Updated results from the 2016 Dynamical Core Model Intercomparison Project (DCMIP-2016)

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Organizing team

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What is DCMIP?

DCMIP: 2-week summer school and Dynamical Core Model Intercomparison Project (DCMIP): 2008, 2012, 2016

in 2016: use **idealized moist test cases** and focus on non-hydrostatic dynamical cores and their physics-dynamics coupling

Three "core" test cases with idealized physics processes:

- **Test 1: Dry and moist (Kessler-physics) baroclinic instability test with "toy" terminator chemistry** (110 km, 30 vertical levels)
- **Test 2:** Moist tropical cyclone test
- **Test 3:** Moist mesoscale storm test (supercell)

Recent paper: "DCMIP2016: a review of non-hydrostatic dynamical core design and intercomparison of participating models", Ullrich et al. (2017) in GMD

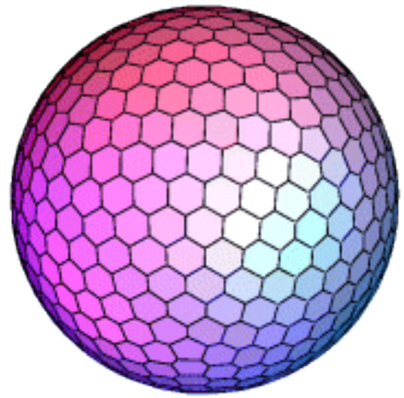
"Living" Test case document and DCMIP-2016 web page:

https://github.com/ClimateGlobalChange/DCMIP2016

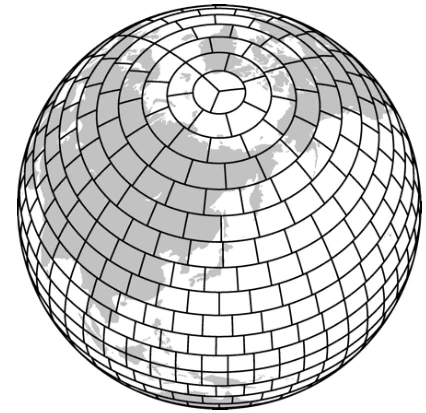
https://www.earthsystemcog.org/projects/dcmip-2016/

DCMIP-2016 Models

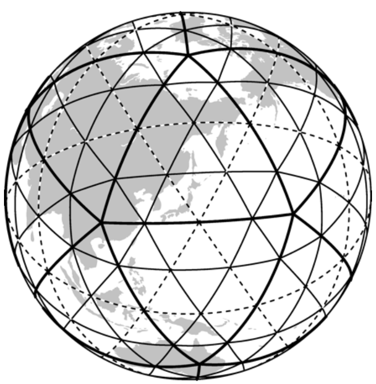
- ACME (E3SM) (DoE, CU)
- FV3 (GFDL)
- Tempest (UC Davis)



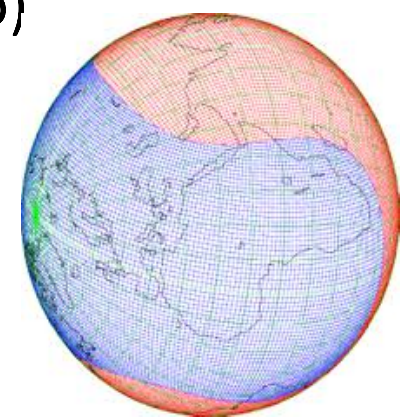
- CSU_LZ (CSU)
- OLAM (U. Miami)
- NICAM (Riken, U. Tokyo)
- MPAS (NCAR)



- FVM (ECMWF)



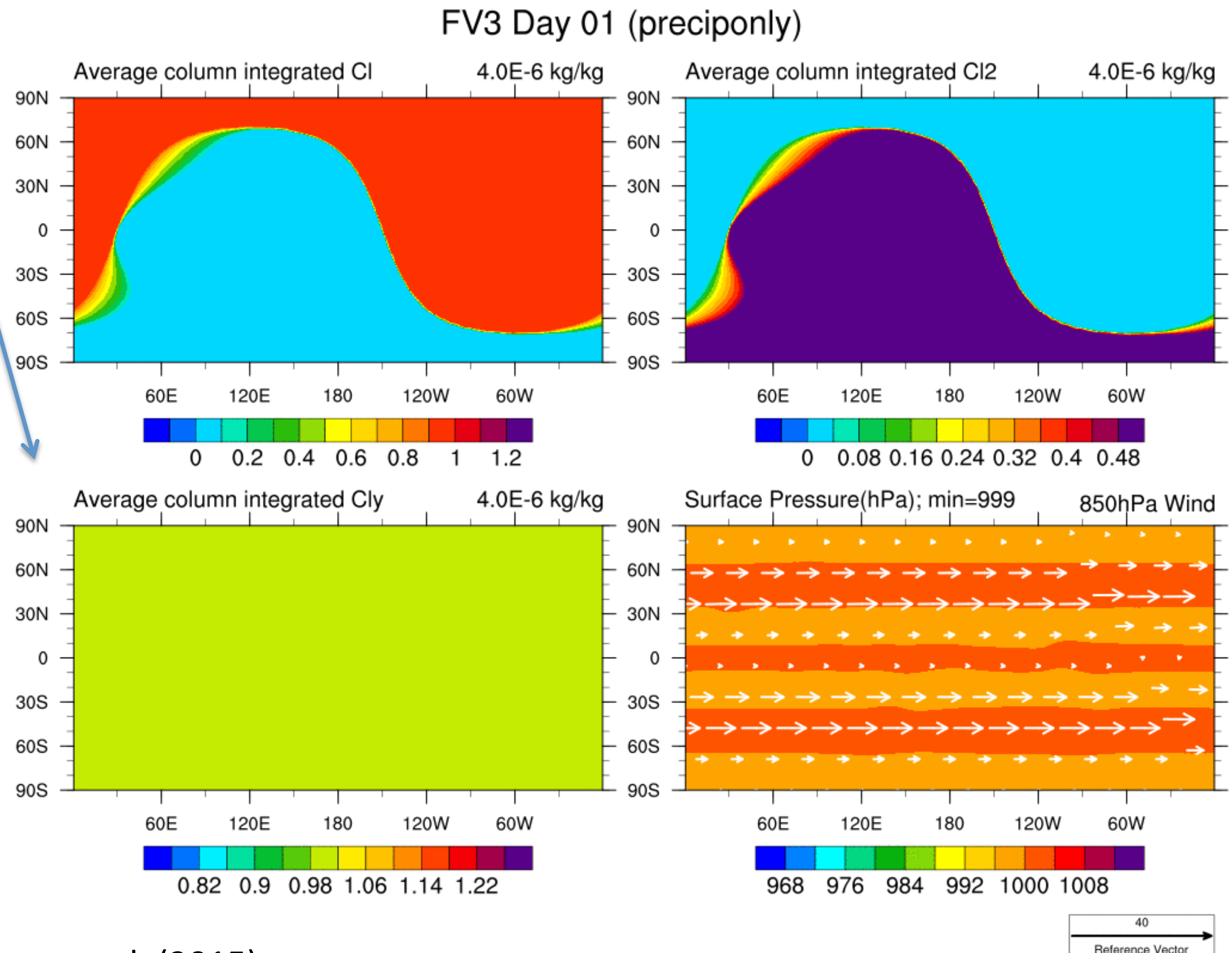
- ICON (DWD & MPI, Germany)
- DYNAMICO (LMD, IPSL, France), hydrostatic



- GEM (Environment Canada)

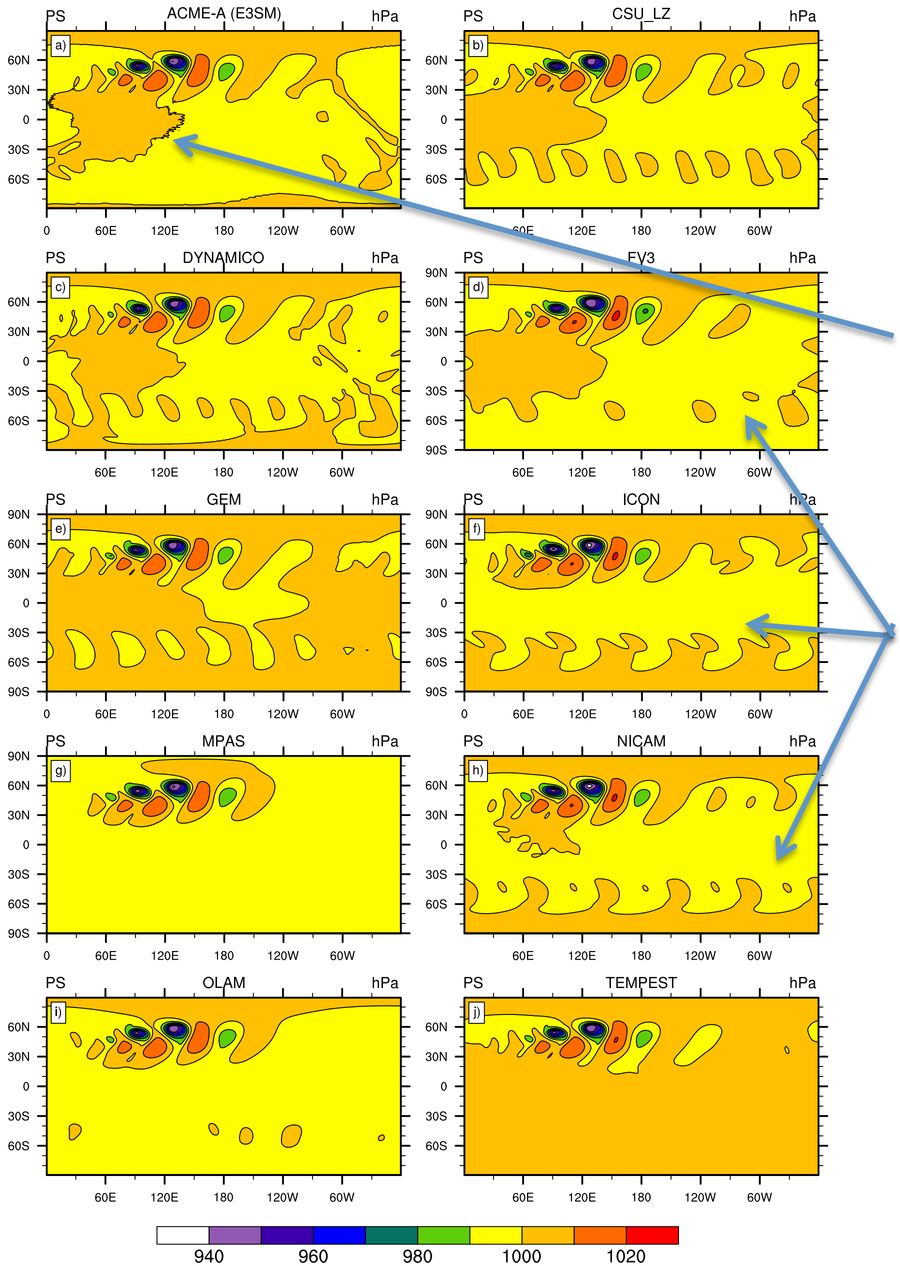
DCMIP-2016 Snapshots: "Toy" Terminator Chemistry

Tracer advection test with correlated tracers: Cly is the sum of Cl and Cl2 (needs to stay constant)



Lauritzen et al. (2015)

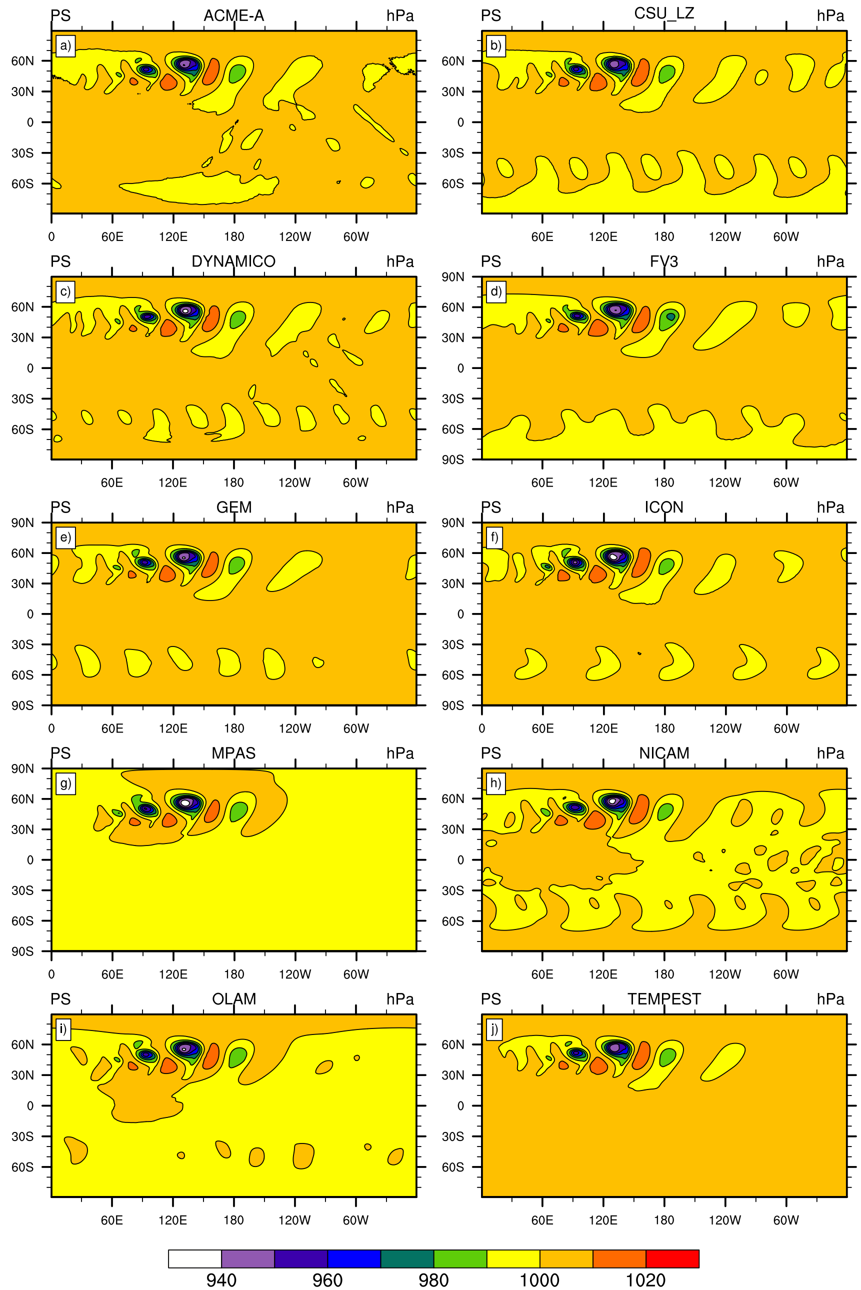
Snapshots of the dry baroclinic wave



Surface pressure at day 10 (Δx=110 km): overall patterns similar, details differ

- Some Gibb's ringing in ACME
- Some grid imprinting (wave 4 and wave 5 signals) in CSU_LZ, DYNAMICO, FV3, ICON, NICAM, apparent in the Southern Hemispheres

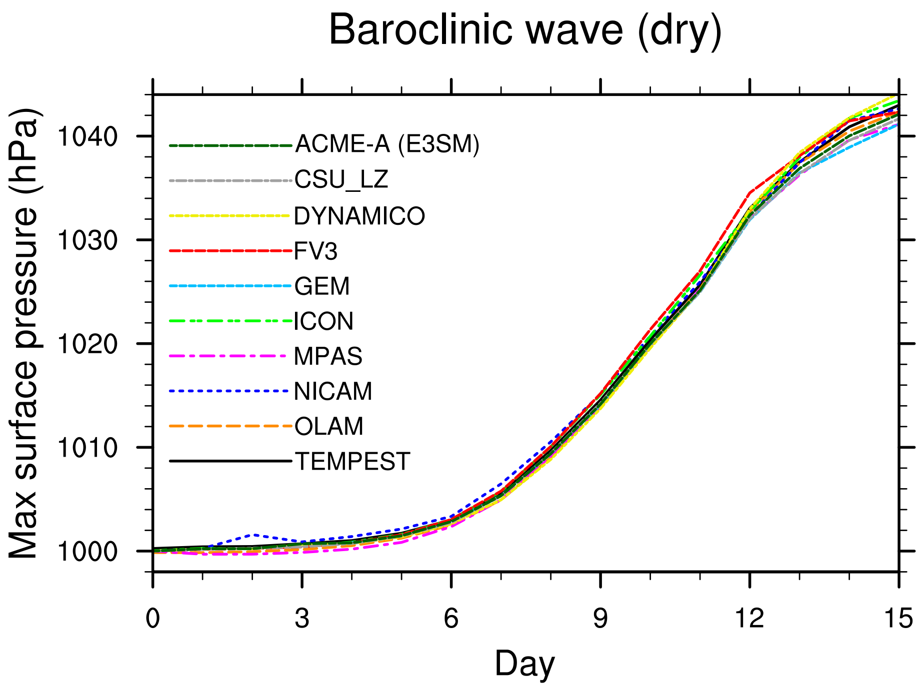
Snapshots of the **moist** baroclinic wave

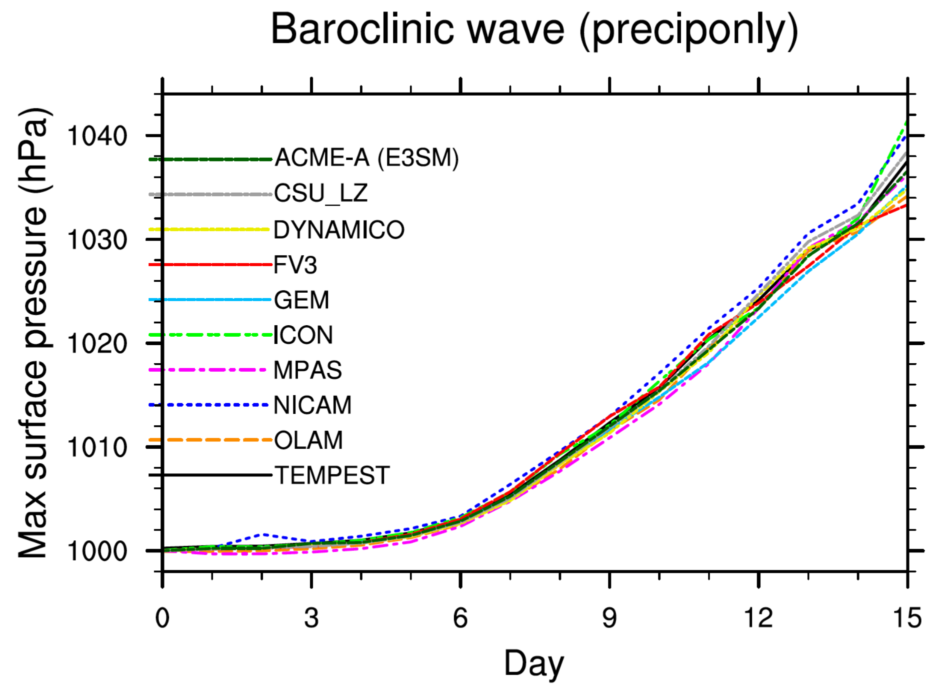


Surface pressure at day 10 (Δx=110 km): overall patterns similar, details differ

- Patterns look almost identical to the dry surface pressure patterns
- Moisture effects weaken high pressure systems and strengthen low pressure systems (e.g. visible in ICON and MPAS)

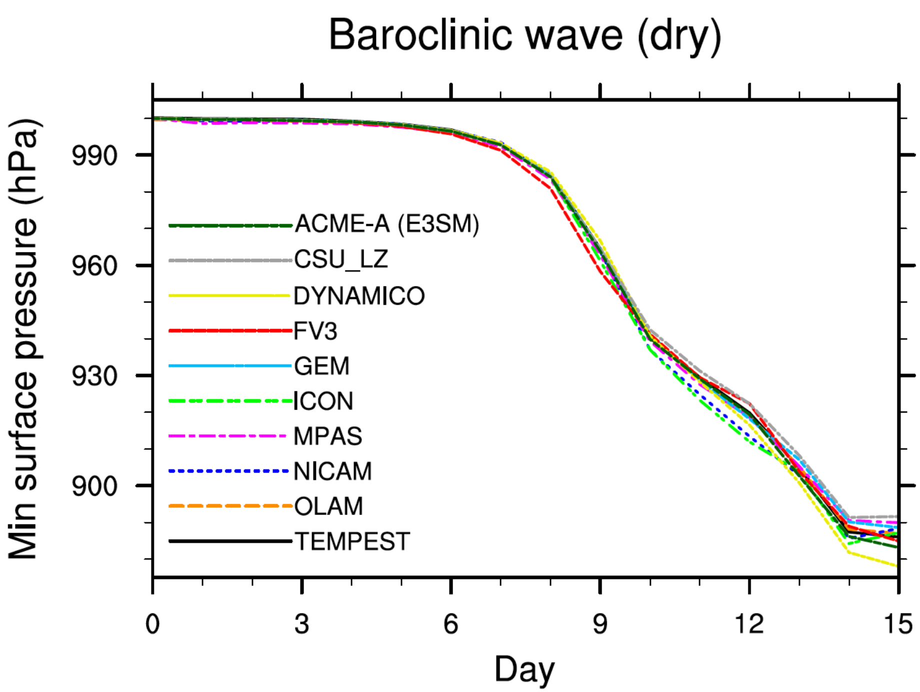
15-Day Time Series: dry and moist ps maxima

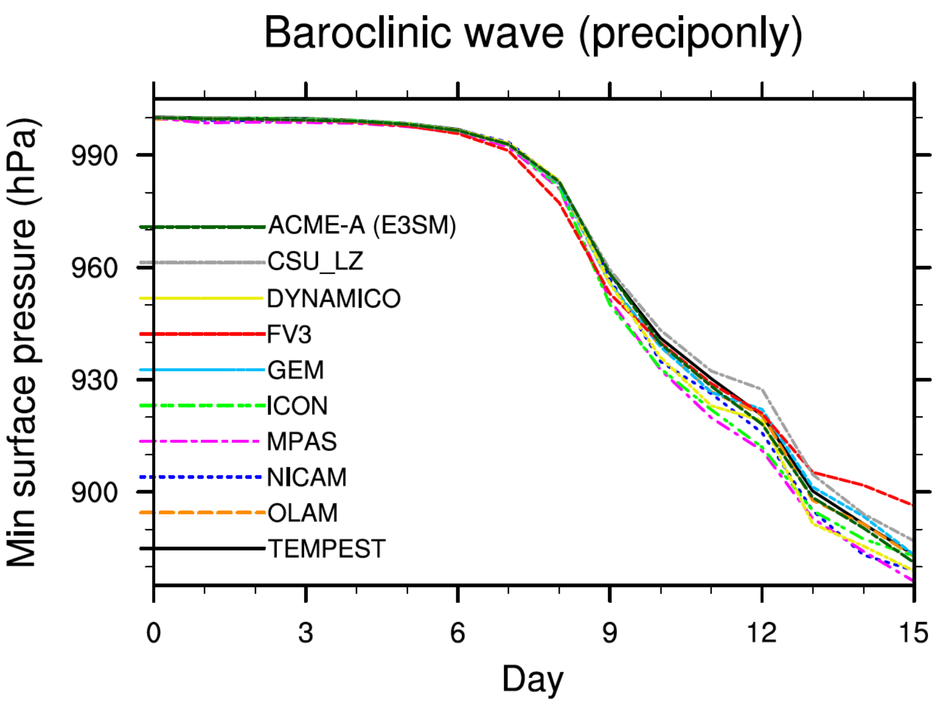




- Moisture effects weaken high pressure systems
- Presence of moisture **widens the ensemble spread** early in the simulations, pointing to the uncertainties in the physics-dynamics interactions

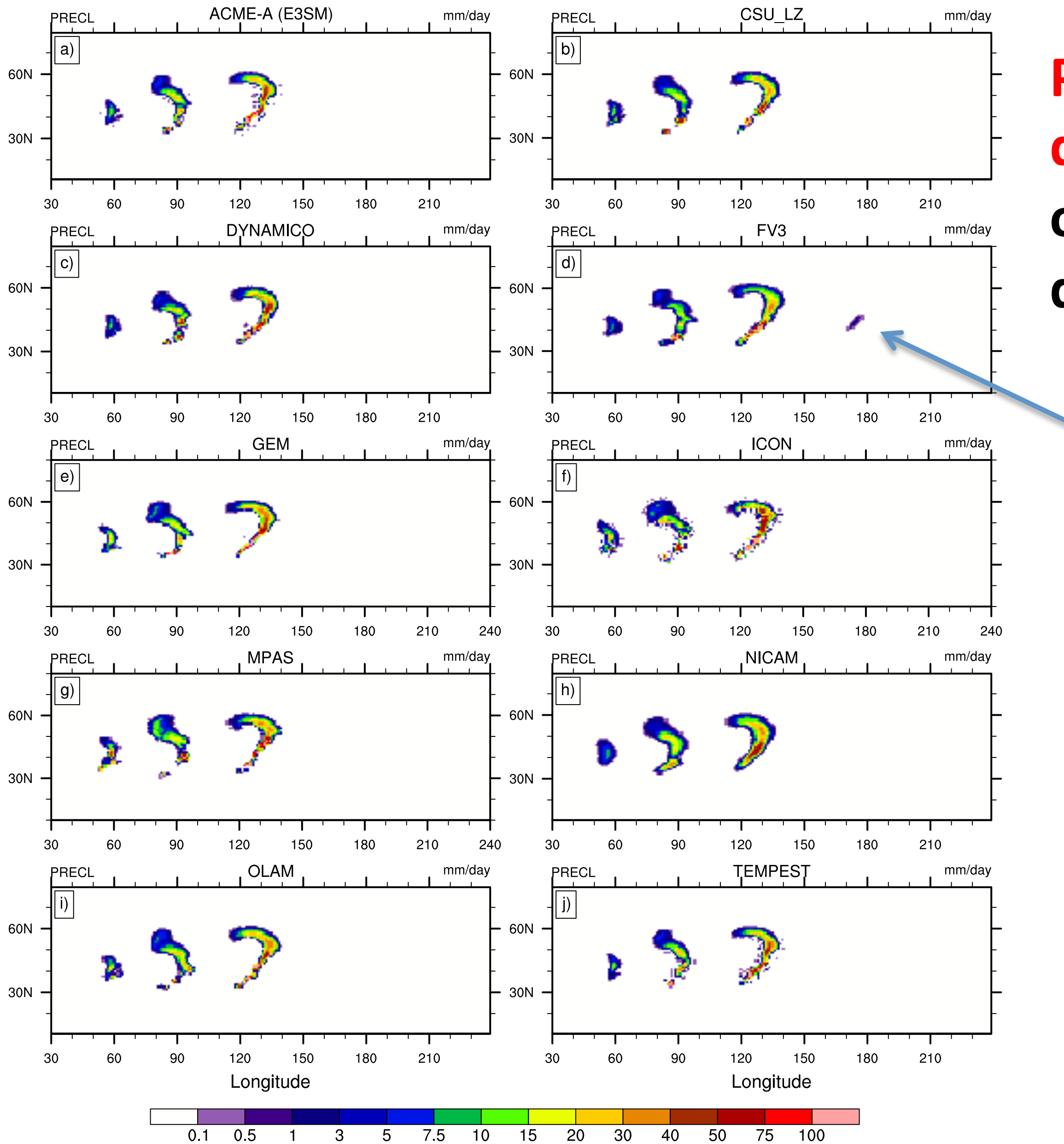
15-Day Time Series: dry and moist ps minima





- Moisture effects: slight tendency to strengthen low pressure systems
- Presence of moisture **considerably widens the ensemble spread**
- Models tend to diverge after day 12

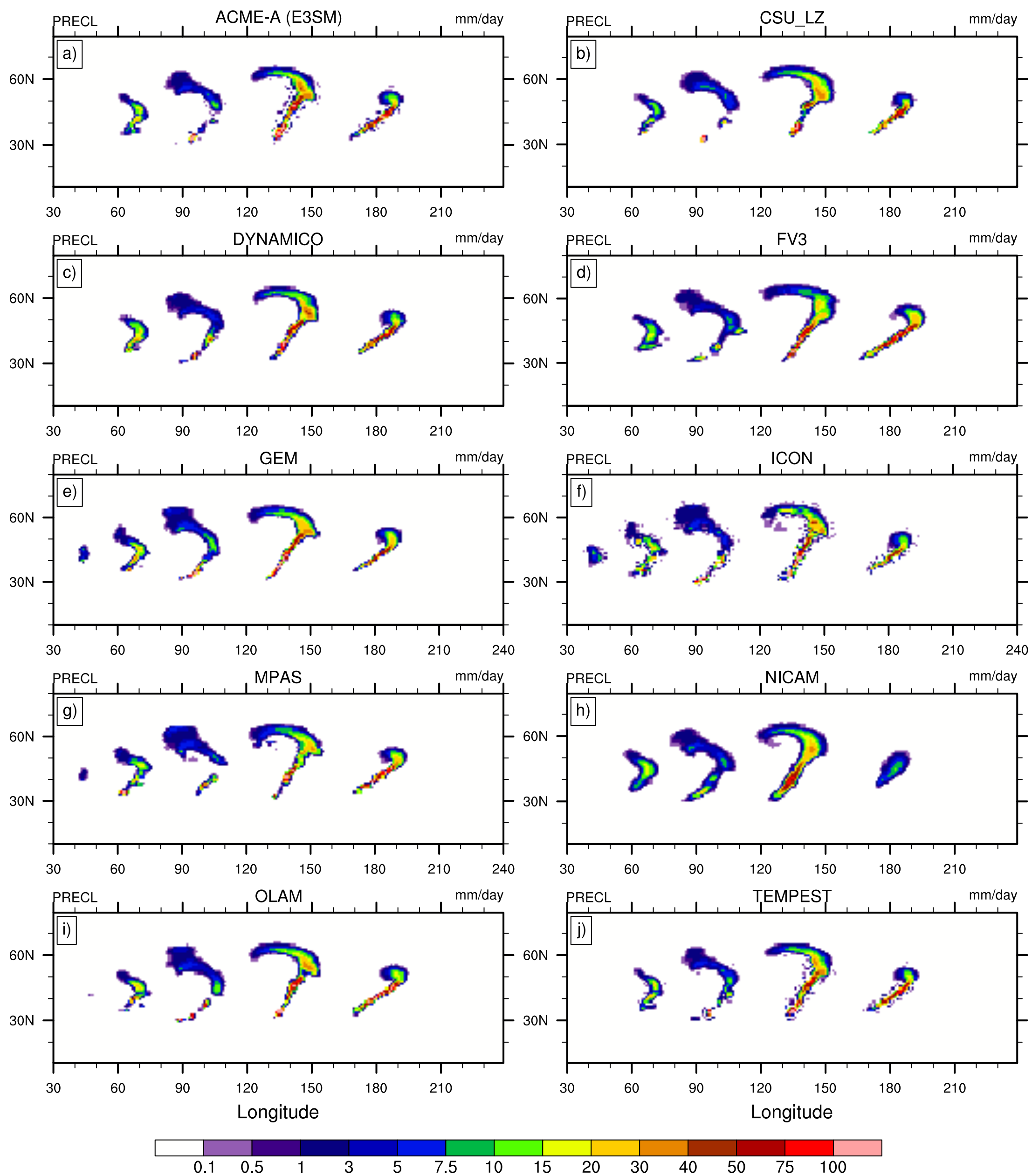
Precipitation rates in the moist baroclinic wave



Precipitation rates at day 9 (Δx=110 km): overall patterns similar, details differ

- FV3 strengthens the fastest, already shows 4th precipitation band
- Differing levels of ‘noise’ (broken contours) and diffusion in the precipitation bands

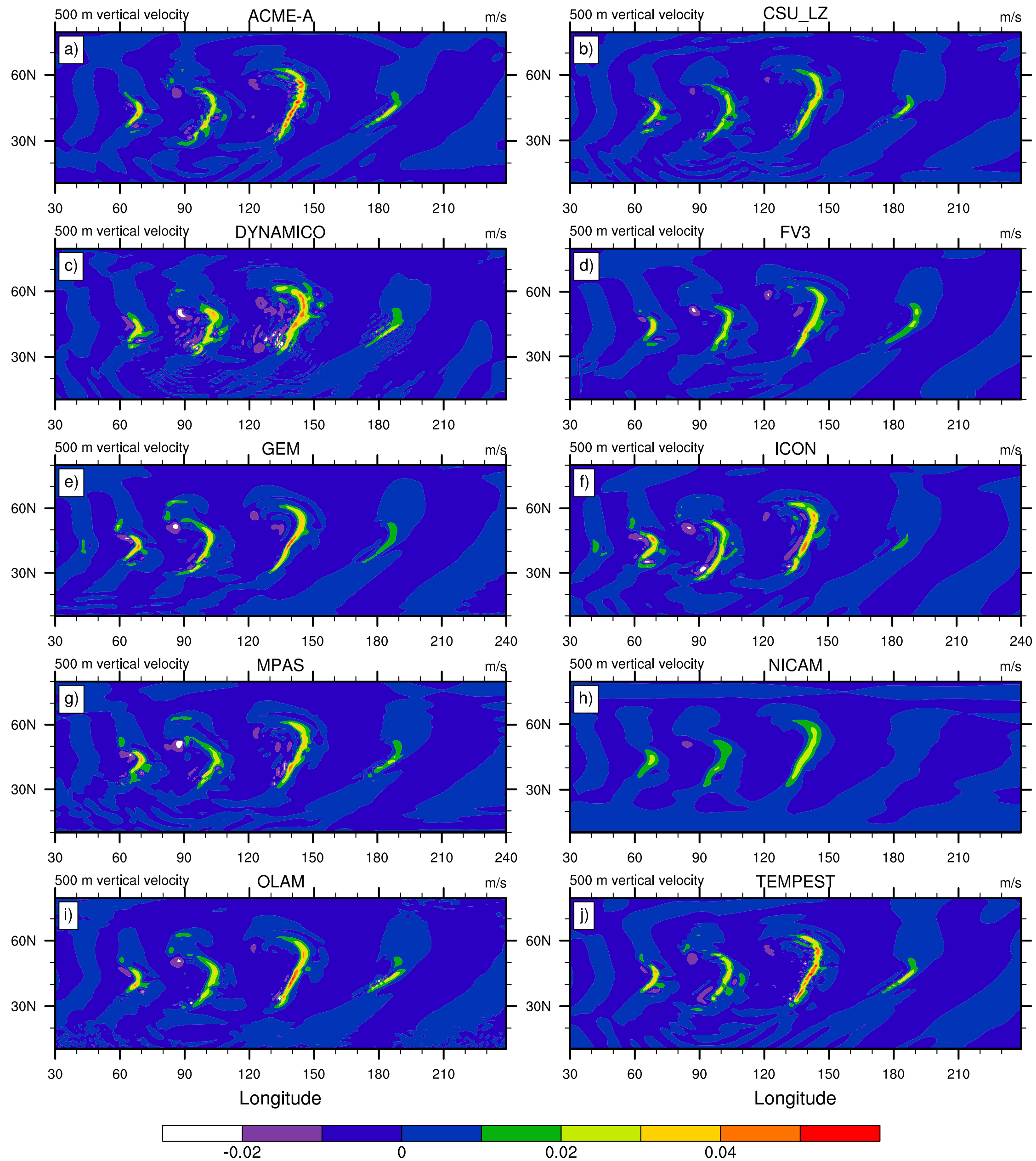
Precipitation rates in the moist baroclinic wave



Precipitation rates at day 10 (Δx=110 km): overall patterns similar, details differ

- At day 10 precipitation bands become very narrow, tend to break up in some models (with very strong grid-point scale precipitation)
- Differing levels of 'noise' and diffusion become even clearer

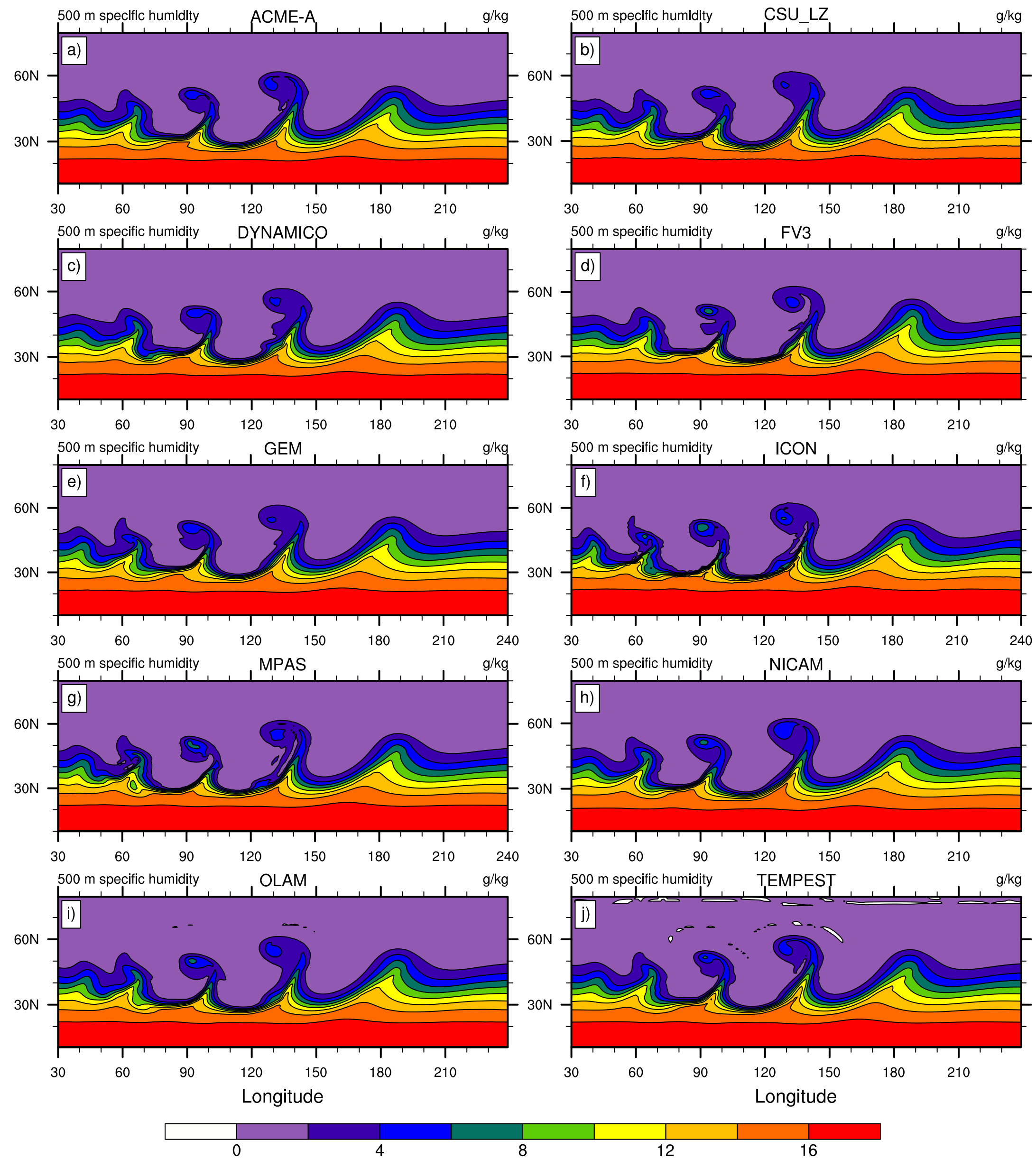
Vertical velocity in the moist baroclinic wave



500 m vertical velocitiy at day 10 (Δx=110 km): overall patterns similar, details differ

- Precipitation bands tightly connected to the narrow updraft areas
- Reduced updrafts translate into reduced precipitation rates
- Noisy updraft areas lead to noise in precipitation rates

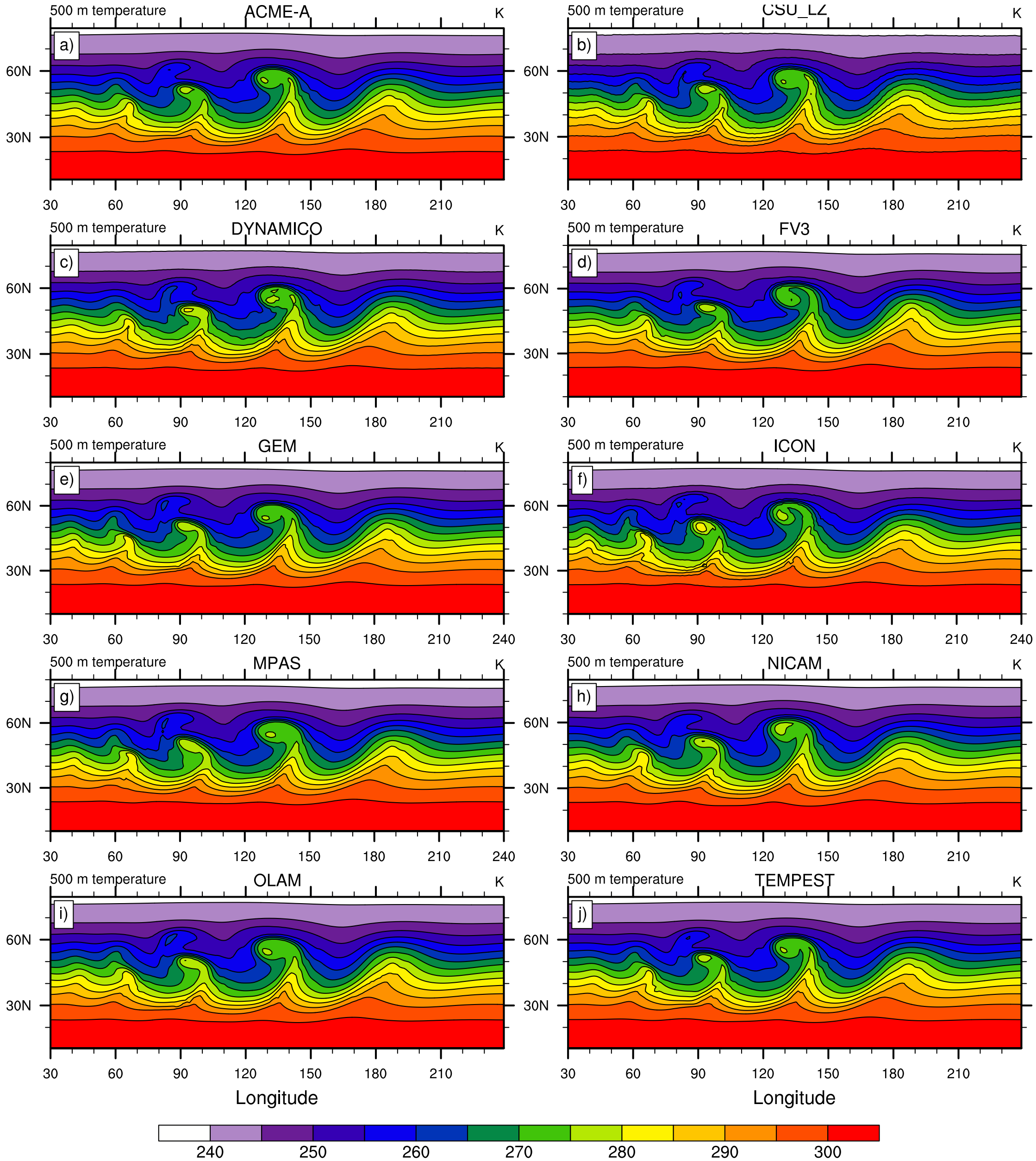
Vertical velocity in the moist baroclinic wave



500 m specific humidity at day 10 (Δx=110 km): overall patterns similar, details differ

- High levels of specific humidity are advected from the moist tropical areas into the midlatitudes (ahead of the low pressure systems)
- Specific humidity provides moisture source for the Kessler precipitation scheme

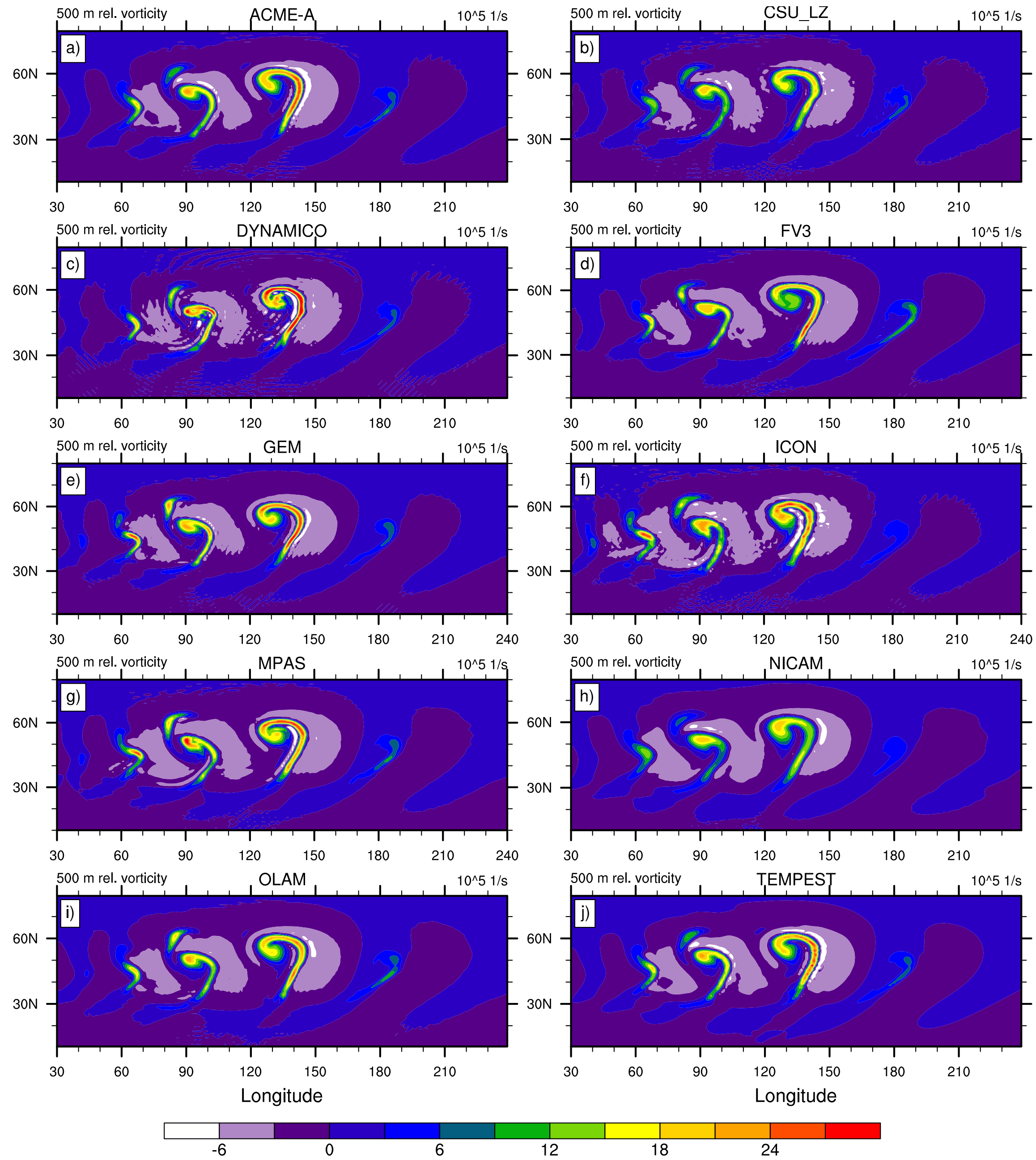
Temperature in the moist baroclinic wave



500 m temperature at day 10 (Δx=110 km): overall patterns similar, details differ

- Breaking waves at day 10 (also visible in the specific humidity field)
- Updrafts are connected to the strong temperature fronts

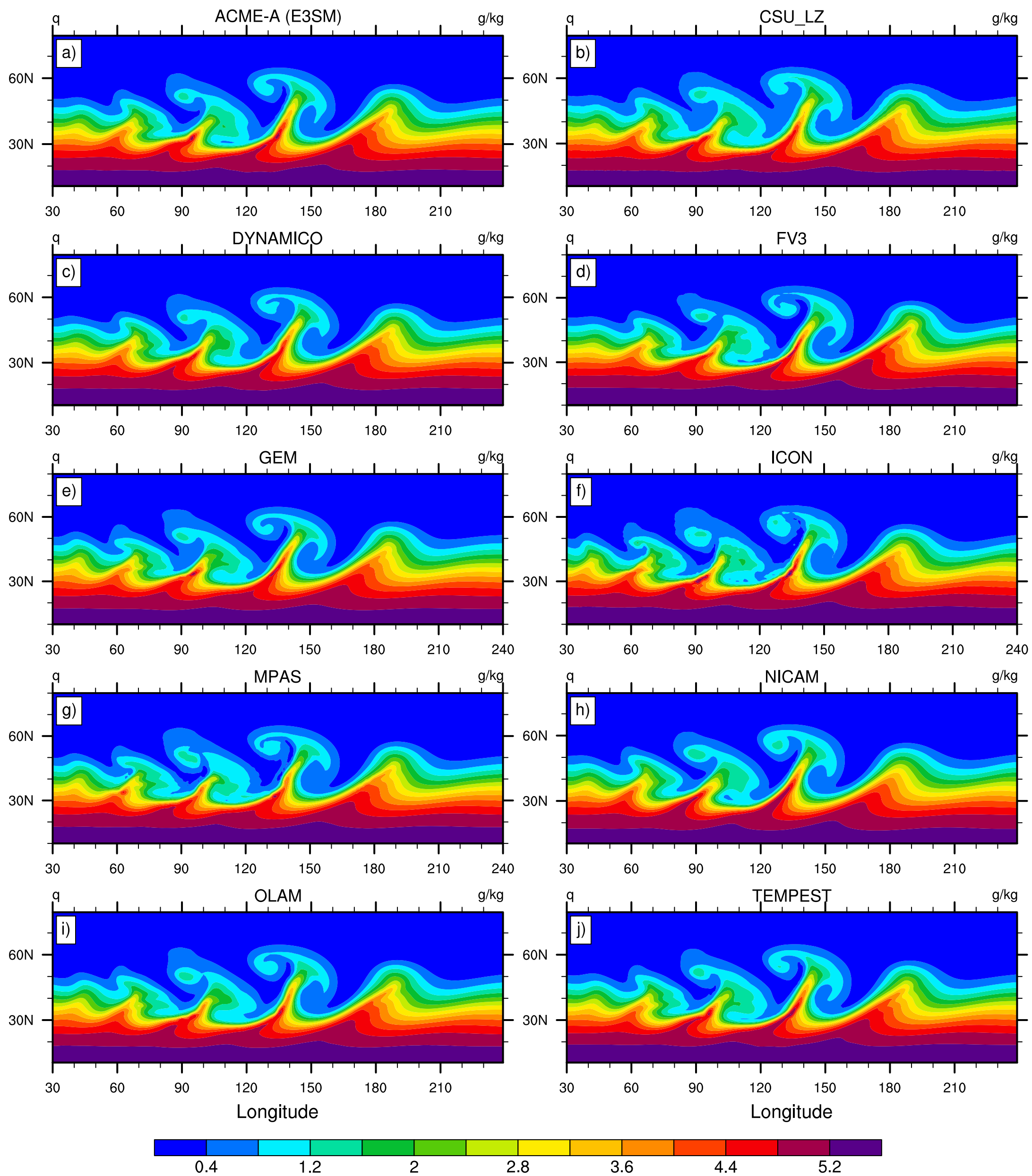
Relative vorticity in the moist baroclinic wave



500 m relative vorticity at day 10 (Δx=110 km): overall patterns similar, details differ

- Maxima and minima differ (by about 30%) and are found in very narrow strips (challenges the 110 km grid spacing)
- Vorticity highlights noise and the diffusive properties of the model

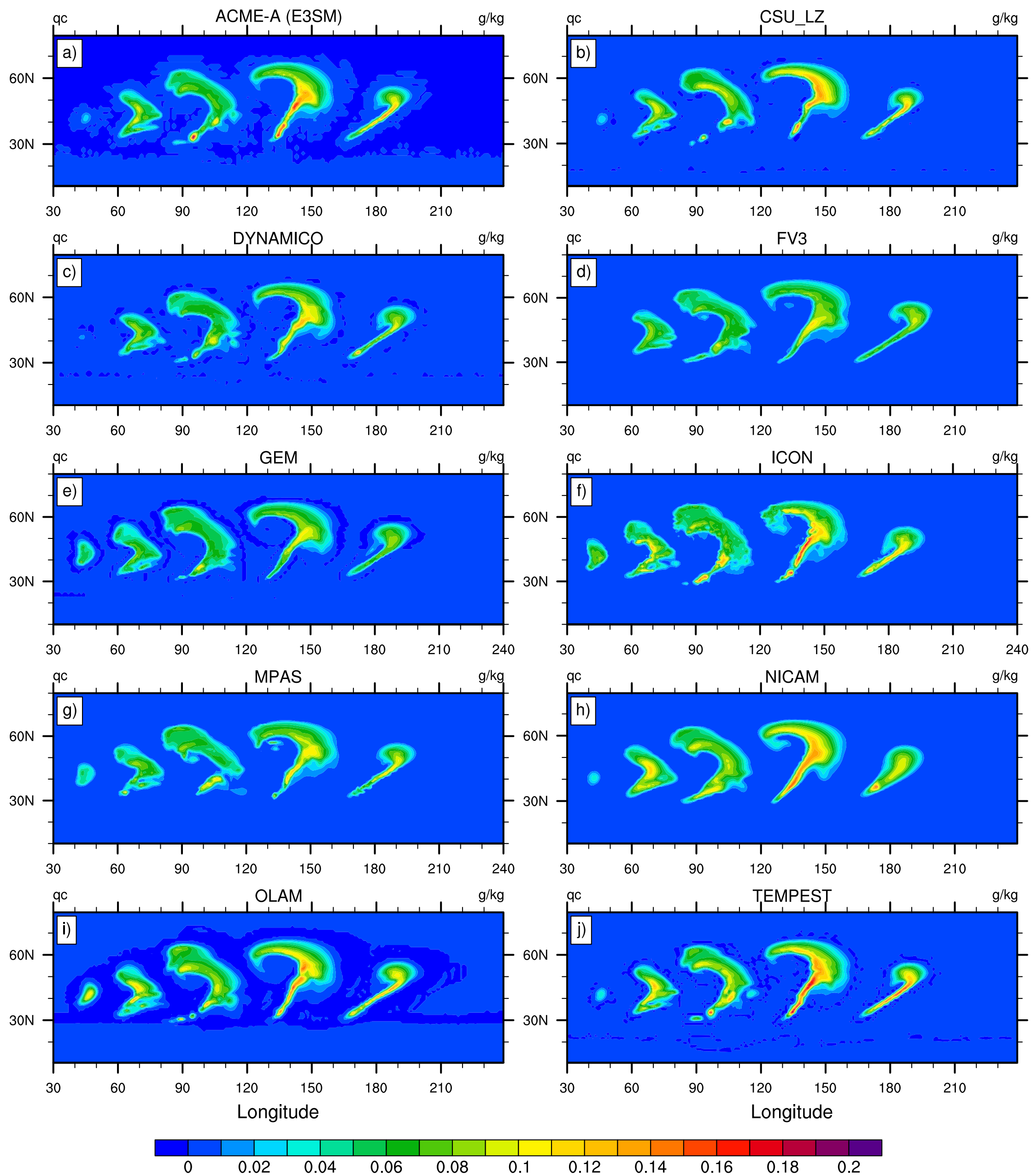
Integrated water vapor: moist baroclinic wave



Vertically integrated water vapor at day 10 (Δx=110 km): overall patterns similar, only details differ

- Seems to be predicted rather well, field is dominated by large-scale resolved advection

Integrated cloud water: moist baroclinic wave

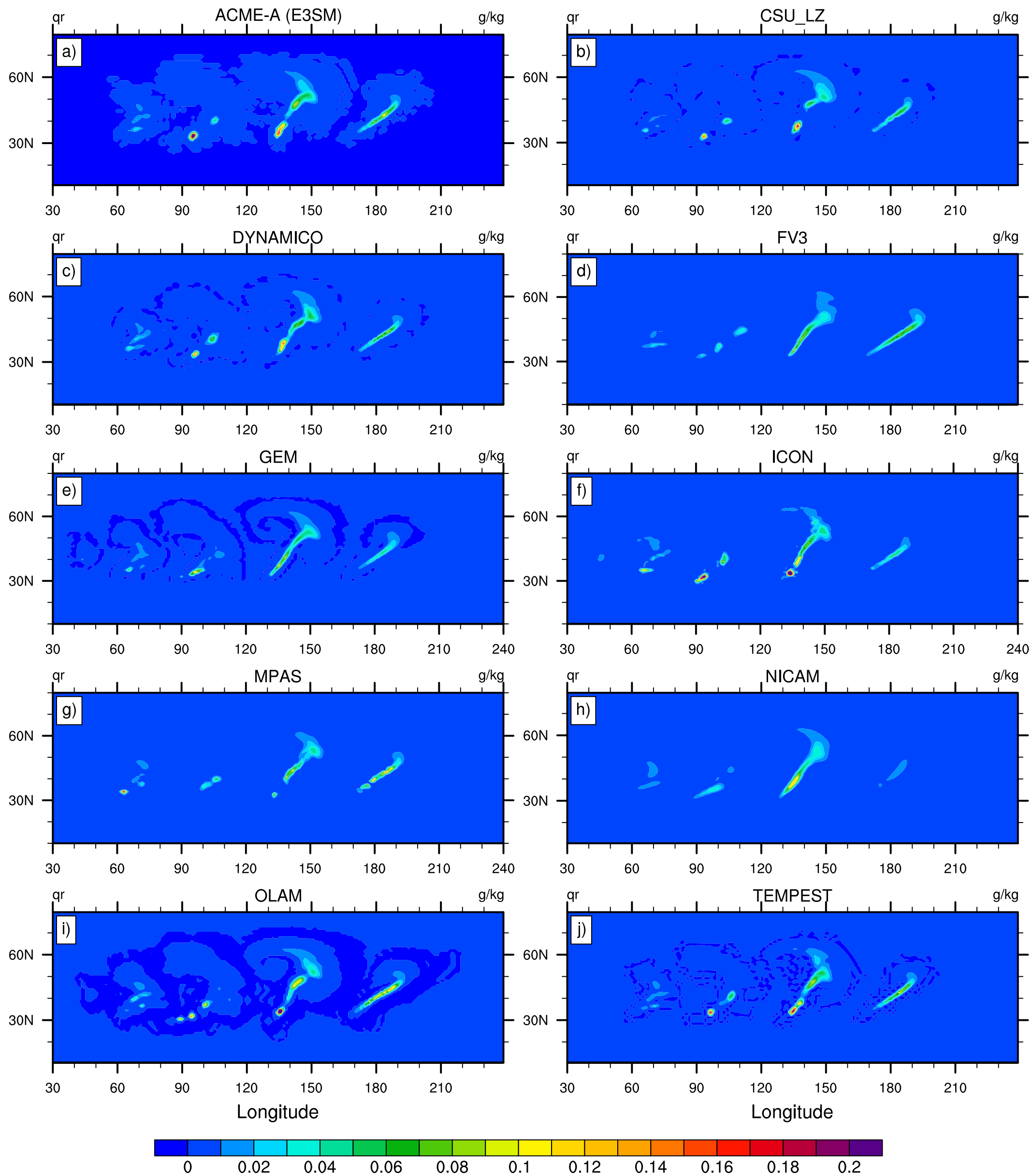


Vertically integrated cloud water at day 10

(Δx=110 km)

- Cloud water highlights the physics-dynamics interactions
- Generation of cloud water is not resolved, parameterized in the Kessler warm rain scheme
- Model differences become more apparent

Integrated rain water: moist baroclinic wave

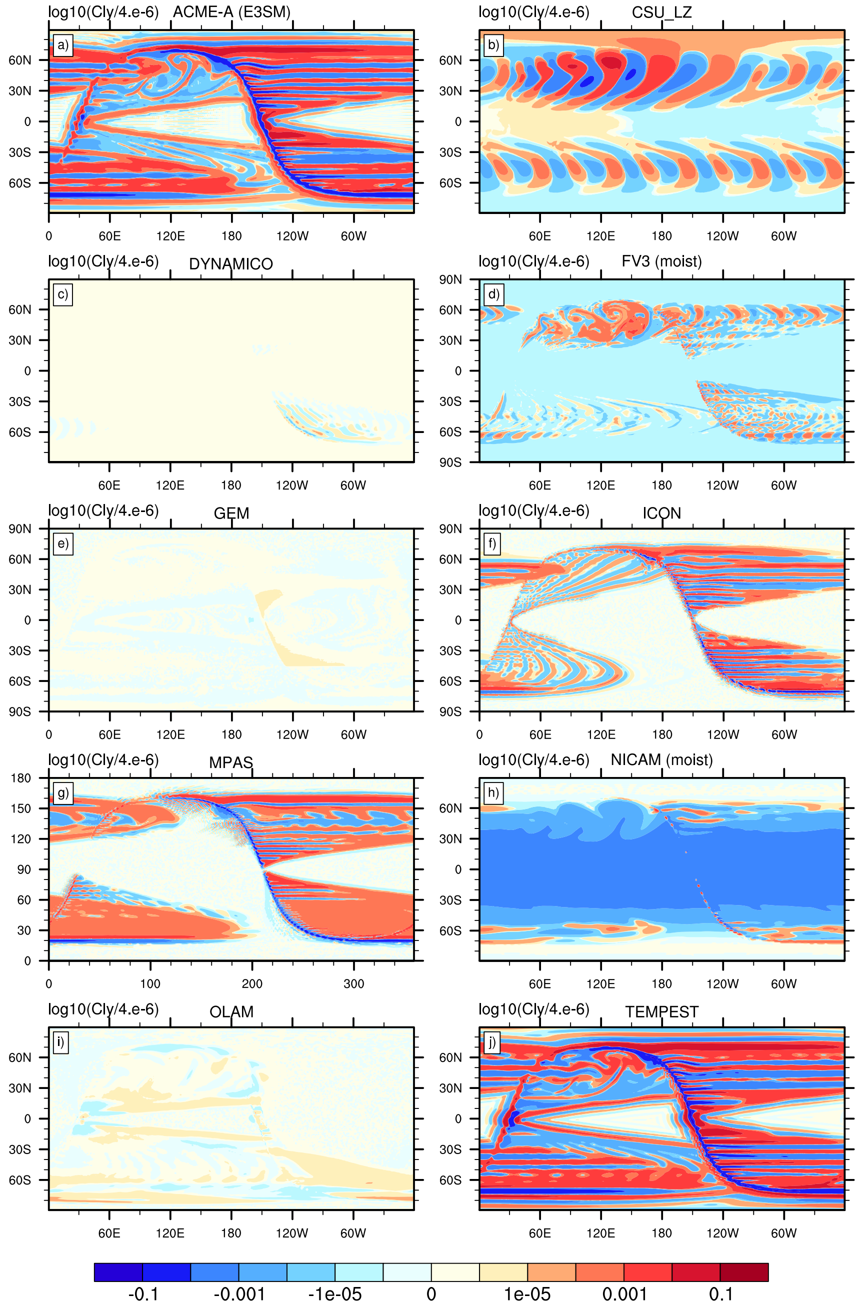


Vertically integrated rain water at day 10

(Δx=110 km)

- Rain water further highlights the physics-dynamics interactions
- Rain water comes from cloud water pool, parameterized in the Kessler scheme
- Differences become even more apparent
- Coherent patterns break up on this metric

Tracer consistency in the dry baroclinic wave

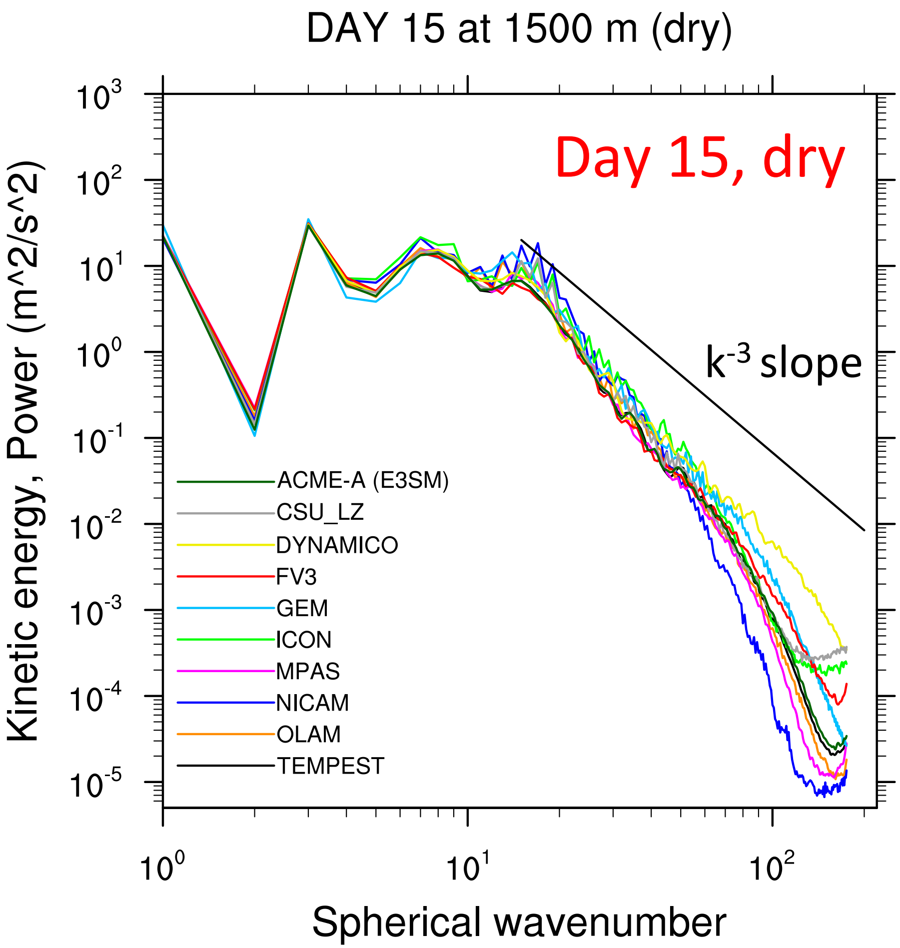


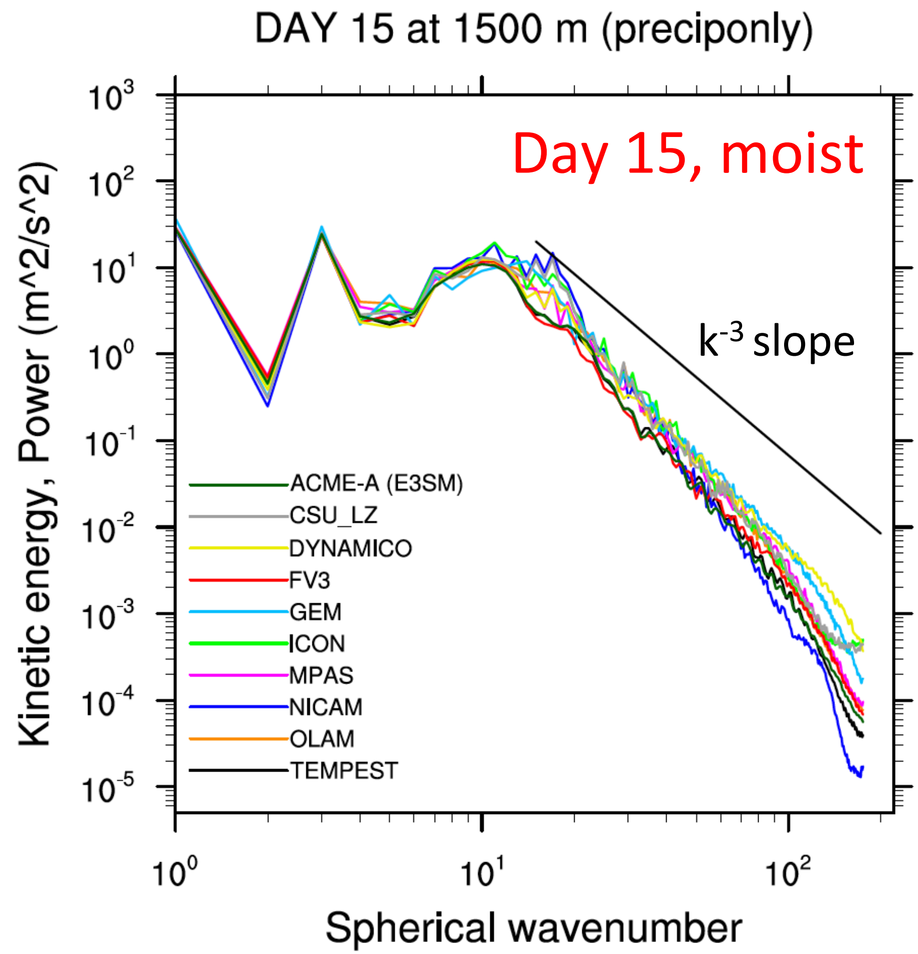
Vertically integrated tracers (weighted sum) at day 10

(Δx=110 km)

- Correlated tracer should stay perfectly correlated
- Analytical solution: zero variations
- Magnitudes of the tracer errors differ greatly (10^{-1} – 10^{-6}), caused by limiters, diffusion and monotonic constraints in the numerics

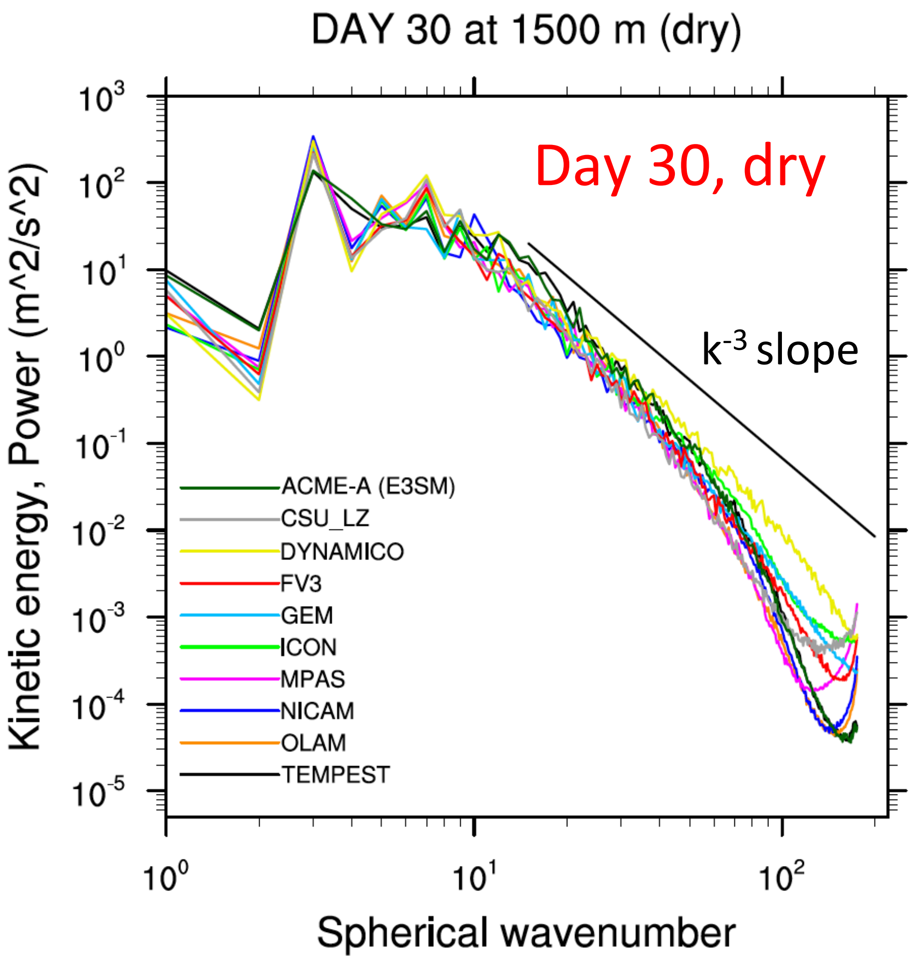
1500 m Kinetic Energy Spectra: dry and moist

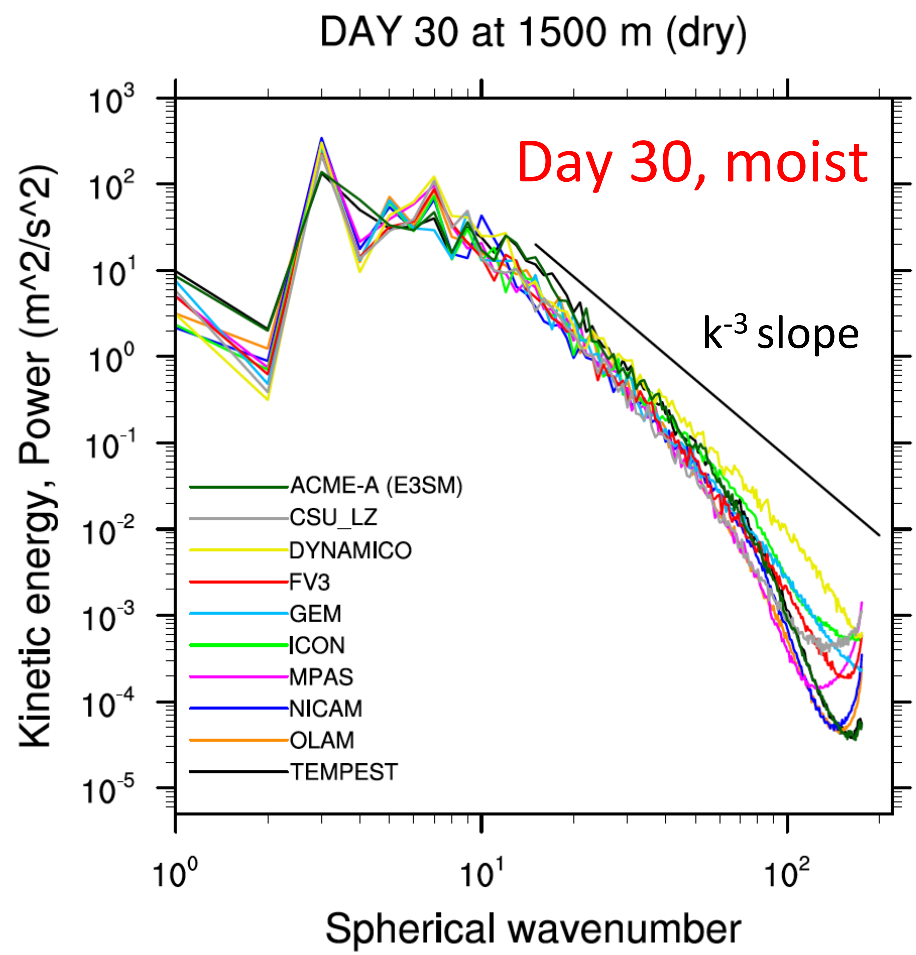




- KE spectra provide information about the diffusion properties
- Some dry dynamical cores accumulate energy at the grid scale (hook)
- The hooks are not apparent in the moist simulations at day 15
- Very big KE differences at high wavenumbers

1500 m Kinetic Energy Spectra: dry and moist





- Day 30 shows global circulation pattern (not just Northern Hemisphere)
- Wide spreads develop, even at low wavenumbers
- Upward KE hook now also in some moist dycores: assess diffusion

Conclusions

- Bugs were found and corrected by the modeling groups
- The interactions between a dynamical core and moisture processes can already be simulated with very simple model configurations, like the Kessler warm-rain scheme
- Rich data base: moist dynamical core configurations reveal aspects of the physics-dynamics coupling
- Idealized test cases are a useful tool (with quick turn around times) to test/understand the moisture aspects, causes and effects can be analyzed more easily
- Current status: we investigate the causes of the dycore differences, GMD paper will follow this spring
- We will further analyze the impact of various numerics choice and physics-dynamics coupling decisions (e.g. Δt)

References

Lauritzen, P. H., A. J. Conley, J.-F. Lamarque, F. Vitt, and M. A. Taylor (2015): **The terminator "toy"-chemistry test: A simple tool to assess errors in transport schemes,** *Geosci. Model Dev.*: 8, 1299-1313, doi:10.5194/gmd-8-1299-2015

Reed, K.A. and C. Jablonowski (2012): **Idealized tropical cyclone simulations of intermediate complexity: a test case for AGCMs**. *J. Adv. Model. Earth Syst.*, Vol. 4, M04 001, doi:10.1029/2011MS000099

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Ullrich, P.A. et al. (2017): DCMIP2016: a review of non-hydrostatic dynamical core design and intercomparison of participating models. Geoscientific Model Development, Vol. 10, 4477–4509, doi: 10.5194/gmd-10-4477-2017

DCMIP-2016 project page:
https://www.earthsystemcog.org/projects/dcmip-2016/