Atm 611 **Problem Set #3** **Fall 2014**

Note: These problems were taken from Ch. 6 of Holton (2004).

1. Suppose that the geopotential height distribution at a certain time has the form:

$$\Phi\,(x,y,p) = \Phi_o(p) - f_o U_o y \cos\left(\frac{\pi p}{p_o}\right) + f_o c k^{-1} \sin kx$$

Here U_o is a constant zonal speed and all other constants are as in problem #1 of problem set #2. Assuming that f and σ are constants, show by evaluating the terms on the right-hand side of the QG tendency equation (6.23) that $\chi = 0$ if $k^2 = \sigma^{-1}(f_o\pi \,/\, p_o)^2$. Make qualitative sketches of the geopotential height fields at 750 hPa and 250 hPa for this case. Indicate regions of maximum cyclonic and anticyclonic vorticity advection at each level (Note: the wavelength corresponding to this value of k^2 is called the Rossby radius of deformation.)

2. Given the following expression for the geopotential height field:

$$\Phi(x,y,p) = \Phi_o(p) + f_o\left\{-Uy + k^{-1}V\cos(\pi p \,/\, p_o)\sin k(x - ct)\right\}$$

Here *U*, *V*, and *c* are constant speeds, use the QG vorticity equation (6.19) to obtain an estimate of ω. Assume that $df/dy = \beta$ is a constant (non zero), and that ω vanishes for $p = p_o$. Sketch the geopotential height field at several levels of your choice so that you have a picture of the three dimensional structure of $\Phi\,(x,y,p)$ in your mind.

3. For the conditions given in problem #2 use the adiabatic thermodynamic energy equation (6.13b but set $J = 0$) to obtain an alternative estimate of ω. Determine the value of *c* for which this estimate of ω agrees with that found in problem #2.

4. For the conditions given in problem #1, use the approximate omega equation (6.36), but don't forget to add the missing "2" in front of this equation, to obtain an expression for ω. Verify that this result agrees with the results of problem #'s 2 and 3. Sketch the phase relationship between Φ and ω at 250 hPa and 750 hPa. What is the amplitude of ω if $\beta = 2 \times 10^{-11} m^{-1} s^{-1}, U = 25\, m\, s^{-1}, V = 8\, m\, s^{-1}, k = 2\pi/(10^4 km)$, $f_o = 10^{-4} s^{-1}, \sigma = 2 \times 10^{-6} Pa^{-2} m^2 s^{-2}$, and $p_o = 1000\ hPa$?

5. Discuss what these results mean synoptically.