ATM 240 – Fall 2016

Problem set #1 39 pts Due: 4 October 2016

Solve these problems (including making the plot) using a programming language or spreadsheet (e.g. Excel). Email your computer code or spreadsheet file when turning in your printed copy.

1. (23pts) **Barotropic instability** of atmospheric flows to the formation of large scale eddies. In Chapter 1 a meridional derivative of absolute vorticity (= ζ_{ay}) in equation (1.3) provides an estimate of the necessary condition for barotropic instability of the atmosphere. This problem estimates that condition using values for the month of January 2010.

a. (3 pts) The values of 250 hPa data for U for grid points at latitudes 5N to 75N using a 2.5 degree interval are available from the course website. Plot the data as a function of latitude from 10N to 70N. (25 values)

b. (14 pts) Use second order, centered, finite differences to obtain ζ_{ay} at grid points from 10N to 70N. Print the values over this latitude range. (25 values) **For full credit, show your intermediate work** by printing out the values of: the cosine (from 5N-75N), the quantity in curly brackets (7.5N-72.5N), the meridional derivative (including the 1/r) of the curly brackets (10N-70N), and the value of β (7.5N-72.5N).

c. (3 pts) Make a plot of ζ_{ay} as a function of latitude, from 10N-70N.

d. (3 pts) If a low pressure system extends from 45N to 60N, is it likely to be unstable? Why or why not? If a low pressure system extends from 30N to 45N, is it likely to be unstable? Why or why not?

Hints:

i) note that $\beta = 1/r\ \partial f/\partial\varphi$ where φ is latitude in radians and $r = 6.4\text{x}10^6$ m.

ii) second order differences include: $f_{x\,at\,pt\,i} = \dfrac{f_{i+1} - f_{i-1}}{2\,\Delta x}$ $\quad f_{xx\,at\,pt\,i} = \dfrac{f_{i+1} + f_{i-1} - 2\,f_i}{\Delta x^2}$

2. (16pts) **Baroclinic instability** of atmospheric flows to develop large scale eddies. In Chapter 1, the inequality (1.5) provides an estimate of the necessary condition for baroclinic instability of the atmosphere. Estimate the stability condition using values for the month of January 2010.

a. (6 pts) The values of 700 and 250 hPa data for U and θ for grid points at latitudes 5N to 75N using a 2.5 degree interval are available from the class website. Plot the data as a function of latitude from 10N to 70N with all U values on one chart and all θ on the other. (4x29 values)

b. (7 pts) Using 250 and 700 hPa data for U and θ evaluate each side of the inequality (1.5) in Chapter 1. Then print both sides of the inequality. Plot both sides of the inequality (1.5) on the same graph from 10N to 70N. (2x29 values)

c. (3 pts) If the vertical wind shear (LHS of eqn. 1.5) exceeds the static stability (RHS of eqn. 1.5) anywhere, indicate those latitudes.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written.
Any plot must be completely and unambiguously labeled, including title and axes.