TROPICAL METEOROLOGY HOMEWORK #1
DUE THURSDAY 02/23/2015
Each problem is worth 5 pts.

1. Dimensional analysis

Suppose a tropical convective system delivers rain at a rate of 5 mm/hr for 4 hours. How much total condensation of water mass per unit area does this rain event produce?

2. First law of thermodynamics in log pressure coordinates:

Show that the dry thermodynamic tendency equation in isobaric coordinates

$$\left(\frac{\partial}{\partial t} + \mathbf{v}_h \cdot \nabla_h\right)T - S_p\omega = \frac{J}{c_p};\ S_p = -T\frac{\partial \ln\theta}{\partial p} \qquad \text{[see Holton 3.6]}$$

can expressed in log pressure coordinates, i.e., $z^* = -H\ln(p/p_s)$, as:

$$\left(\frac{\partial}{\partial t} + \mathbf{v}_h \cdot \nabla_h\right)\frac{\partial \Phi}{\partial z*} + w^* N^2 = \frac{\kappa J}{H}$$

$$N^2 \equiv \frac{R_d}{H}\left(\frac{\partial T}{\partial z*} + \frac{\kappa T}{H}\right);\ \kappa = \frac{R_d}{c_p} \qquad \text{[see Holton 8.45]}$$

Here, N is the Brunt-Väisälä frequency, which is found to vary slowly with height in the troposphere: the log pressure formulation can thus be simplified by approximating N as constant.

3. Richardson number:

In the lecture on scale analysis, we noted the importance of the Rossby number, defined as the ratio of advective (or inertial) force to the Coriolis force, i.e., $\mathrm{Ro} = \frac{U}{fL}$. Another important dimensionless number is the Richardson number, which is defined as the ratio of the buoyancy and inertial forces, i.e., $\mathrm{Ri} = \left(\frac{HN}{U}\right)^2$.

a) Estimate Ri for *nonprecipitating* synoptic scale motions in the Tropics for the characteristic scales assumed in the scale analysis.

b) How would you expect Ri to change for *precipitating* synoptic scale systems in the Tropics? [*Hint: Think about what happens to the Brunt-Väisälä frequency in regions of precipitation.*]

4. The Hadley Cell on Planet X

Consider the Held-Hou model Hadley cell width,

$$Y = \left(\frac{5\Delta\theta g H}{3\Omega^2\theta_0}\right)^{1/2}.$$

For a planet, X, with a length of day 20% longer than Earth, a mass 3x as large as Earth but with the same planetary density, and an incoming stellar energy flux at the top of the atmosphere 1/2 as large, find Y_X, expressed in terms of Earth quantities. Assume the tropospheric depth and equator-to-pole temperature gradient of planet X are the same as on Earth, and treat θ_0 as X's planetary blackbody temperature.