Examining the longwave radiative effects of a tropopause vortex

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Outline

- The specifics
- Addition of moisture
- Vortex initialization
- What should we expect radiatively?
- Dry evolution
- Moist evolution

Specifics

- Updgraded to WRF v. 2.2.0 (previously v. 2.1.0)
- $Nx = Ny = 64$, $Nz = 60$
- $\Delta t = 415$ s, run time 3 days, 11 hours
- Periodic horizontal boundaries
- Hydrostatic
- RRTM longwave radiation, no shortwave radiation, no other physics or microphysics

Adding in moisture

- η levels defined by hydrostatic pressure

$$\eta = \frac{p_h - p_{ht}}{p_{hs} - p_{ht}} = \frac{p_h - p_{ht}}{\mu}$$

- η level spacing defined by a hyperbolic tangent profile

- Moist pressure is:

$$p_m = \left[\rho_d \kappa \theta \left(1 + \frac{q_v}{\varepsilon}\right)\right]^{\frac{1}{1-\gamma}} = p_d \left(1 + \frac{q_v}{\varepsilon}\right)^{\frac{1}{1-\gamma}}$$

where $\kappa = R_d p_o^{-\gamma}$, $\gamma = R_d/c_p$ and $\varepsilon = R_d/R_v = 0.622$.

- Show web animation

Vortex initialization

Mean state potential temperature:

$$\theta^m(z) = \frac{\theta_o}{g} N^2 z + \theta_o.$$

Perturbation to potential temperature of form:

$$\theta' = A \exp^{-\left[\left(\frac{x-x_o}{a}\right)^2 + \left(\frac{y-y_o}{b}\right)^2\right]}$$

centered at the top of the model. Moisture profile defined by temperature and specified constant relative humidity

$$q = \frac{\varepsilon r e_s}{100\,(p - e_s)}$$

where $\varepsilon = 0.622$, r is the relative humidity, and

$$e_s(T) = 6.112 exp\left(\frac{17.67 T(^\circ C)}{T(^\circ C) + 243.5}\right).$$

(*Show plots of initial conditions*)

Infrared cooling rate

The First Law of Thermodynamics, is

$$\frac{dQ}{dt} = \frac{du}{dt} + \frac{dw}{dt}$$

where Q is the diabatic heating, u the internal energy, and w the mechanical work. The above can be written in terms of the dry and moist static energies as

$$\frac{dQ}{dt} = c_p\frac{dT}{dt} + g\frac{dz}{dt} + L\frac{dq}{dt}$$

where T is the temperature, g the gravitational acceleration, L the latent heat, and q the specific humidity. After doing a lot of algebraic manipulation, one can show that the radiative flux, F, is related to the heating by the following:

$$\rho\frac{dQ}{dt} = \frac{\partial F}{\partial z} = -\rho c_p\frac{\partial T}{\partial t}. \tag{1}$$

(*End of slides!*)