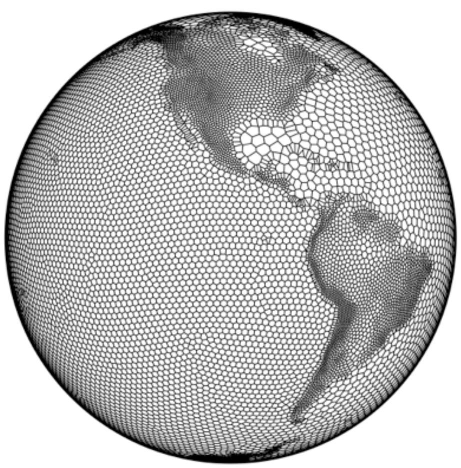
Yin-Yang grid

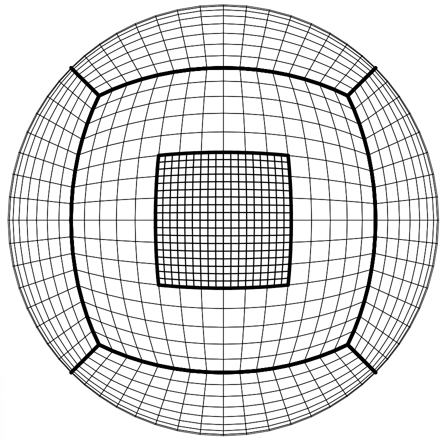
- GEM-yinyang
  (Environment Canada)

DCMIP Models: Nested Grids

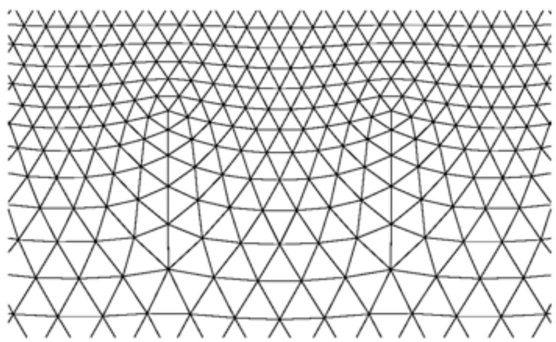








Models with optional variable-resolution-grid via embedded high-resolution regions

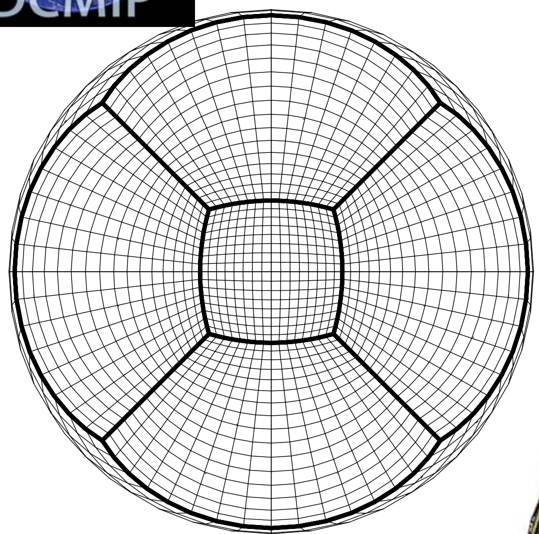


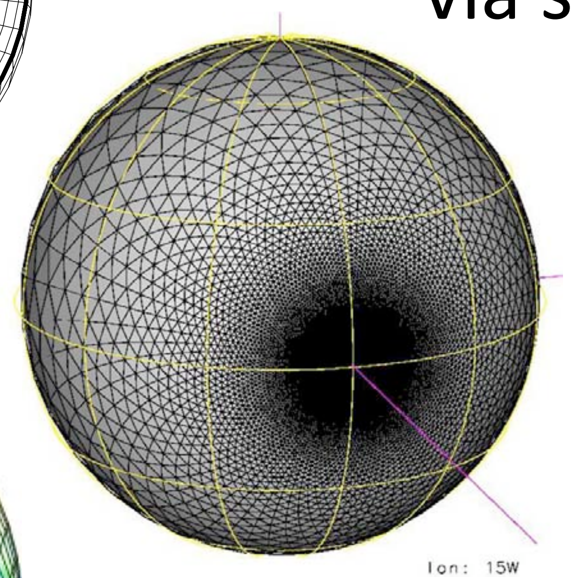
- CAM-SE
- FV3-GFDL
- ICON-MPI-DWD
- OLAM
- MPAS

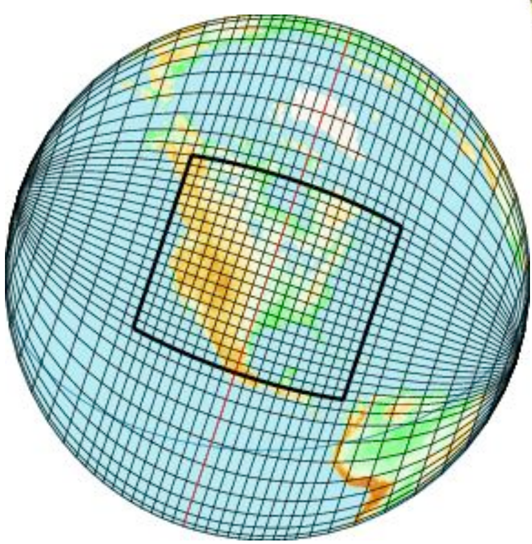
DCMIP Models: Stretched Grids

Models with optional variable-resolution-grid via stretched grids

- FV3-GFDL
- NICAM
- GEM-latlon







Meet the Teams

Goals and Wish-List for the DCMIP Test Suite

Test cases should

- be designed for **hydrostatic** and **non-hydrostatic** dynamical cores on the sphere,
  ideally: for both **shallow** and **deep atmosphere** models
- be easy to apply: analytic initial data (if possible)
  suitable for **all grids**
  formulated for **different vertical coordinates**
- be as easy as possible, but as complex as necessary
- be cheap and easy to evaluate: standard diagnostics
- be relevant to atmospheric phenomena
- reveal important characteristics of the numerical scheme
- have an analytic solution or converged reference solutions
- deal with moisture in a simple way
- find broad acceptance in the modeling community

The Architecture of the DCMIP Test Suite

The tests are hierarchical and increase in complexity

http://earthsystemcog.org/projects/dcmip-2012/test_cases

- **3D Advection**
  - Pure 3D advection without orography
  - Pure 3D advection in the presence of orography
- **Dry dynamical core without rotation**
  - Stability of a steady-state at rest in presence of a mountain
  - Mountain-induced gravity waves on small planets
  - Thermally induced gravity waves on small planets

- **Dry dynamical core with the Earth's rotation**
  - From large (hydrostatic) to small (nonhydrostatic) scales, nonlinear baroclinic waves on a shrinking planet with dynamic tracers PV and θ
- **Simple moisture feedbacks**
  - Moist baroclinic waves with large-scale condensation
  - Moist baroclinic waves with simplified physics (simple-physics)
  - Idealized tropical cyclones

The DCMIP Test Case Hierarchy

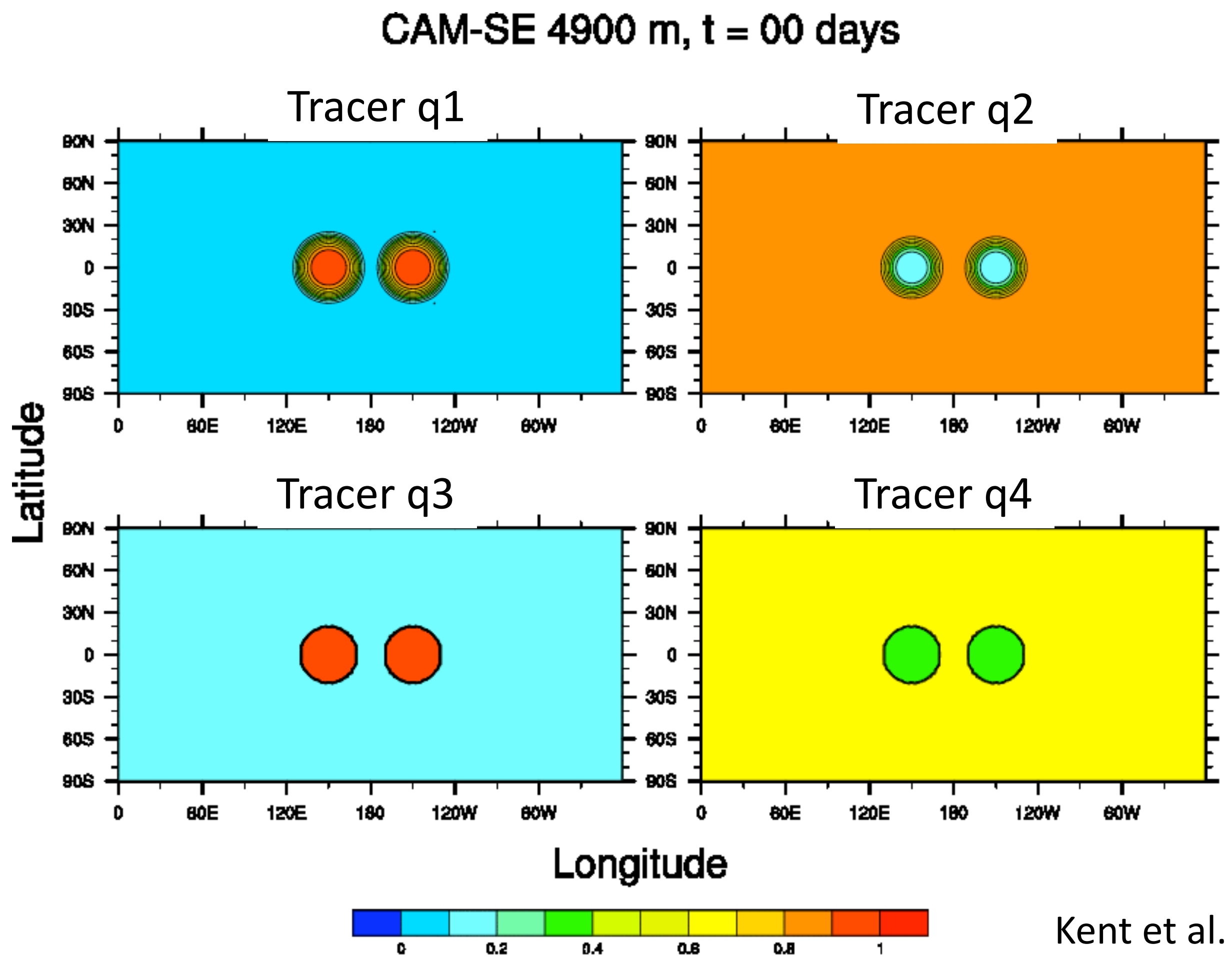
Table 1: Overview of all DCMIP test cases

11	3D deformational flow
12	3D Hadley-like meridional circulation
13	2D transport of thin cloud-like tracers in the presence of orography
200	optional: Steady-state at rest in the presence of moderatley-steep orography
201	optional: Steady-state at rest in the presence of steep orography on a small planet (X=500)
21	Mountain waves over a Schaer-type mountain on a small planet without shear (X=500)
22	Mountain waves over a Schaer-type mountain on a small planet with shear (X=500)
31	Gravity wave on a small planet, along the equator (X=125)
410	Dry baroclinic instability with dynamic tracers EPV and Θ and X=1
411	Dry baroclinic instability with dynamic tracers EPV and Θ and X=10 (scaled small planet)
412	Dry baroclinic instability with dynamic tracers EPV and Θ and X=100 (scaled small planet)
413	Dry baroclinic instability with dynamic tracers EPV and Θ and X=1000 (scaled small planet)
42	Moist baroclinic instability (with large-scale condensation)
43	optional: Moist baroclinic instability (with simplified physics forcing)
51	Idealized tropical cyclone (with simplified physics forcing)
52	optional: Idealized tropical cyclone (with full physics forcing)

[Check the DCMIP-2012 web page]()

3D Advection: Deformational Flow

Test 11: 4 correlated tracers in a reversing sheared flow

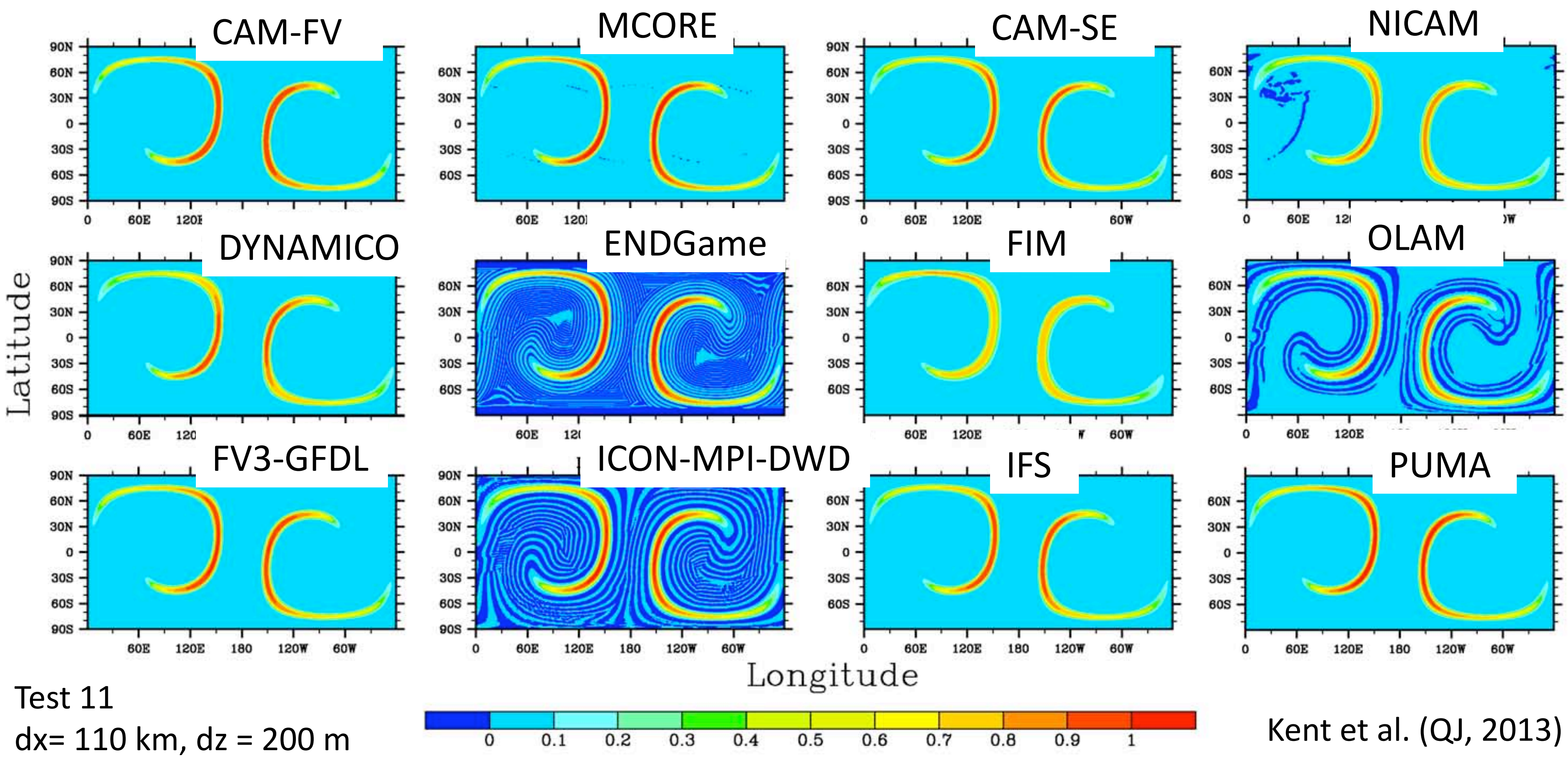


Test 11
dx= 110 km, dz = 200 m

Kent et al. (QJ, 2013, in submission): suggests 3D version of Lauritzen and Thuburn (QJ, 2012)

3D Advection: Deformational Flow

Test 11: Correlated tracers in a reversing sheared flow (tracer q1 at day 6)

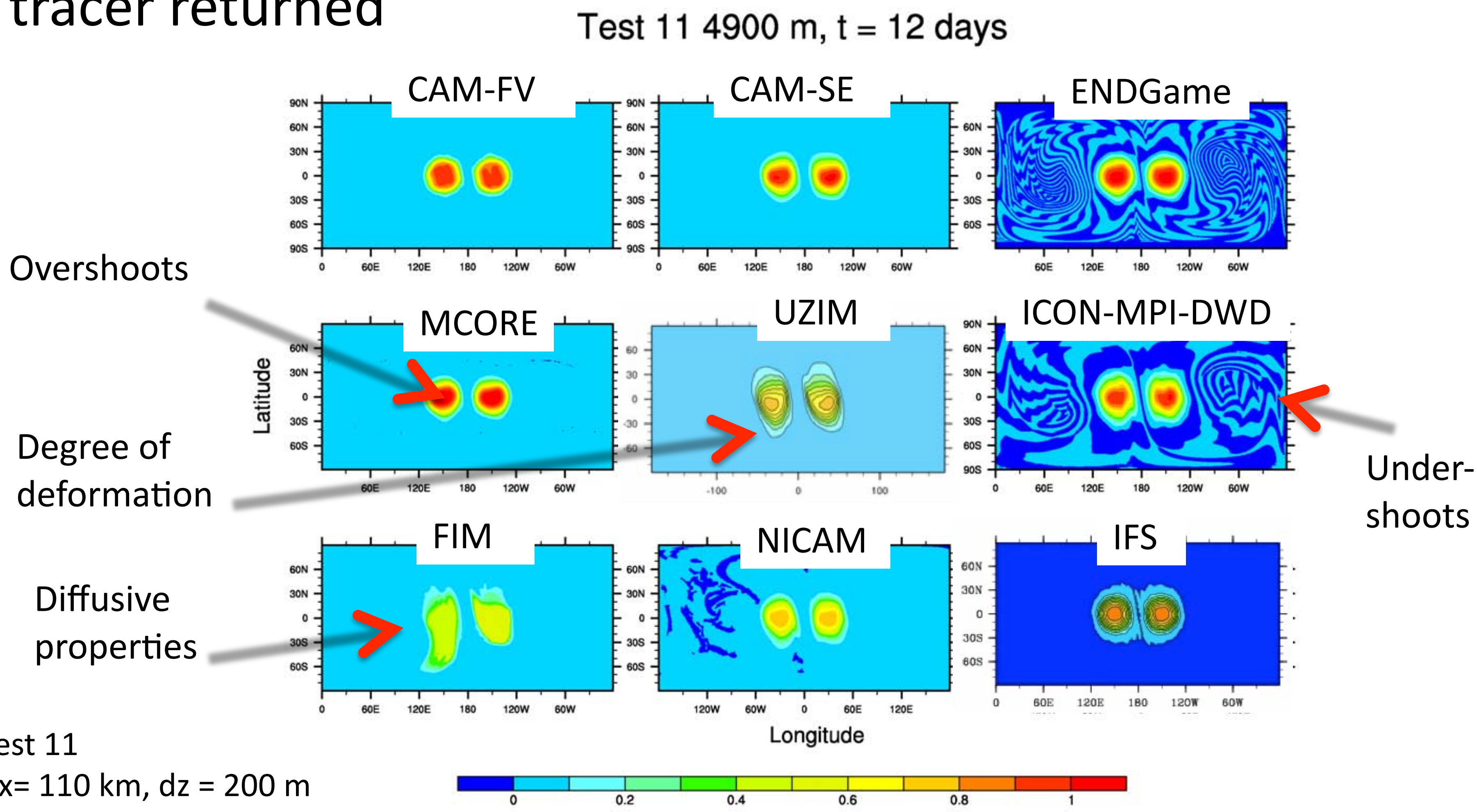


Test 11
dx= 110 km, dz = 200 m

Kent et al. (QJ, 2013)

3D Advection: Deformational Flow

Test 11: Tracer q1 at day 12 after the flow reversed and tracer returned

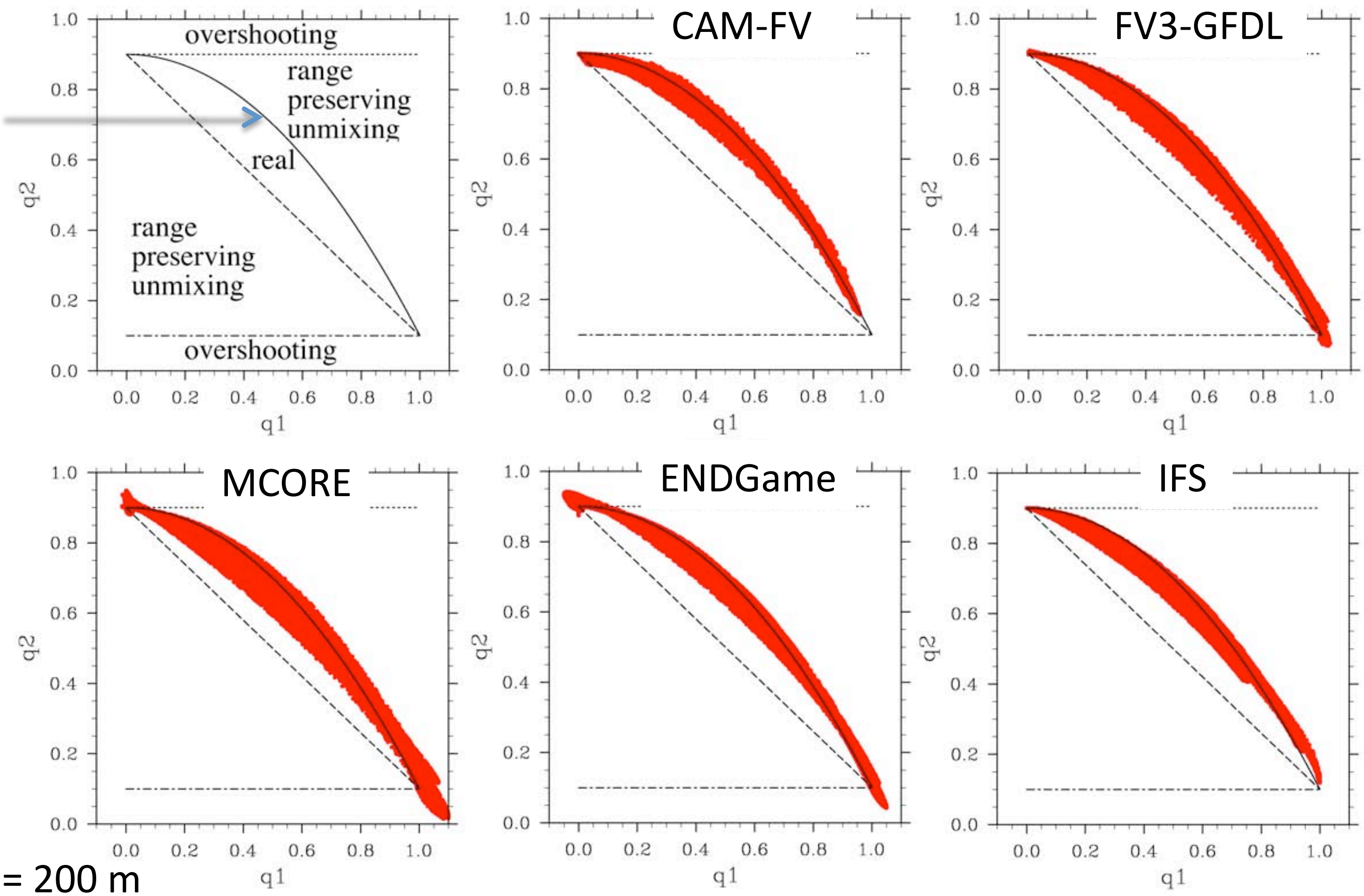


Test 11
dx= 110 km, dz = 200 m

3D Advection: Deformational Flow

Test 11: Correlated tracers q1 & q2: Mixing diagnostics at day 6

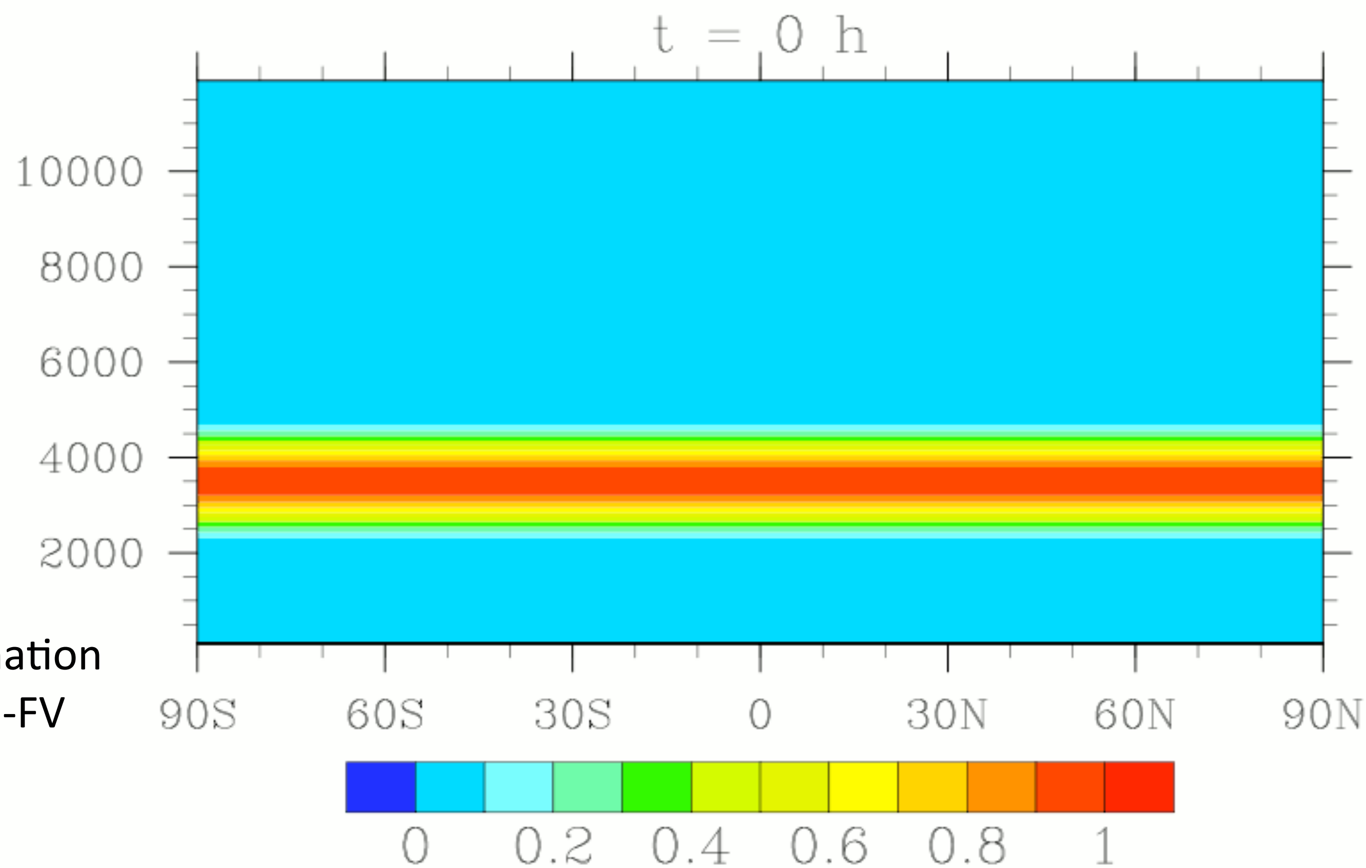
Functional relationship between q1 and q2



dx= 110 km, dz = 200 m

Advection: Hadley-cell like circulation

Test 12: Band-like tracer q is stretched thin after 12 h, but is still resolved. Returns to its original position after 24 h.

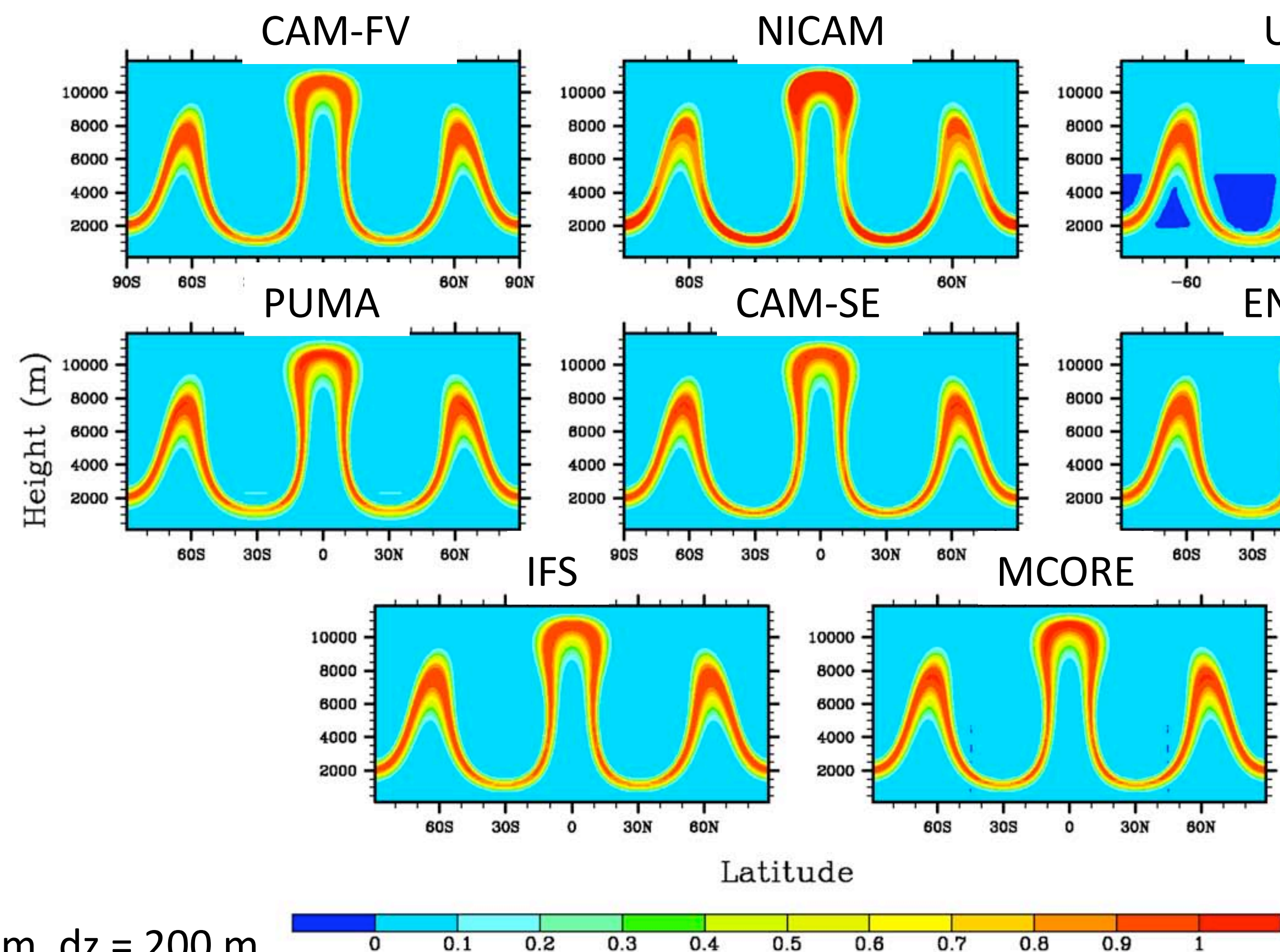


24 h animation with CAM-FV

dx= 110 km, dz = 200 m

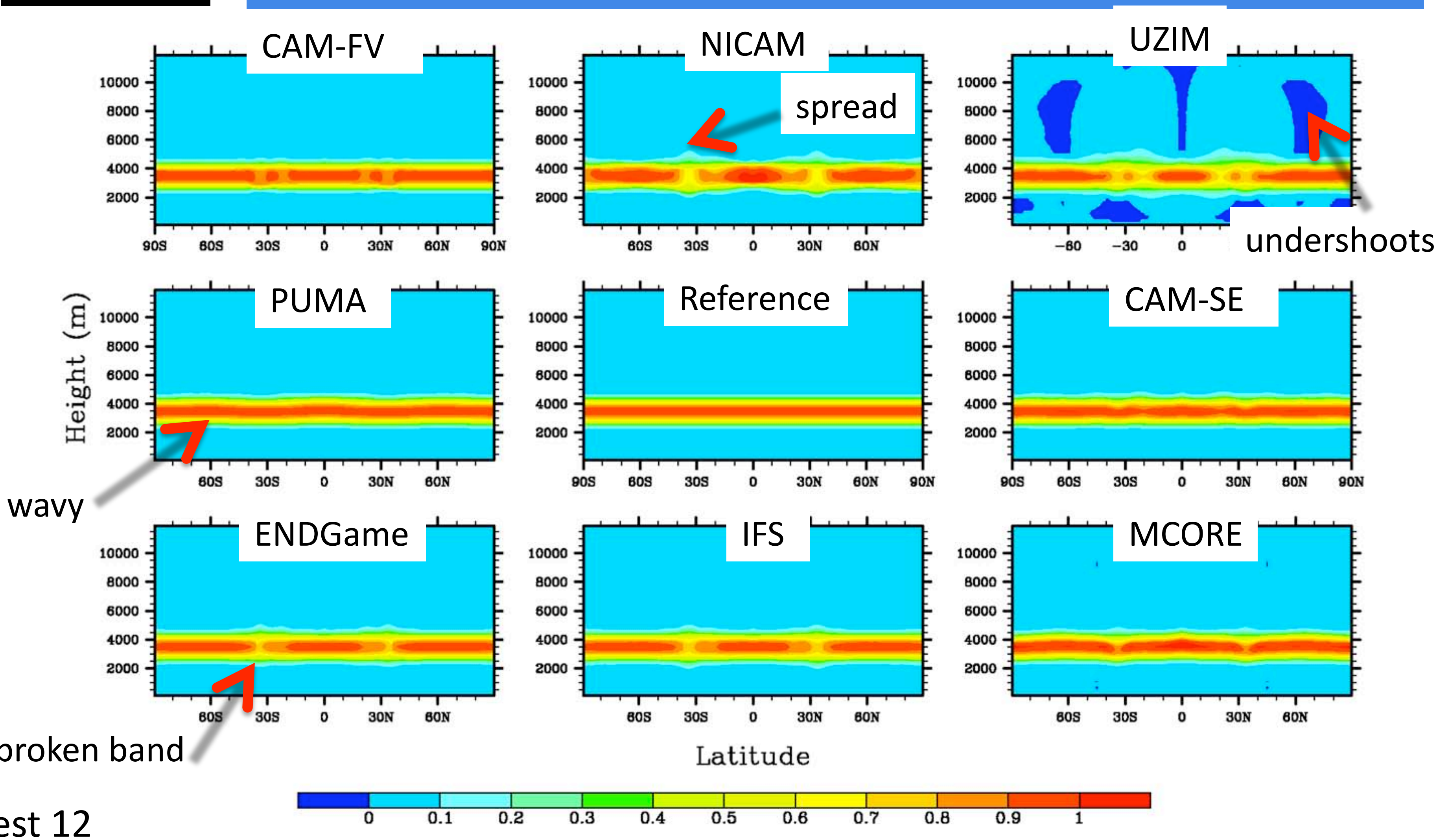
Advection: Hadley-cell like circulation

Test 12: Tracer q after 12 h



dx= 110 km, dz = 200 m

Advection: Hadley-cell like circulation



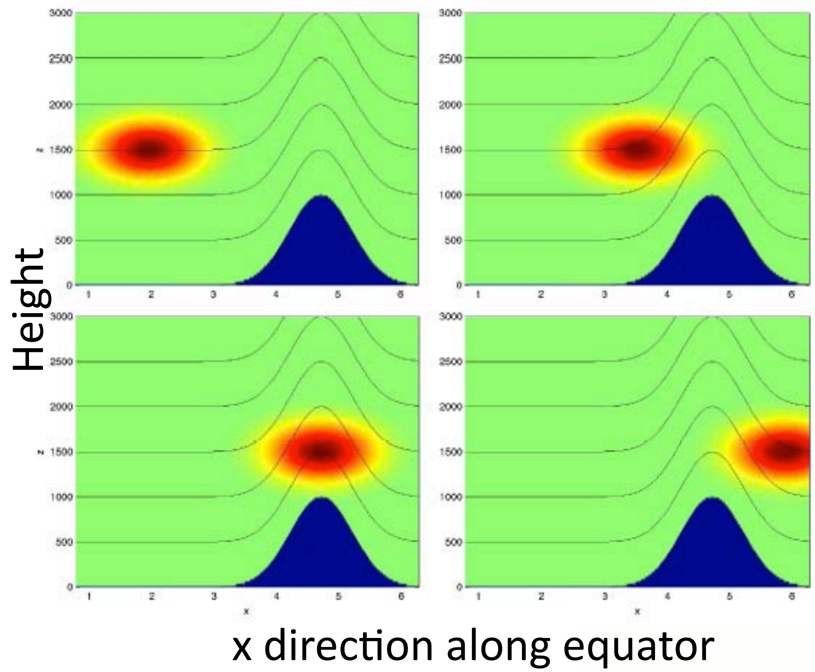
Test 12

dx= 110 km, dz = 200 m

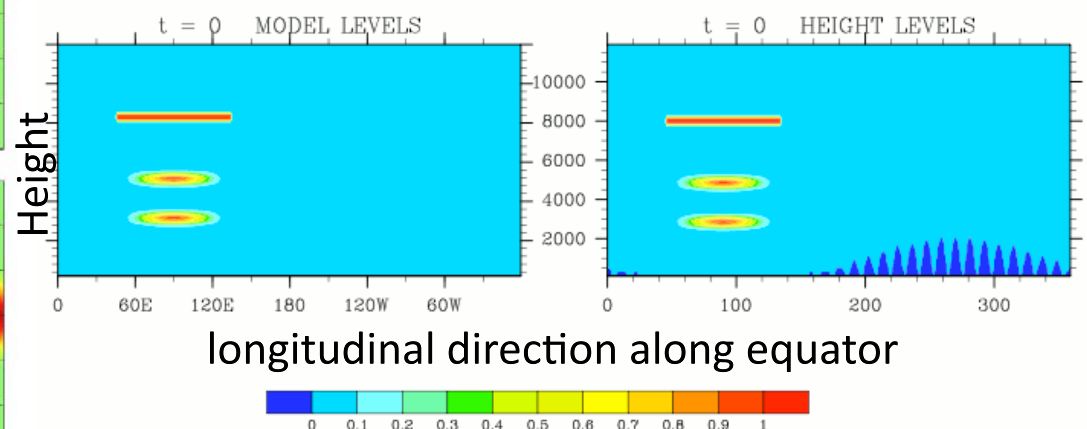
Initial state is the reference solution **after 24 h**

2D Advection Over Topography

Schematic: Desired 2D horizontal transport in the presence of topography with terrain-following vertical coordinates



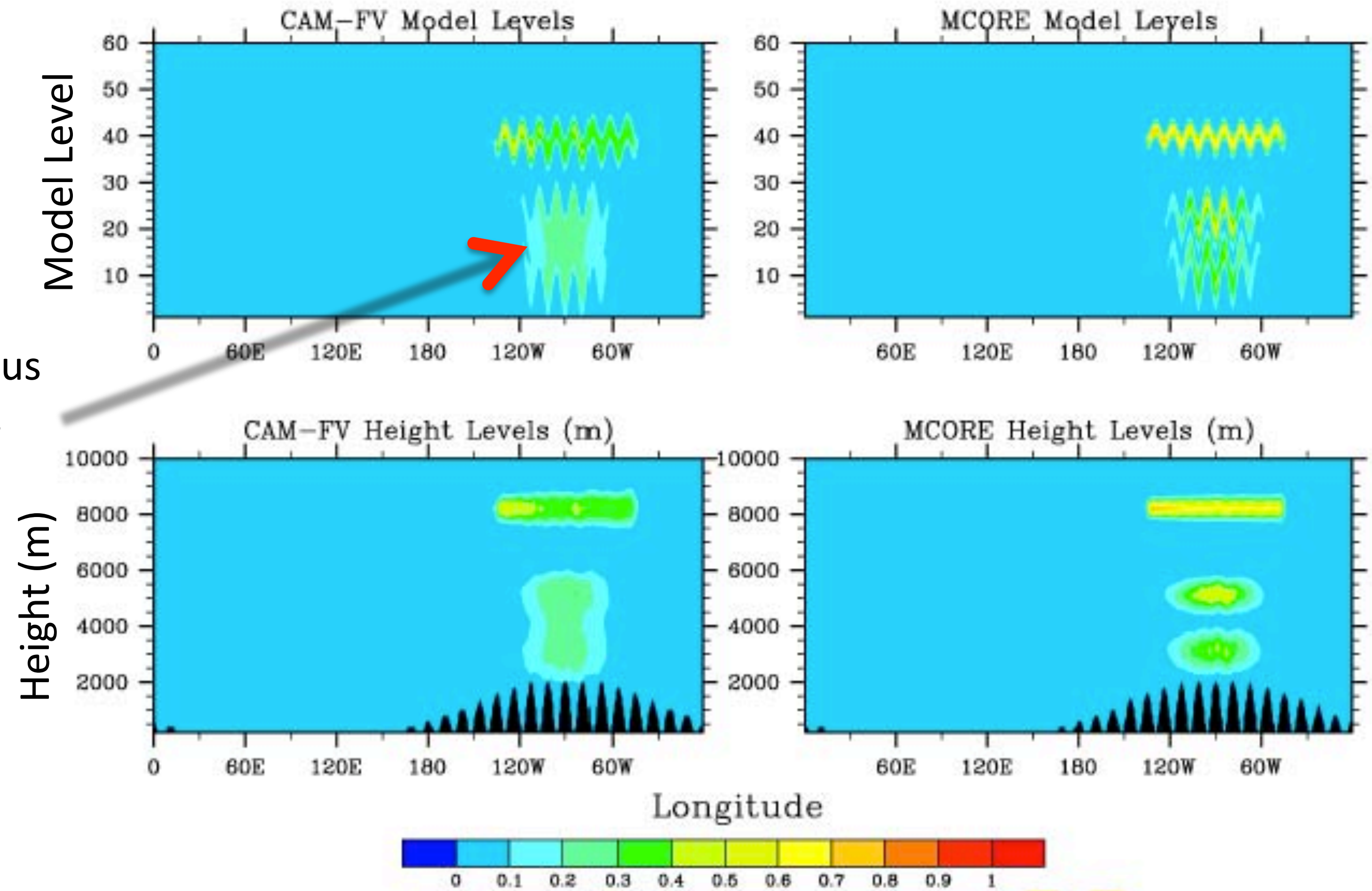
Transport of 3 cloud-like tracer fields with CAM-FV (12-day animation)



Test 13: Initial state is the reference solution **after 12 days**

2D Advection Over Topography

Tracers at day 6 (after half a revolution)



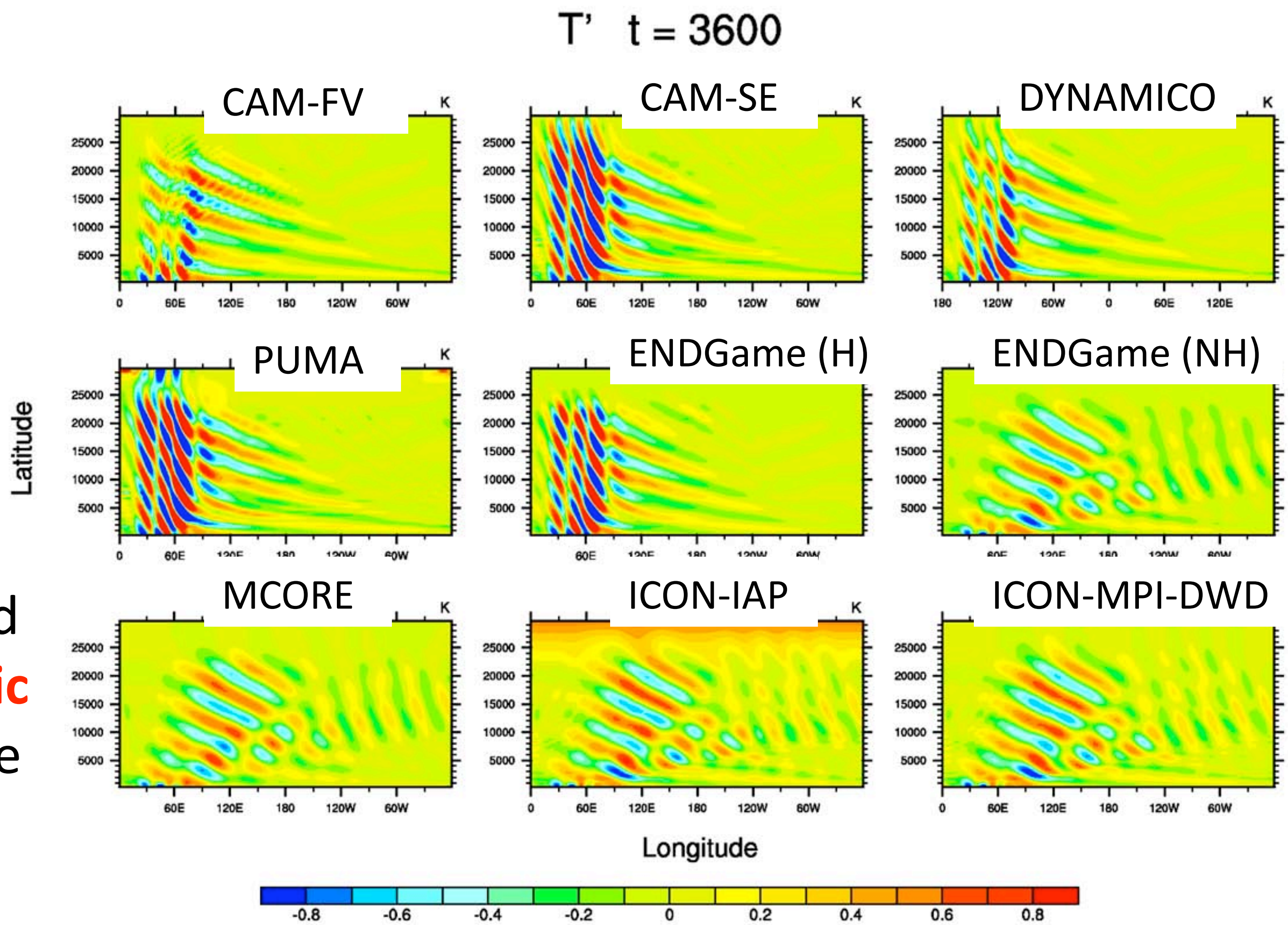
Strong spurious mixing across model levels

Test 13

dx= 110 km, dz = 200 m

Flow over Topography: Gravity Waves

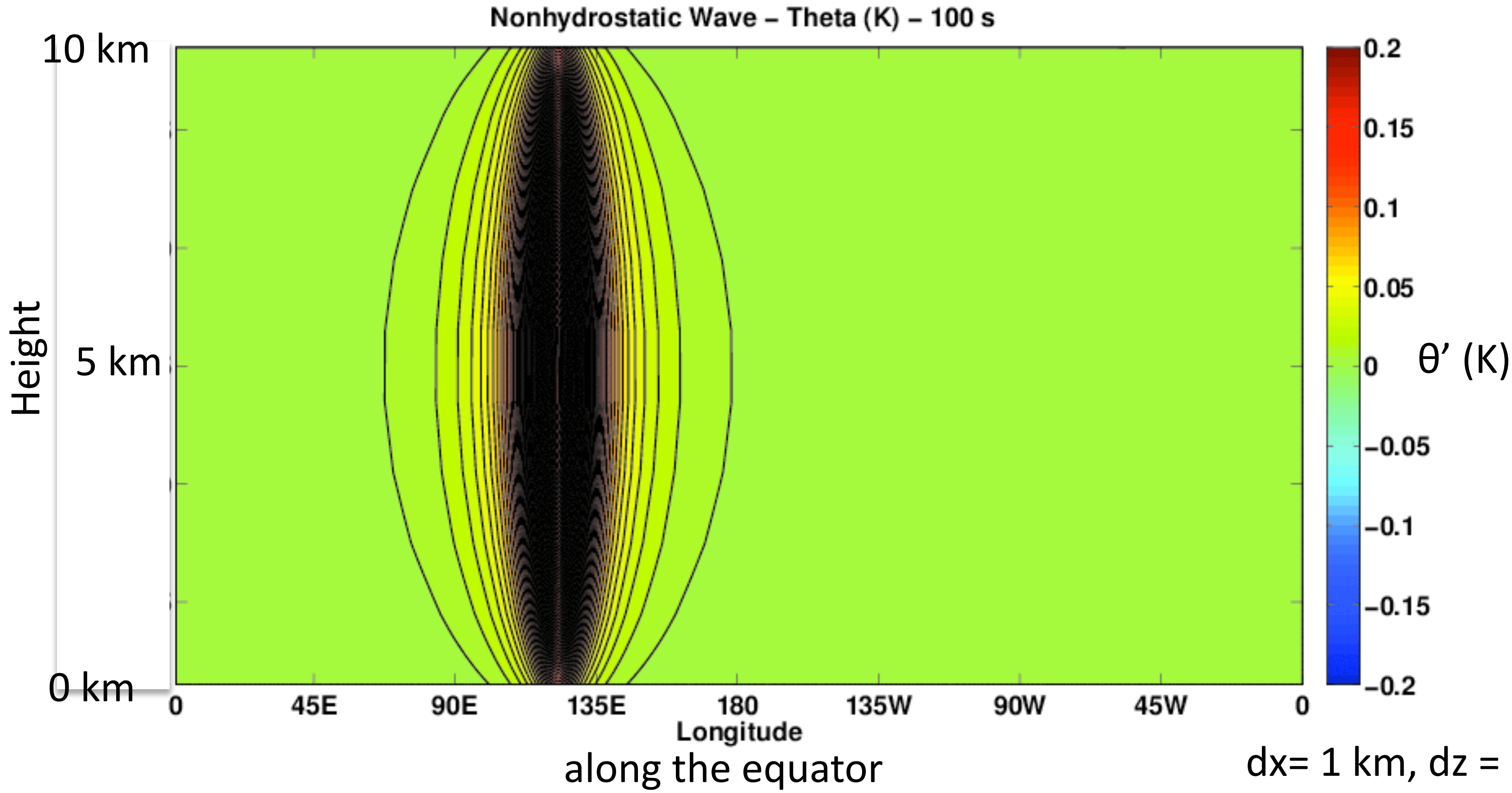
Test 21 on a reduced-size Earth with a circumference at the equator of 80 km: Distinguishes between **hydrostatic** and **non-hydrostatic** responses, here T perturbation



dx=334 m, dz = 500 m

Warm Bubble Triggered Gravity Waves

Test 31 on reduced-size Earth with circumference ≈ 320 km:
with translating west wind: Example of nonhydrostatic response in the potential temperature perturbation θ’ (MCORE, animation)

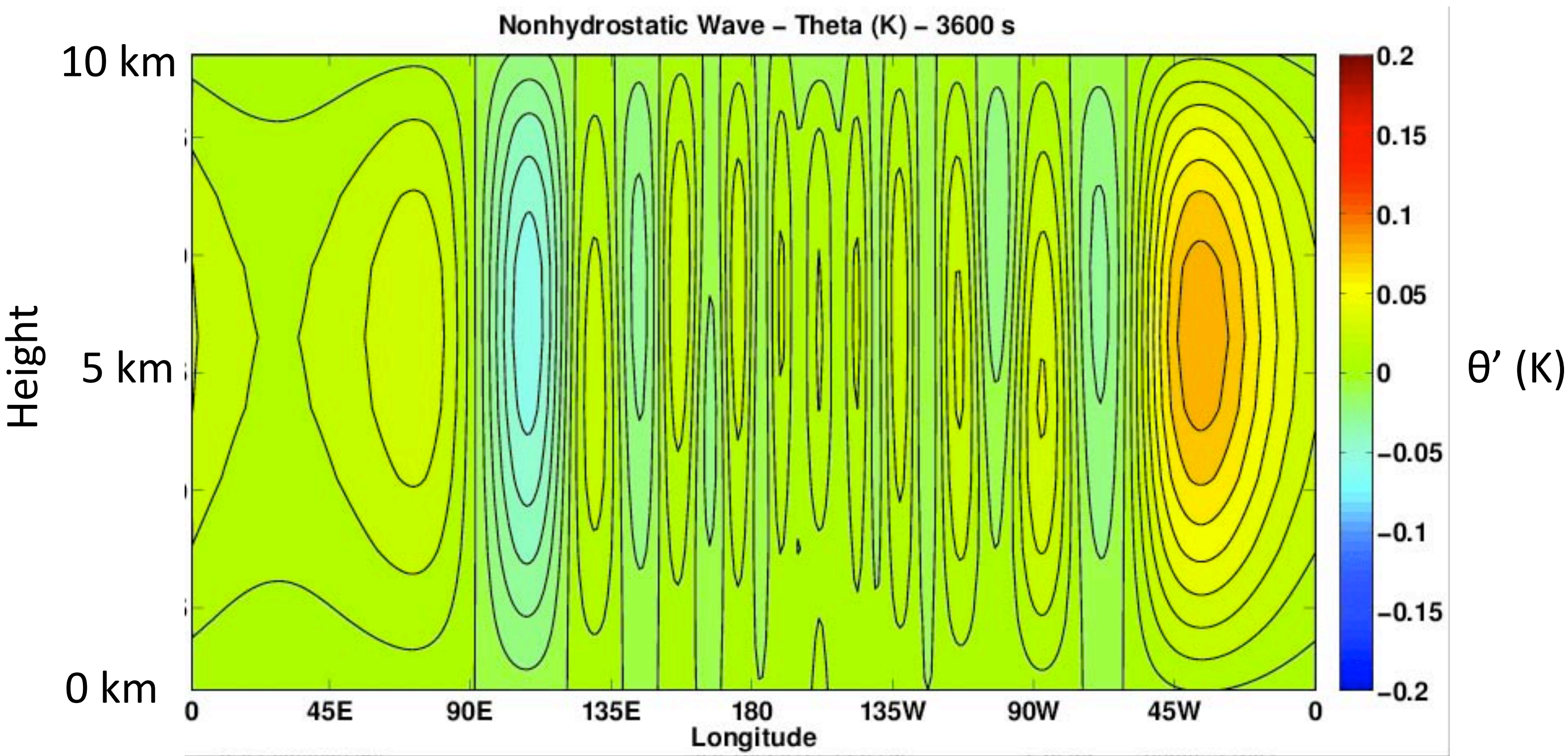


dx= 1 km, dz = 1 km

Warm Bubble Triggered Gravity Waves

Test 31 on reduced-size Earth with circumference ≈ 320 km:

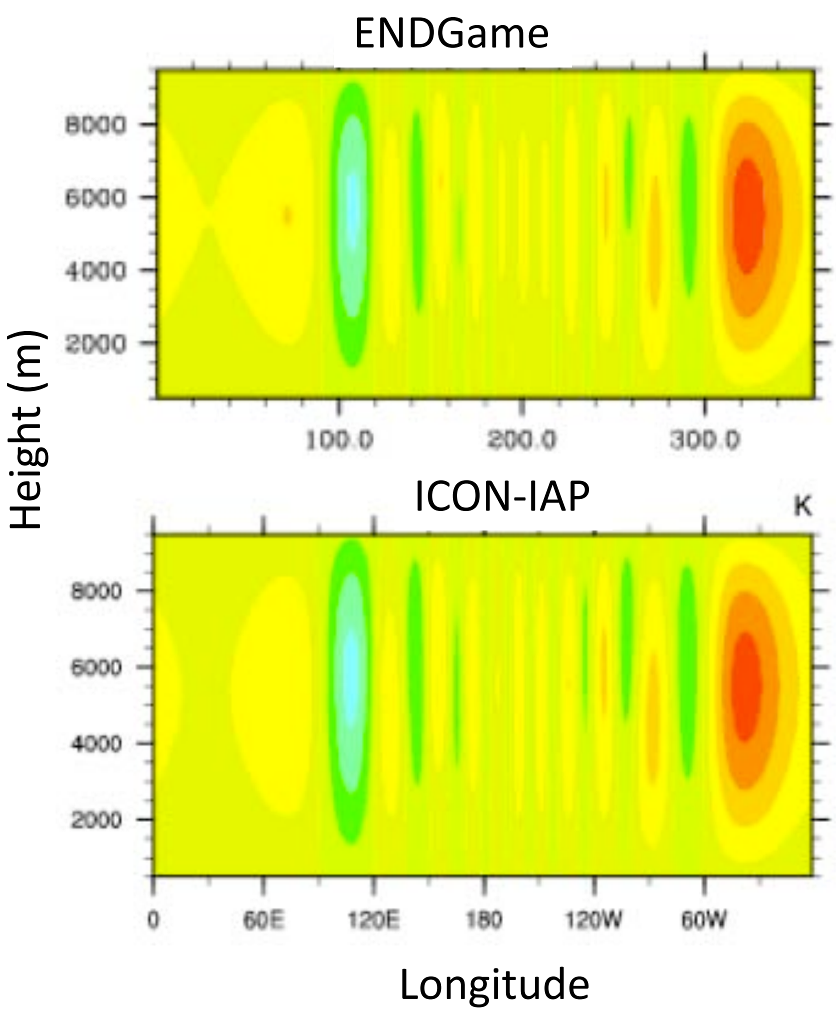
Potential temperature perturbation θ’ (K) along the equator after 3600 s in MCORE



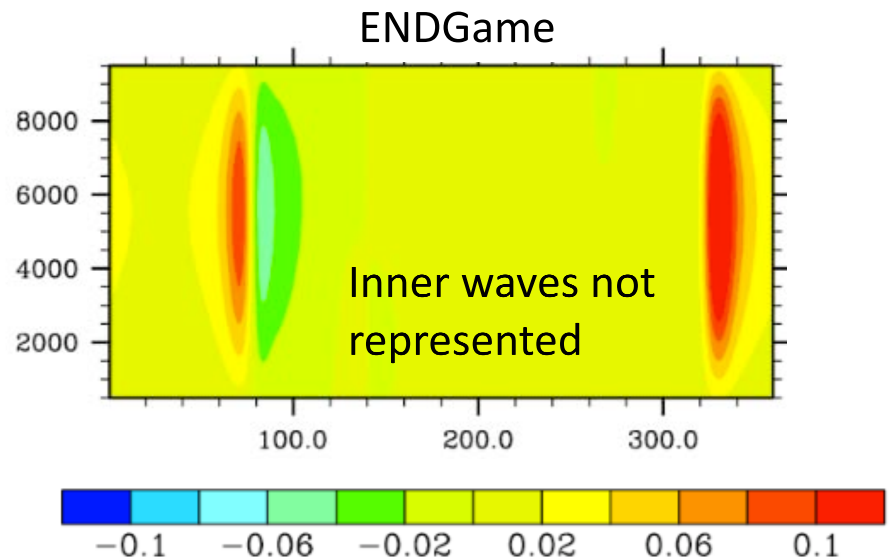
dx= 1 km, dz = 1 km

Warm Bubble Triggered Gravity Waves

Non-hydrostatic



Hydrostatic



Potential temperature perturbation θ' (K) at the equator after 3600 s

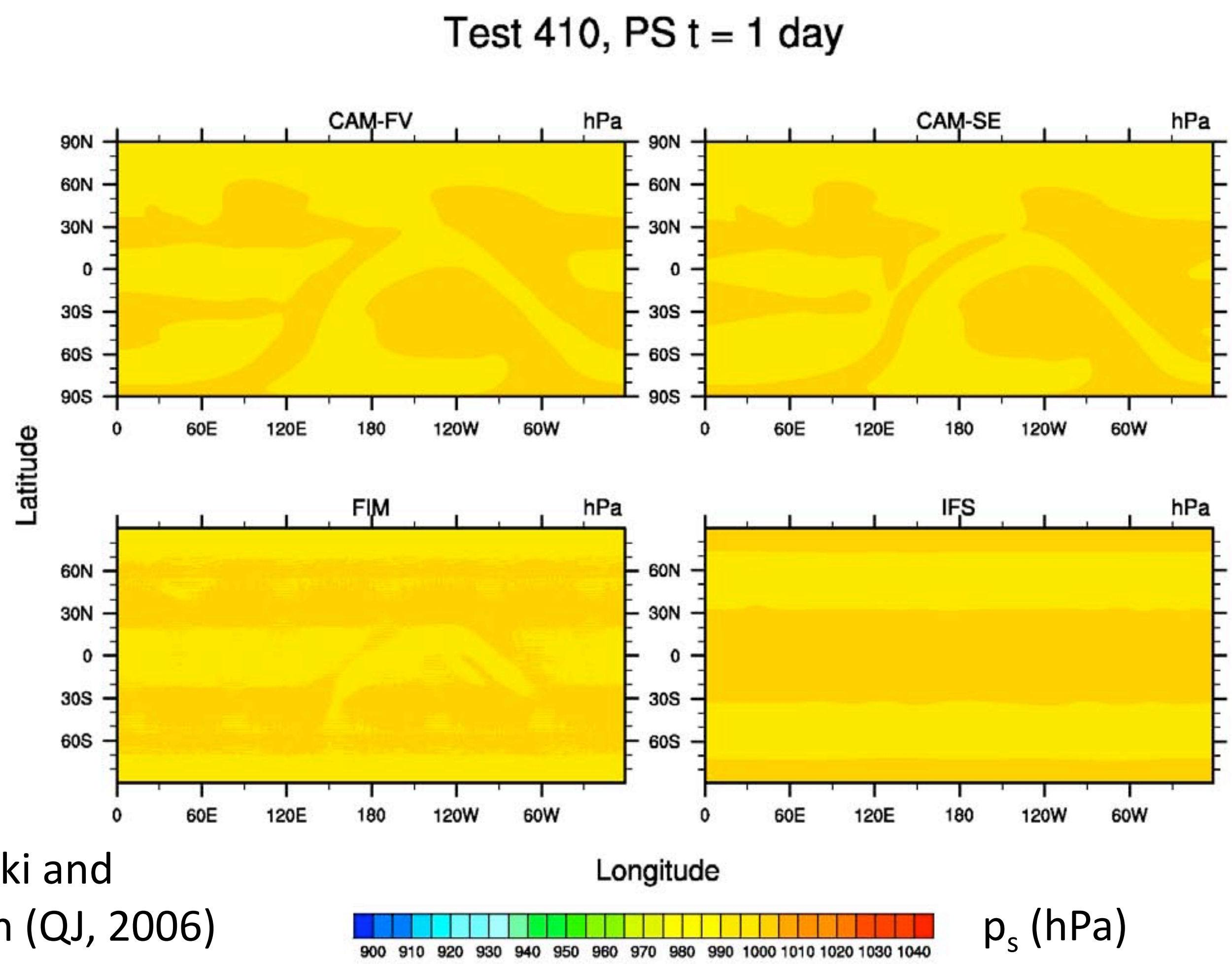
Compare: phase velocity, amplitude, symmetry properties, differences to hydrostatic solution

Test 31, dx= 1 km, dz = 1 km

Baroclinic Wave: surface pressure

Test 410: Baroclinic wave, evolution of the surface pressure

(30-day animation)

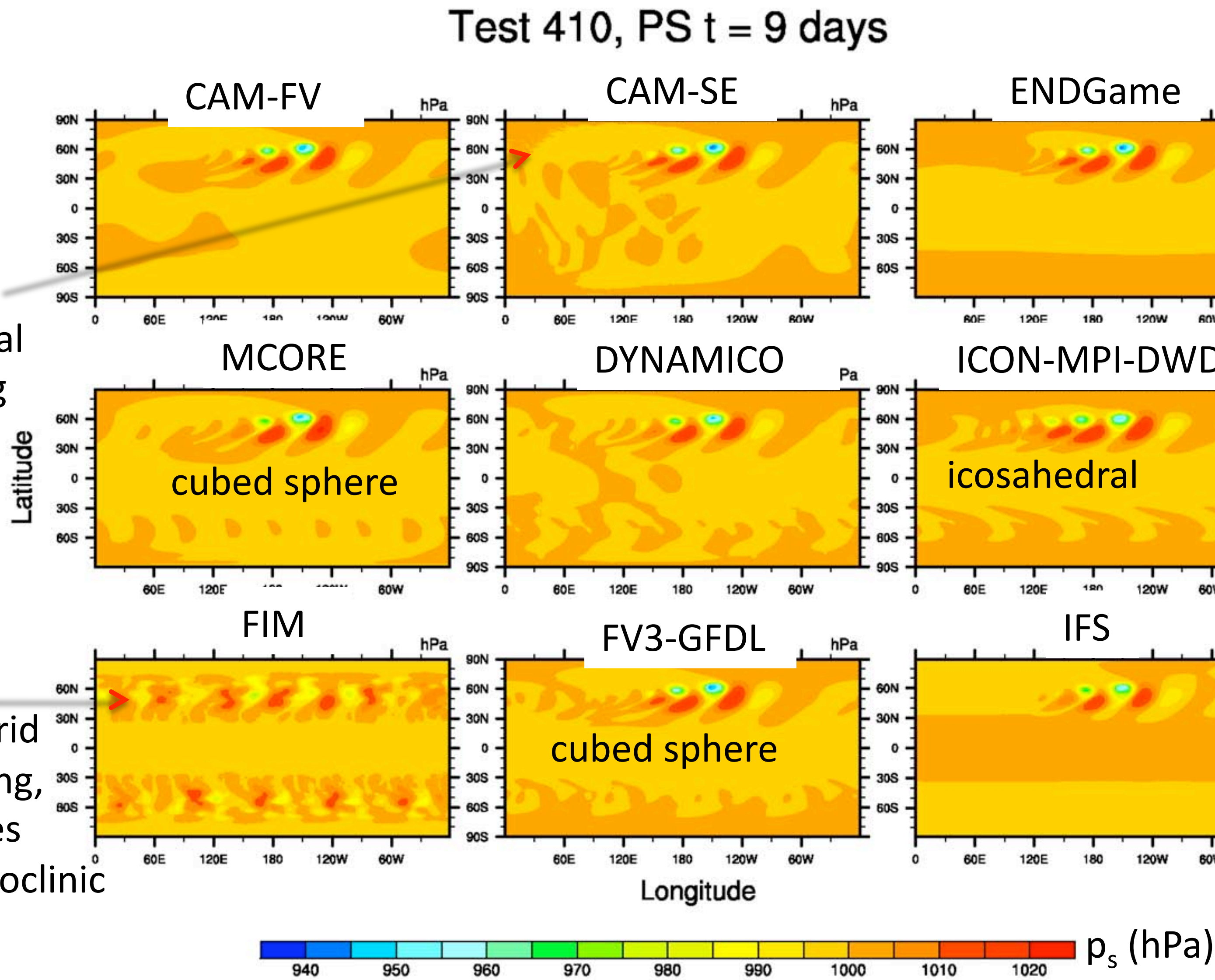


p_s (hPa)

Jablonowski and Williamson (QJ, 2006)

X=1
1°x1°L30

Baroclinic Wave: surface pressure



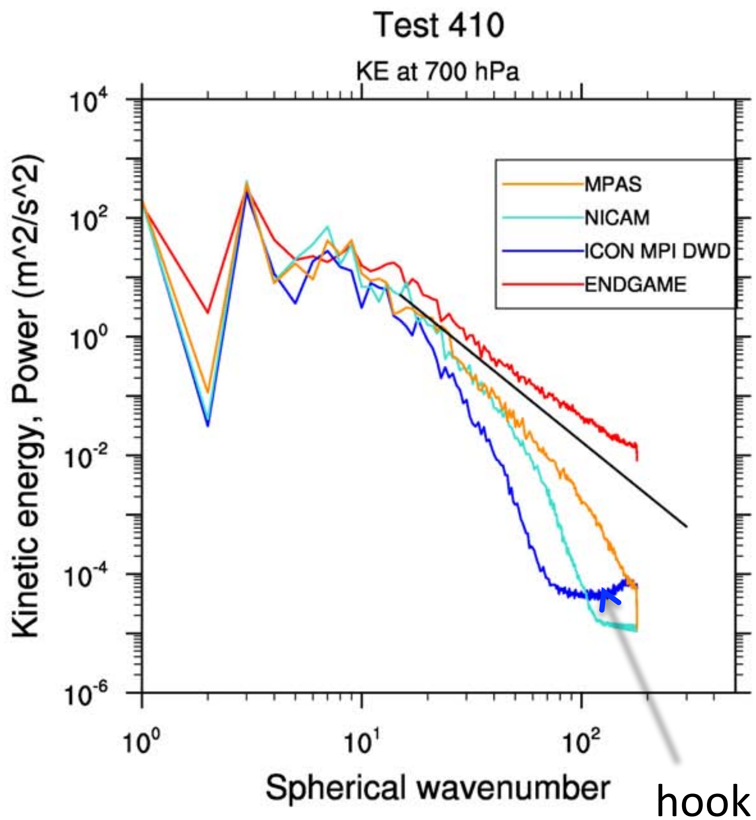
slight spectral ringing

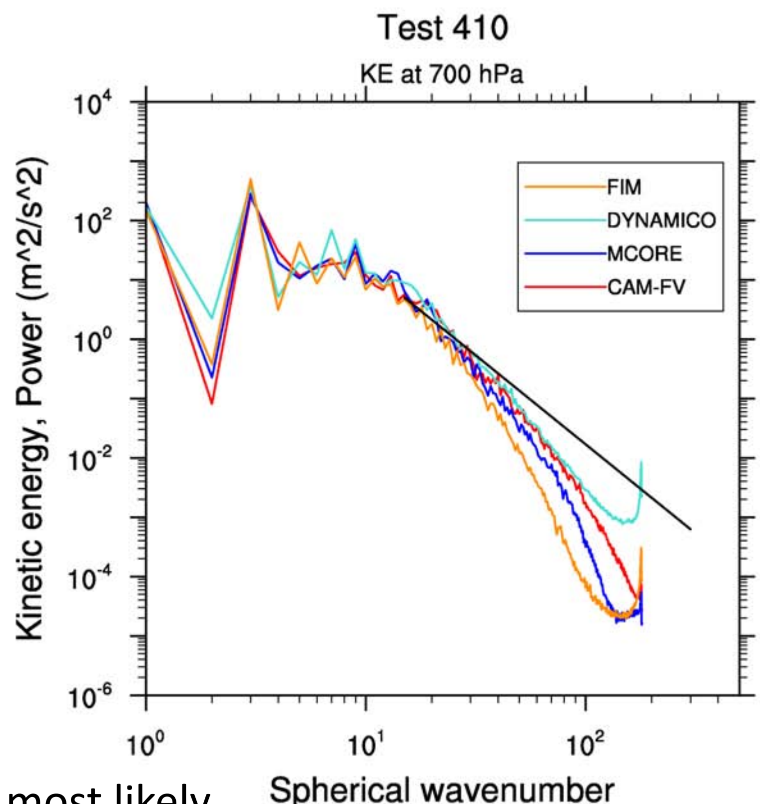
strong grid imprinting, interferes with baroclinic wave

X=1
1°x1°L30

Baroclinic Wave: KE spectra

Test 410: Baroclinic wave, KE spectra as a diagnostic tool, Diffusion characteristics are expressed by steepness of tail



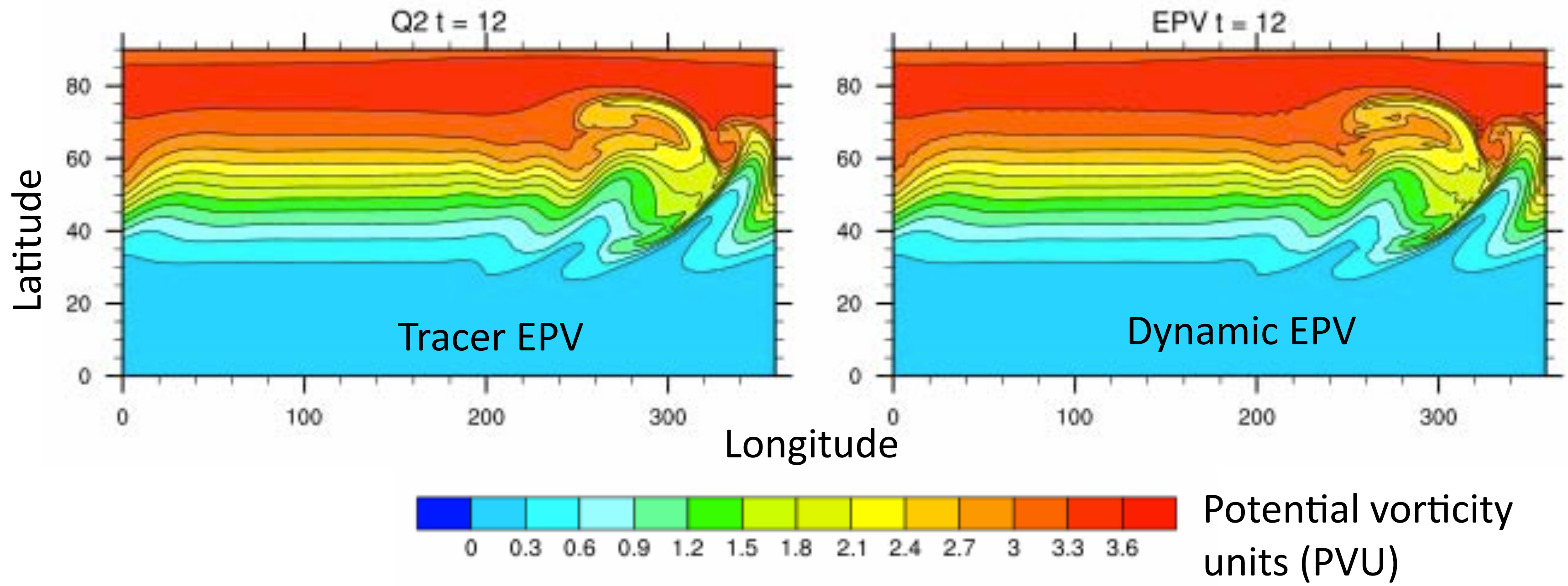


hook most likely
linked to interpolation issue

1°x1° L30
dx = 110 km

Baroclinic Wave: Tracer consistency

Test 410: Consistency of the Ertel potential vorticity (EPV) in CAM-FV (at day 12 on the 315 K isentropic level)



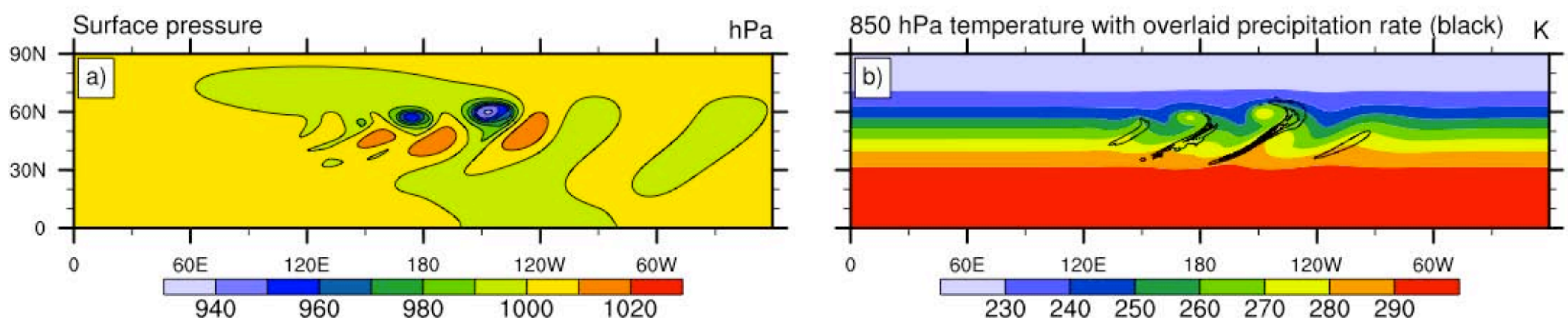
Compare the evolution of the dynamic EPV and EPV transported as a passive tracer

1°x1° L30
dx = 110 km

Baroclinic Wave: Moisture and Large-Scale Condensation

Test 42:

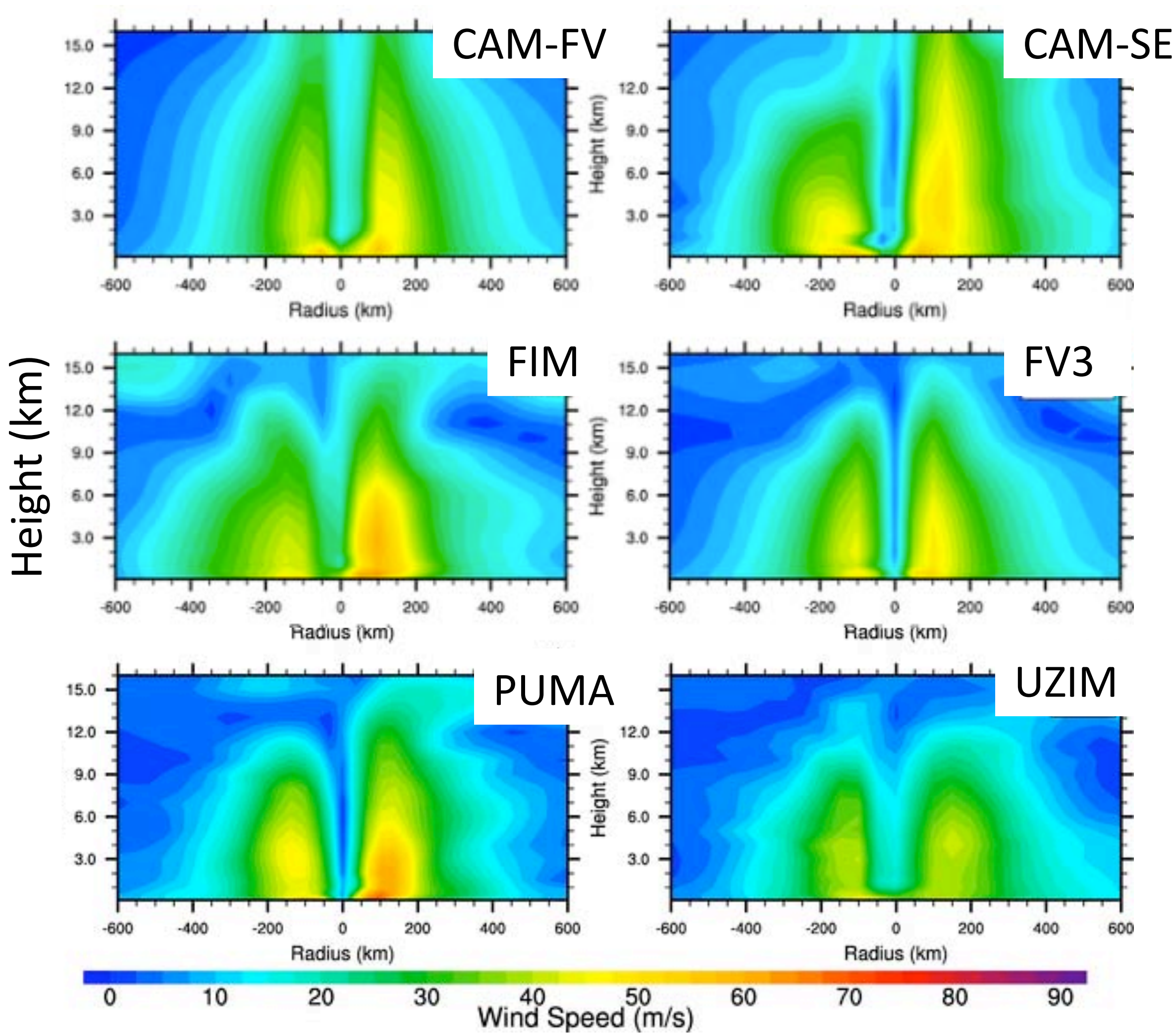
Large-scale condensation in a moist version of the baroclinic wave leads to an intensification of the baroclinic wave in CAM-FV (1°x1° L30), here at day 9



Provides a first glimpse at the non-linear physics-dynamics interactions in the presence of moisture

1°x1° L30
dx = 110 km

Tropical Cyclone with Simple-Physics



Test 51:

Idealized TC on an aqua-planet: Simulations with Simple-Physics

Height-longitude cross section of the wind speed (m/s) at day 10: wide spread in results

Reed and Jablonowski (MWR, 2011)
Reed and Jablonowski (James, 2012)

0.5° x 0.5° L30, dx= 55 km

DCMIP Cyberinfrastructure

- Interactive communication platform via a Wiki-driven shared workspace http://earthsystemcog.org/projects/dcmip-2012/
- Model metadata services:
  - Customized metadata form
  - Metadata viewer
- Data services:
  - Earth System Grid (ESG) data base, on NOAA server
  - Searchable data catalog
  - Linked to model metadata
  - Linked on online visualization: Live Access Server (LAS)

Some Thoughts

- The end of the DCMIP-2012 Summer School has been the start of a community-wide DCMIP as a long-term resource
- DCMIP is a forum for new science:
  - Objective evaluation of dynamical cores and their interactions with moisture
  - An effort towards a standard test suite that follows a hierarchical approach
  - Establish new cyberinfrastructure as a scientific tool for our community
  - Open invitation to participate and contribute

Some Final Observations

- We see both very interesting agreements and spreads among the results, let us learn from them
- The spread will give us insight into the uncertainty of the simulations, and the characteristics of the numerical schemes
- We might find bugs in our codes, and DCMIP data
- We might want to fine-tune the test cases
- DCMIP-2012 is not a 'beauty contest': our goal is to expose the pros and cons of the dynamical core modeling approaches via objective evaluations

DCMIP Sponsors

Endorsed by the WMO Working Group on Numerical Experimentation (WGNE)

References

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