Dynamical Core Model Intercomparison Project 2016

DCMIP2016 Test Cases

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DCMIP2016 Test Suite

Focus on non-hydrostatic models, physics-dynamics coupling and variable-resolution modeling systems.

- **Test 1:** Moist baroclinic instability with “toy” Terminator chemistry
- **Test 2:** Moist tropical cyclone test
- **Test 3:** Moist supercell storm test

Physics Routines

Kessler Microphysics: Requires water species for water vapor, cloud water and rain water. Computes tendencies for evaporation, autoconversion, collection and precipitation.

Latent heat release: $$\frac{\Delta\theta}{\Delta t} = -\frac{L}{c_p \pi}\left(\frac{\Delta q_{vs}}{\Delta t} + E_r\right)$$

Water vapor tendency: $$\frac{\Delta q_v}{\Delta t} = \frac{\Delta q_{vs}}{\Delta t} + E_r$$

Cloud water tendency: $$\frac{\Delta q_c}{\Delta t} = -\frac{\Delta q_{vs}}{\Delta t} - A_r - C_r$$

Rain water tendency: $$\frac{\Delta q_r}{\Delta t} = -E_r + A_r + C_r - V_r \frac{dq_r}{dz}$$

Reference: J. B. Klemp, W.C. Skamarock, and S.-H. Park (2015) "Idealized global nonhydrostatic atmospheric test cases on a reduced-radius sphere." *J. Adv. Model. Earth Syst.*, 07, doi:10.1002/ 2015MS000435

Physics Routines

Boundary Layer and Surface Fluxes: A simple mixing parameterization that represents boundary layer processes and surface fluxes (based on Reed and Jablonowski, 2012).

$$\frac{\Delta T}{\Delta t} = -\frac{1}{\rho}\frac{d}{dz}\left(\rho\overline{w'T'}\right)$$
$$\frac{\Delta q_v}{\Delta t} = -\frac{1}{\rho}\frac{d}{dz}\left(\rho\overline{w'q'}\right)$$
$$\frac{\Delta u}{\Delta t} = -\frac{1}{\rho}\frac{d}{dz}\left(\rho\overline{w'u'}\right)$$
$$\frac{\Delta v}{\Delta t} = -\frac{1}{\rho}\frac{d}{dz}\left(\rho\overline{w'v'}\right)$$

Surface Fluxes:

$$(\overline{w'u'})_s = -C_d|\mathbf{v}_a|u_a$$
$$(\overline{w'v'})_s = -C_d|\mathbf{v}_a|v_a$$
$$(\overline{w'T'})_s = C_H|\mathbf{v}_a|(T_s - T_a)$$
$$(\overline{w'q'})_s = C_E|\mathbf{v}_a|(q_{vs,s} - q_a)$$

Boundary layer mixing:

$$\overline{w'u'} = -K_m\frac{du}{dz} \qquad \overline{w'\theta'} = -K_E\frac{d\theta}{dz}$$
$$\overline{w'v'} = -K_m\frac{dv}{dz} \qquad \overline{w'q'} = -K_E\frac{dq}{dz}$$

Reference: Reed, K. A. and C. Jablonowski (2012), Idealized tropical cyclone simulations of intermediate complexity: a test case for AGCMs, J. Adv. Model. Earth Syst., 4, M04001, doi:10.1029/2011MS000099.

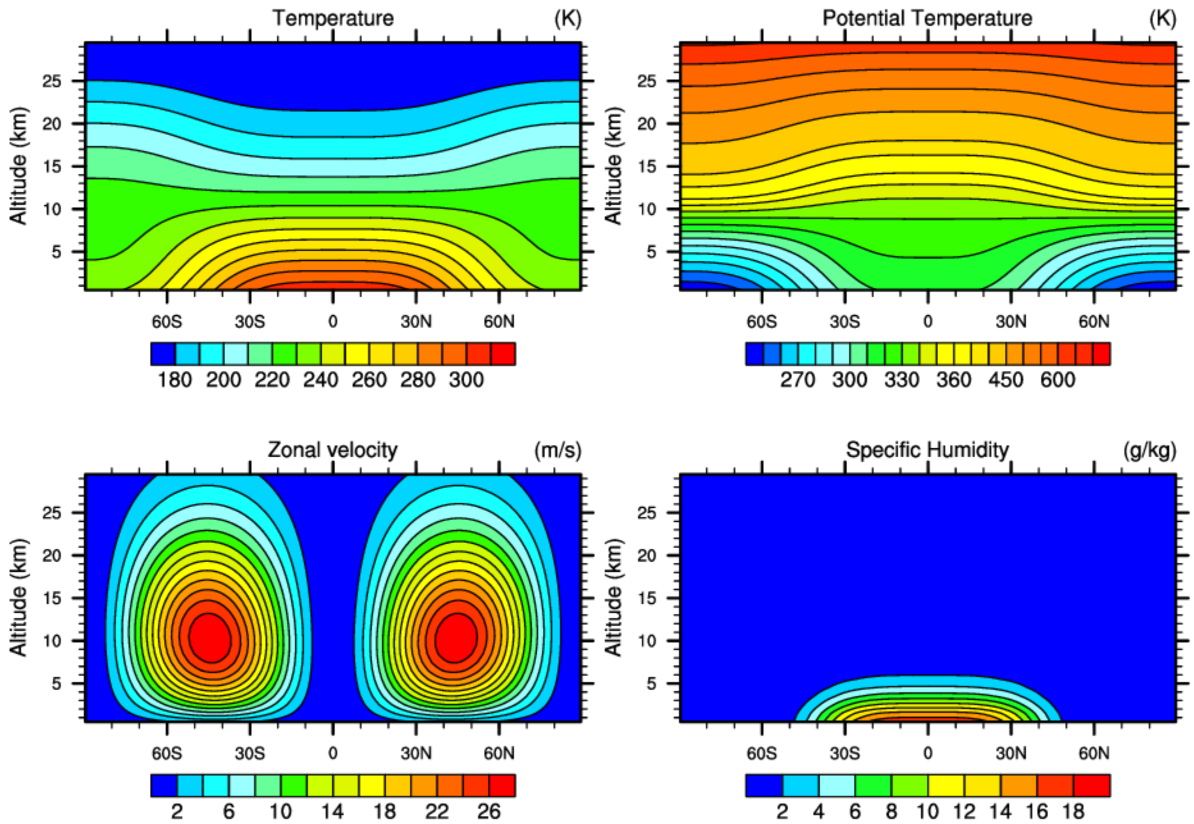
Physics Routines

2nd order Constant Coefficient Diffusion: One requirement from modeling groups is the implementation of constant coefficient 3D diffusion. Analogous to the Straka density current test, this provides a mechanism to ensure convergence of the solution.

Test 1: Moist Baroclinic Wave

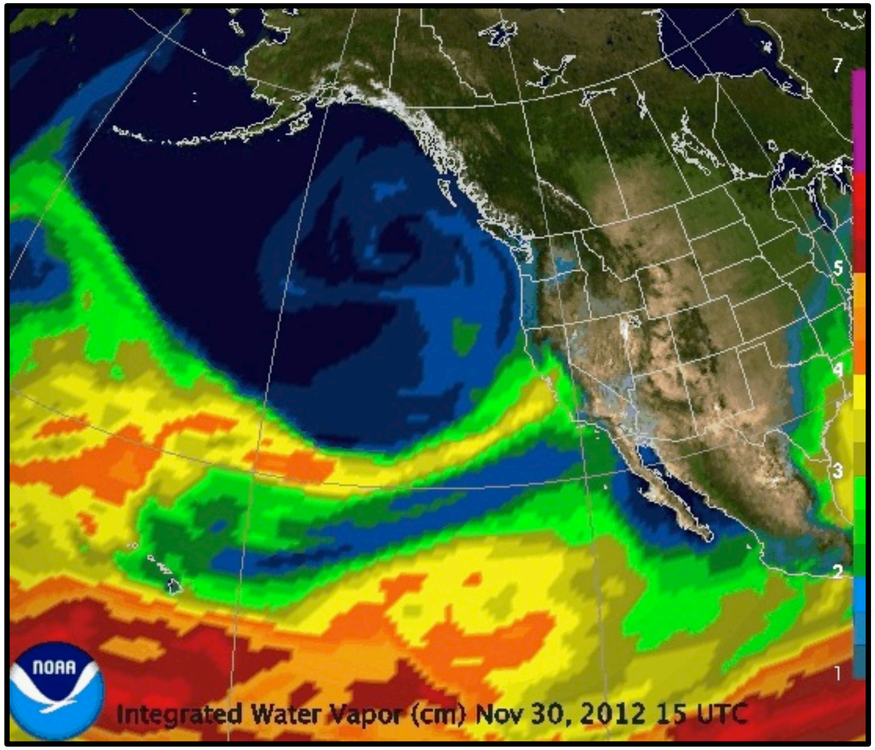
The moist baroclinic wave is a modified version of the UMJS baroclinic instability featuring:

- Zero bottom topography
- Constant surface pressure
- No stratosphere
- Alternate deep atmosphere formulation
- Baroclinically unstable initial state
- Leads to atmospheric river-like features

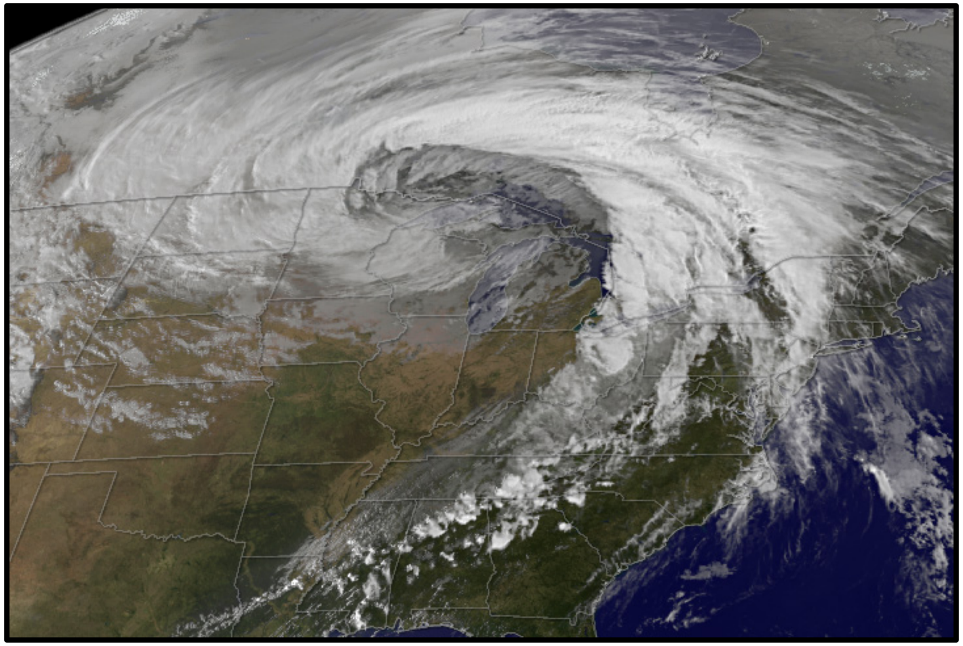


Reference: Ullrich, P.A., T. Melvin, C. Jablonowski and A. Staniforth (2014) "A proposed baroclinic wave test case for deep- and shallow-atmosphere dynamical cores." *Quart. J. Royal Meteor. Soc.*, Volume 140, Issue 682, pp. 1590-1602, doi: 10.1002/qj.2241.

Test 1: Moist Baroclinic Wave

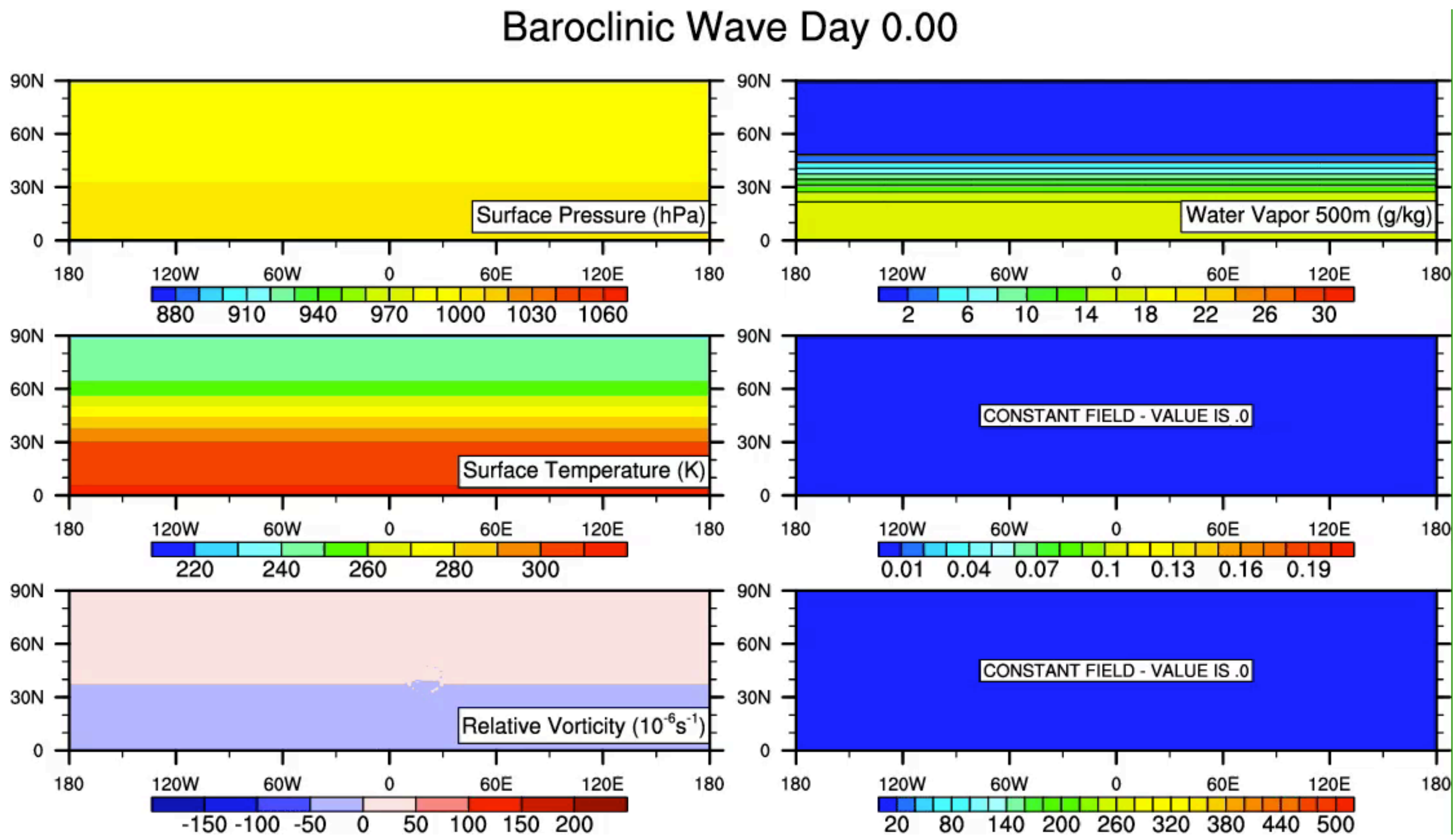


Atmospheric River



Extratropical Cyclone

Test 1: Moist Baroclinic Wave



Planetary boundary layer and surface fluxes disabled, Kessler physics enabled

Test 1: Terminator Chemistry

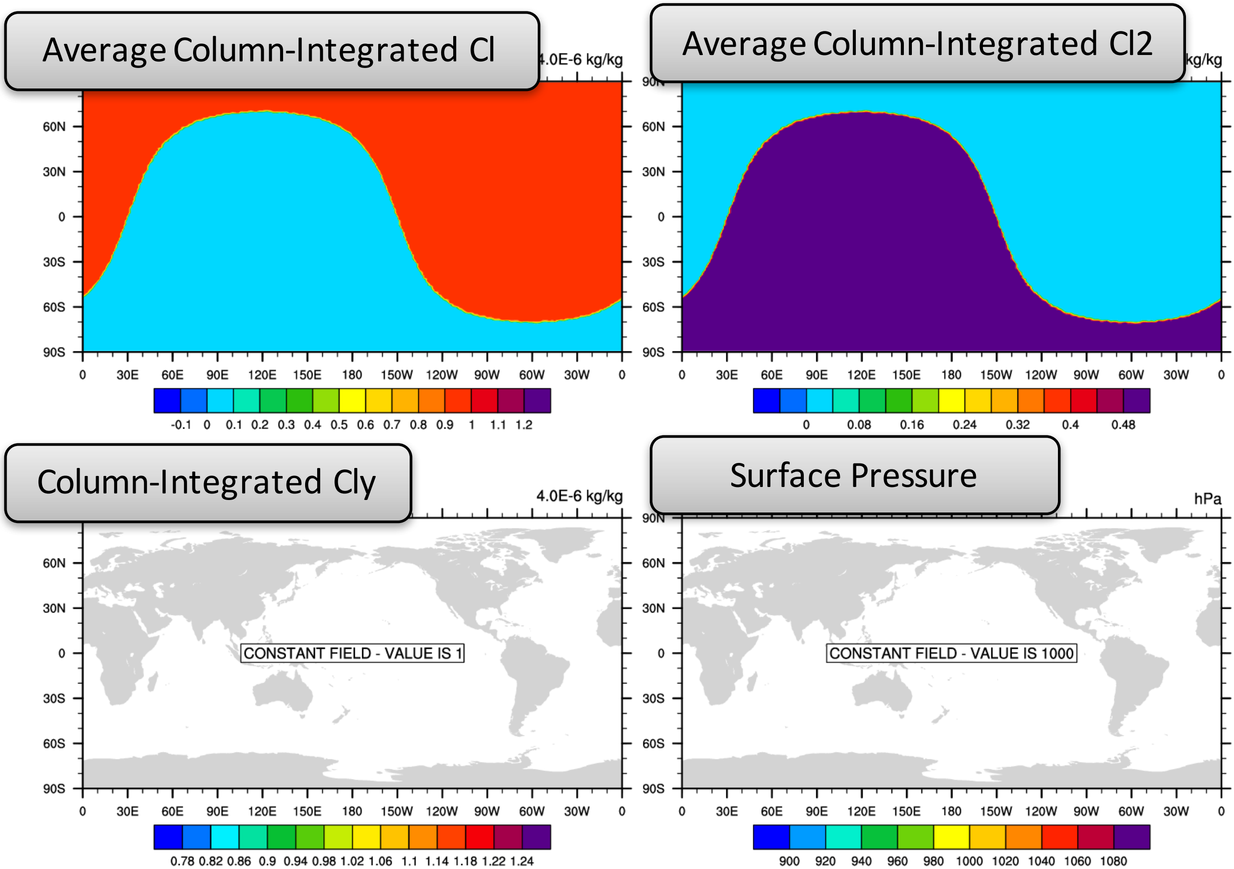
Many chemical processes in the atmosphere have the form

$$X_2 + \nu \rightarrow X + X \qquad (k_1)$$
$$X + X \rightarrow X_2 \qquad (k_2)$$

These two species have associated transport eq'ns

$$\frac{D[X]}{Dt} = 2k_1[X_2] - 2k_2[X]^2,$$
$$\frac{D[X_2]}{Dt} = -k_1[X_2] + k_2[X]^2,$$

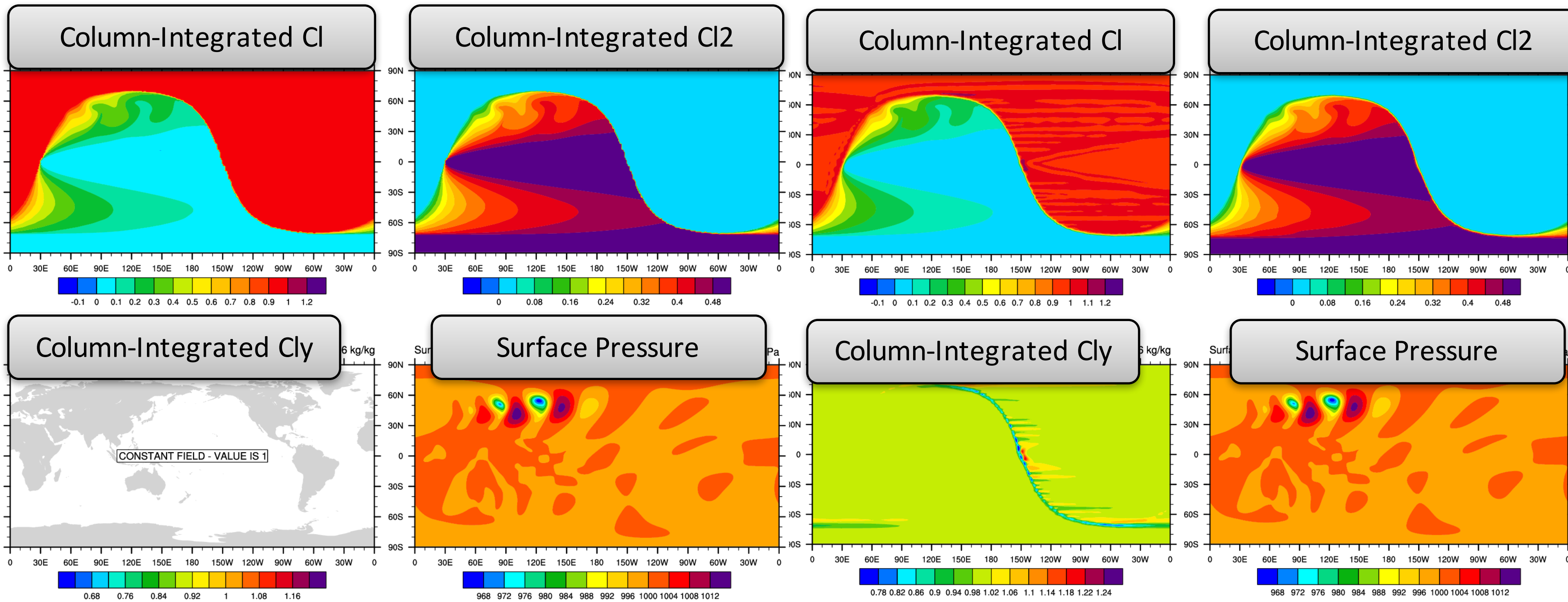
$$\Rightarrow \quad \frac{D}{Dt}([X] + 2[X_2]) = 0$$



Test 1: Terminator Chemistry

Day 9 results with baroclinic wave background dynamics.

HOMME-CSLAM **HOMME-SE**

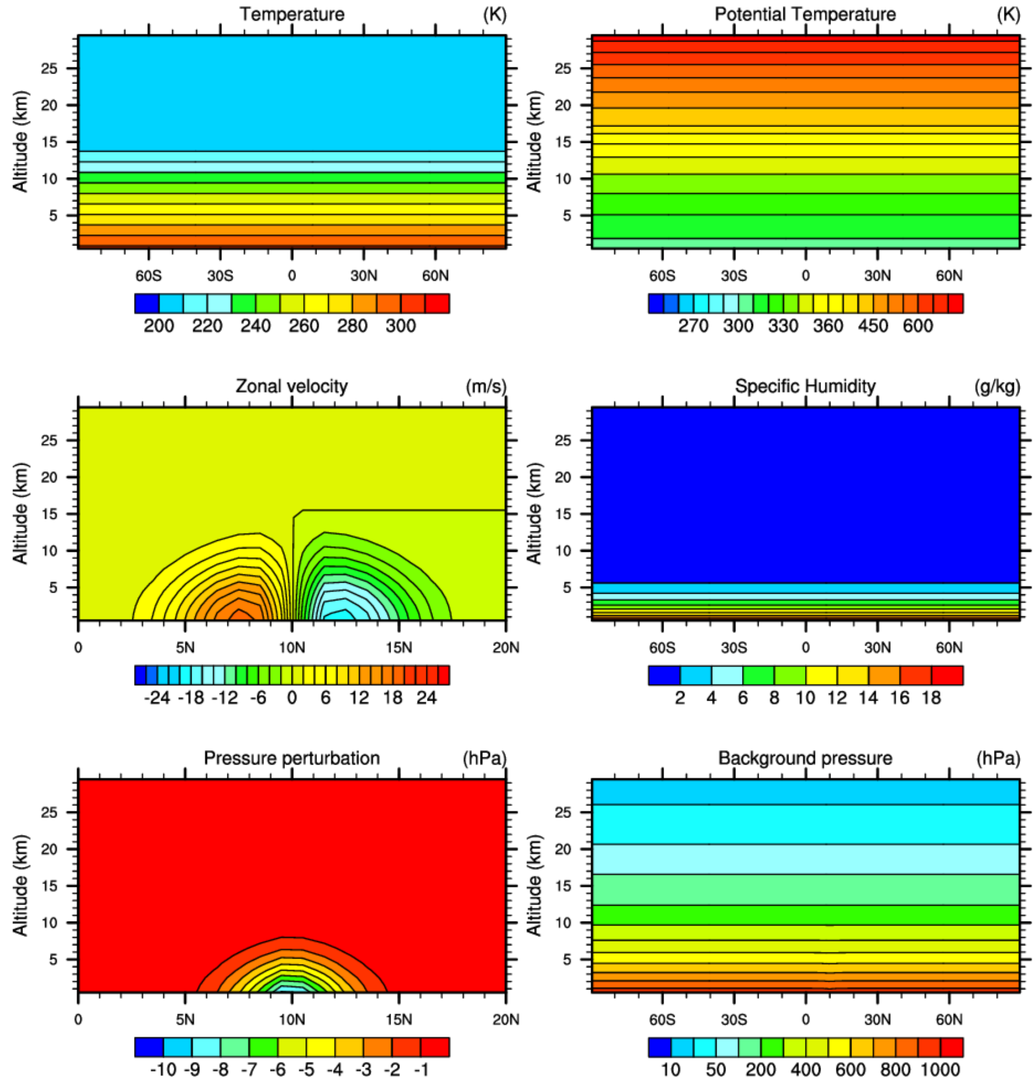


Test 2: Tropical Cyclone

The moist tropical cyclone test incorporates a nearly convectively unstable atmospheric state using the Jordan tropical sounding:

- Zero bottom topography
- Localized feature
- Initial profile in gradient wind balance
- Incorporates surface fluxes and boundary layer

Reference: Reed KA and Jablonowski C. "Idealized tropical cyclone simulations of intermediate complexity: a test case for AGCMs." *J. Adv. Model. Earth Syst.* 2012; 4:M04 001, doi:10.1029/2011MS000099.



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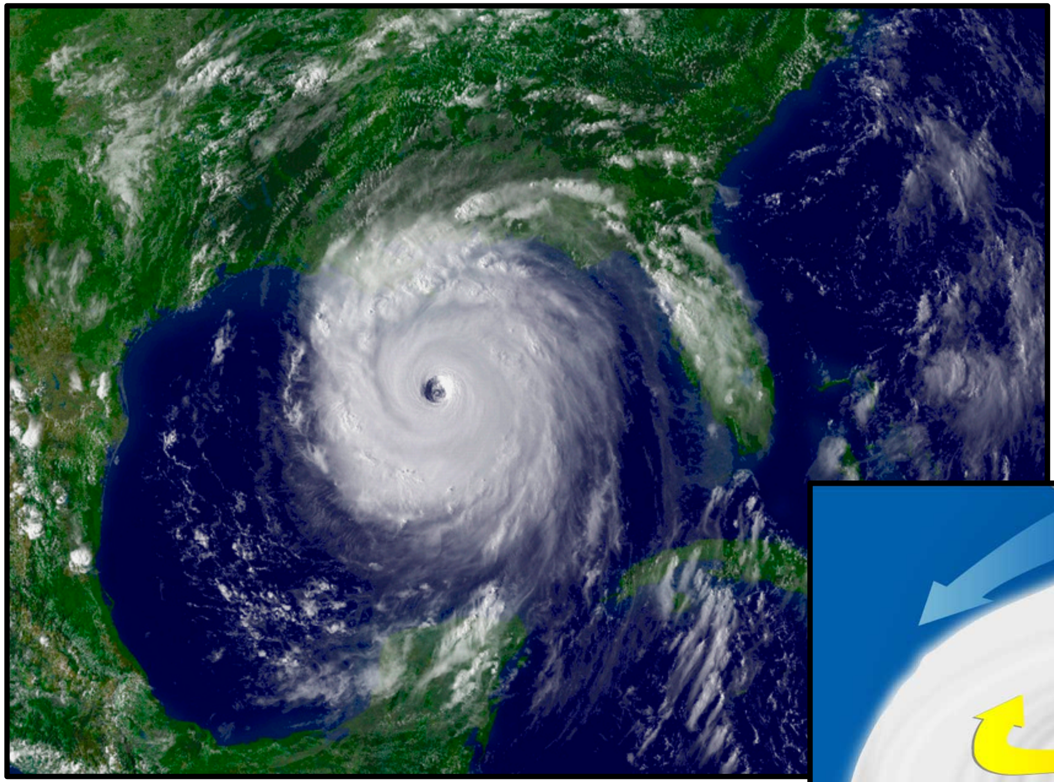
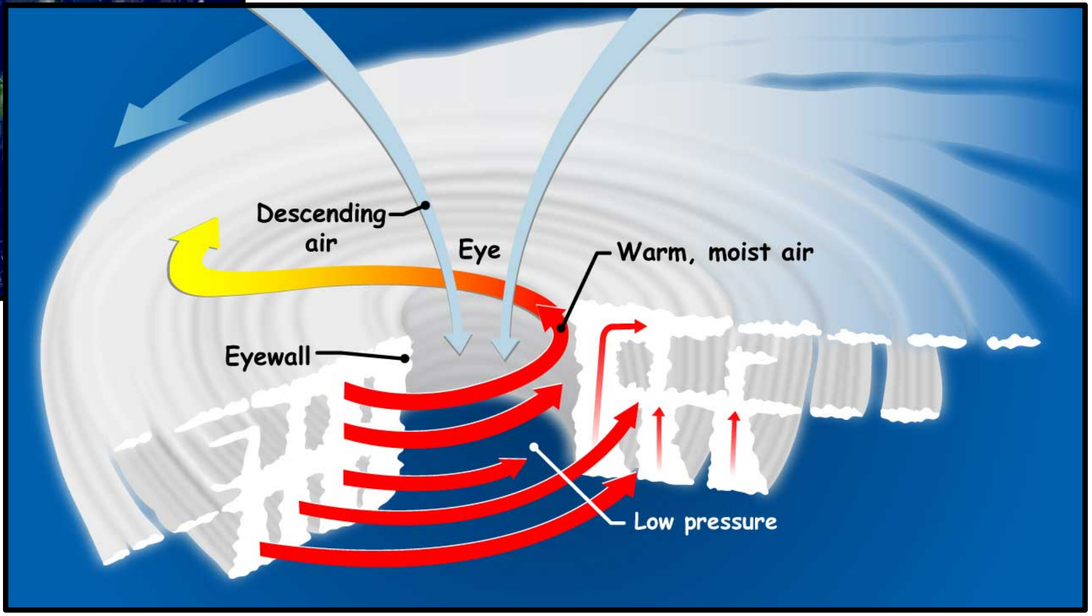
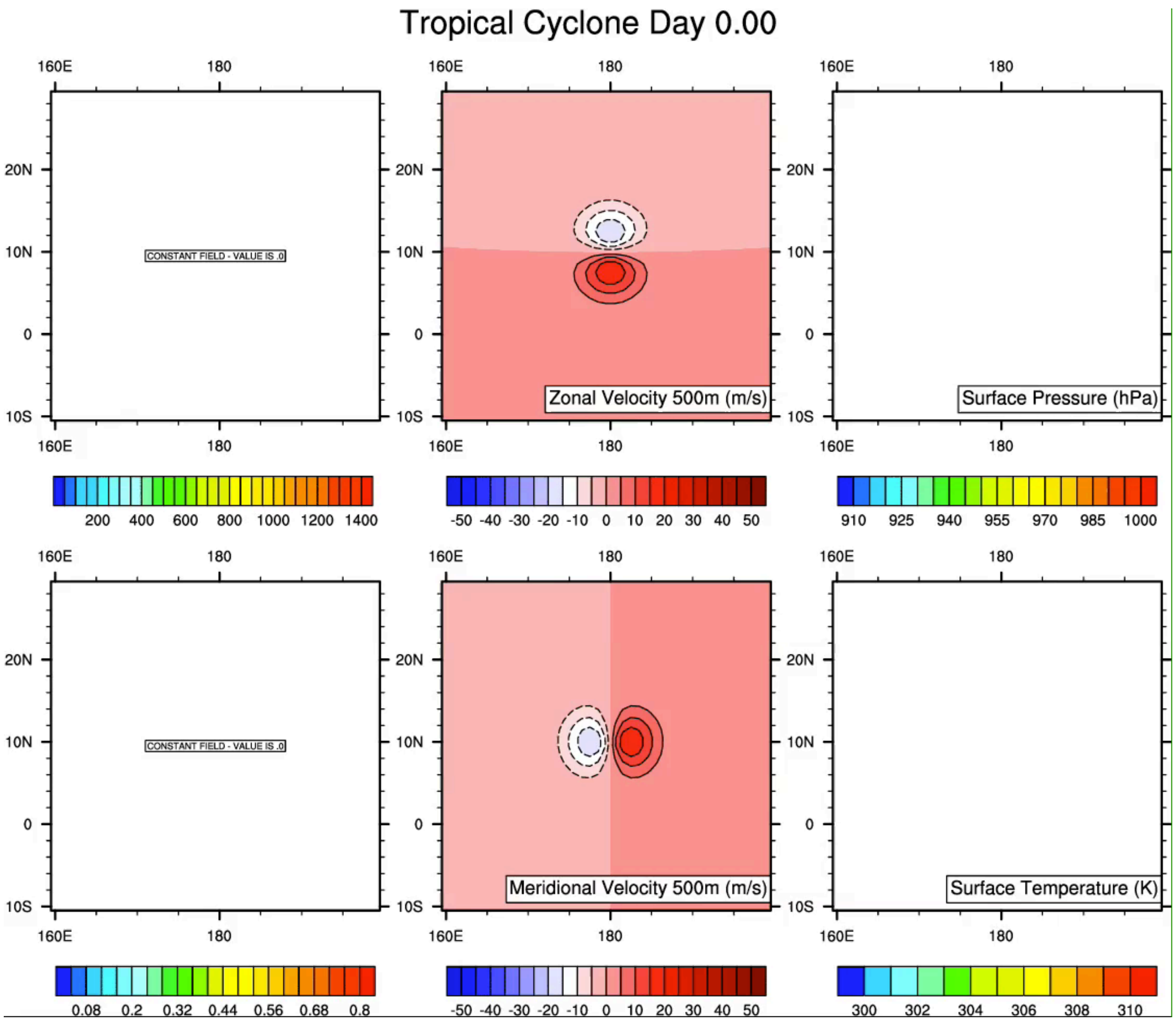




Tropical Cyclone

Test 2: Tropical Cyclone



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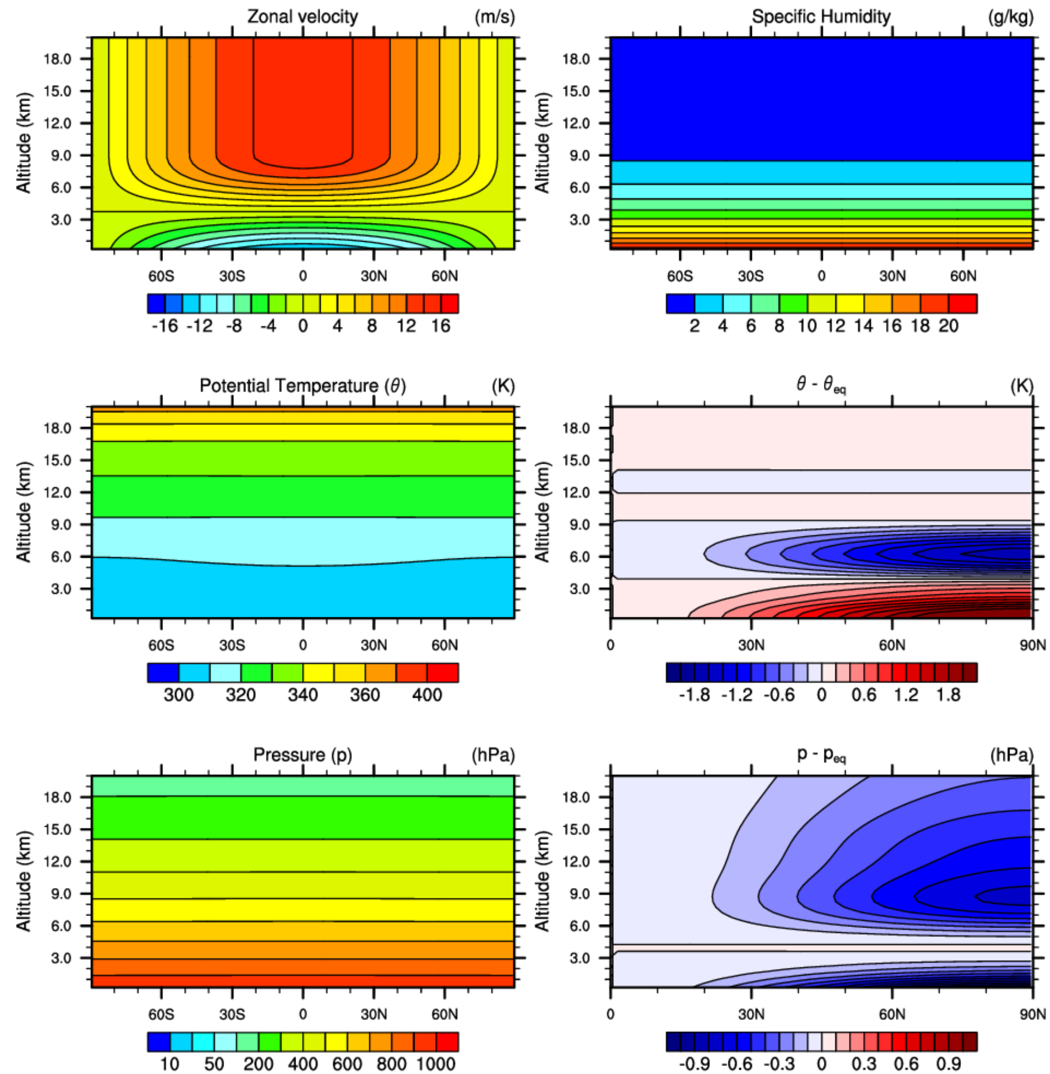
Test 3: Supercell

The supercell on a reduced radius sphere mimics a traditional test case for mesoscale dynamics.

- Zero bottom topography
- Localized feature
- Non-hydrostatic dynamics
- Initial profile in gradient and hydrostatic balance
- Reduced radius (X=120)
- No Coriolis force



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Test 3: Supercell

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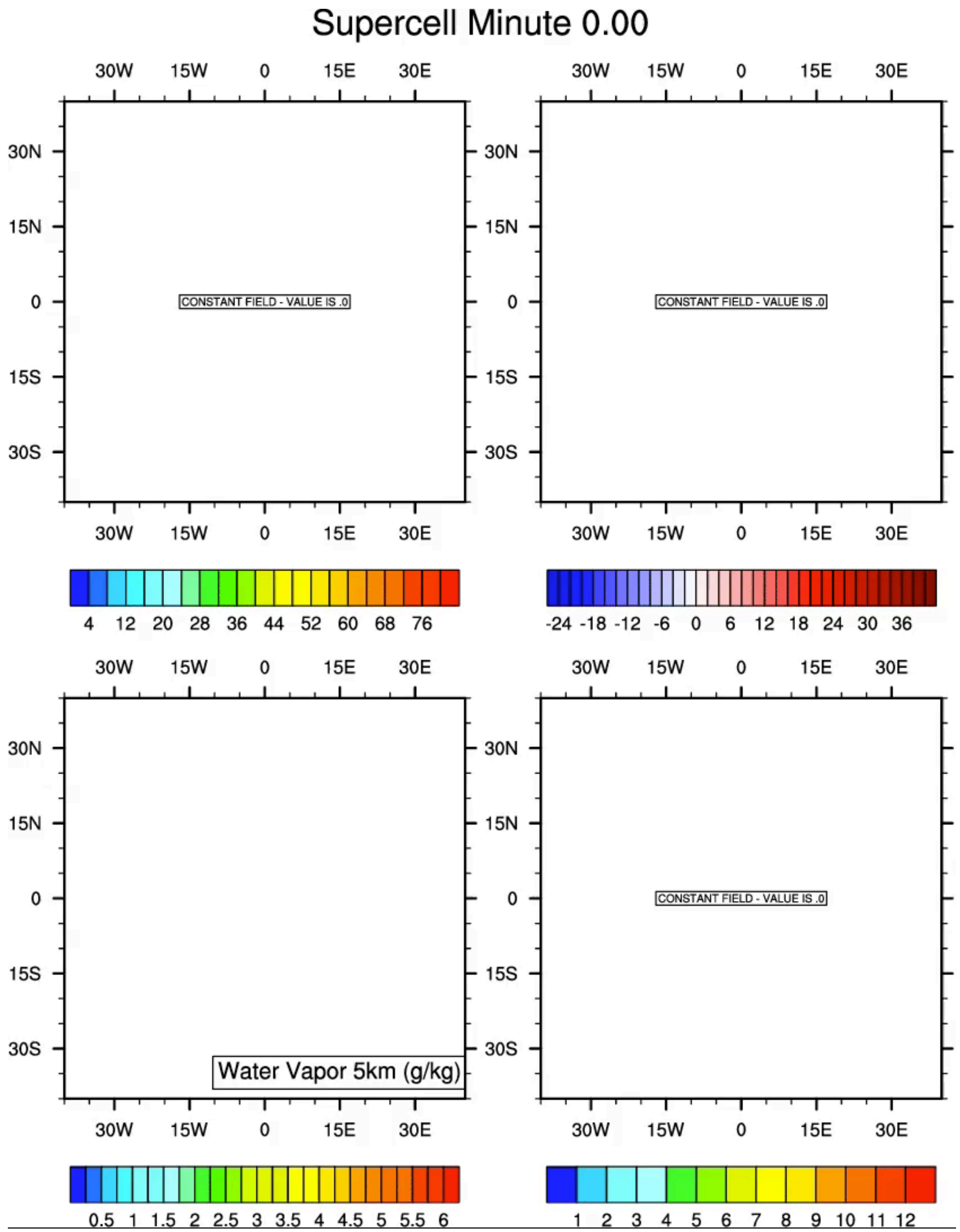
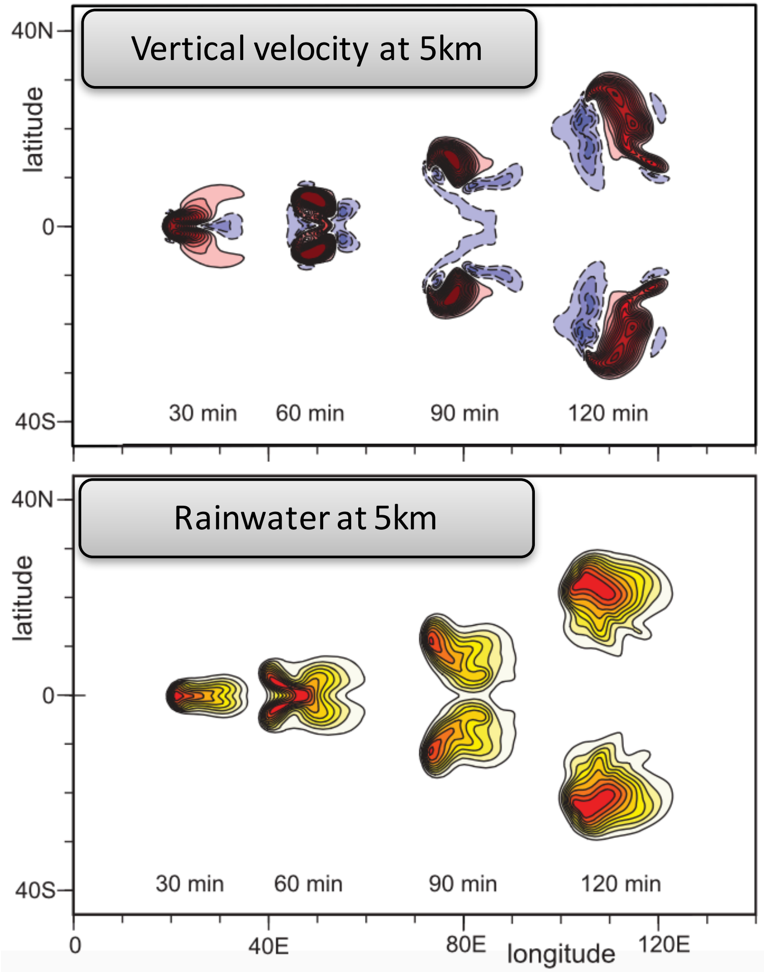
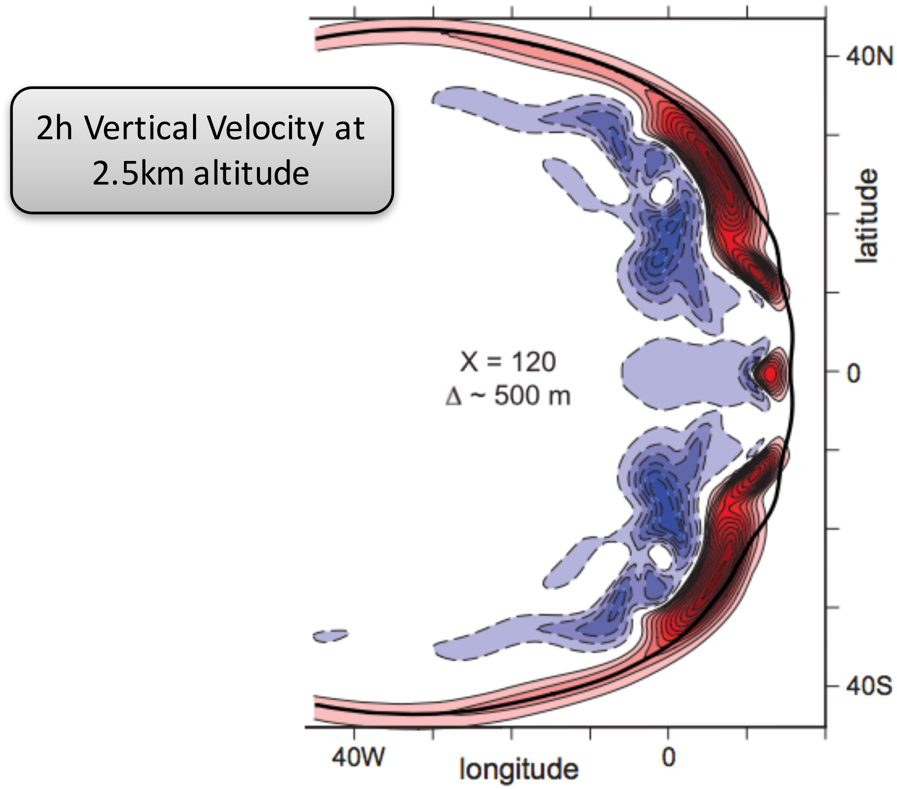
Right: Preliminary simulation of the supercell.



Test 3: Supercell





Reference: J. B. Klemp, W.C. Skamarock, and S.-H. Park (2015) “Idealized global nonhydrostatic atmospheric test cases on a reduced-radius sphere.” *J. Adv. Model. Earth Syst.*, 07, doi:10.1002/ 2015MS000435