Homework 3

due at the start of class on Sept. 16, 2015

[50 pts.]

Name: ____

Estimate of Time Spent: ______________ Actual Time Spent: ______________

Problem 1: Reading-in global atmospheric data

Download the netcdf file (.nc) from the class webpage. It contains ECMWF reanalysis data on the 300 hPa pressure surface for the period January 1-8, 2013 (with one longitude-latitude field every 6 hours at 00UTC, 06UTC, 12UTC, 18UTC). Read in the data with the programming language of your choice. You will be using this data for the next problem, and other data of this form for subsequent homework sets.

Problem 2: Approximations to the momentum equations (gravity, viscosity)

(a) Using the data from Problem 1, estimate typical values* of the local accelerations of the zonal and meridional wind in the Northern midlatitudes (30-60^{o} N), namely:

$$\frac{\partial u}{\partial t} \quad \text{and} \quad \frac{\partial v}{\partial t}. \tag{0.1}$$

To estimate these time tendencies, use the method of *centered finite differences*[1], e.g.:

$$\frac{\partial u^{i}}{\partial t} \approx \frac{u^{i+1} - u^{i-1}}{2\Delta t}, \tag{0.2}$$

where the superscripts are the time stamps and Δt is the time step - in this case, 6 hours. For example, to obtain the time tendency for January 3 at 12 UTC you will take the difference between the u fields on January 3 at 18UTC and January 3 at 6 UTC and divide by 12 hours.

(b) Obtain the next order correction for the zeroth order approximation of the gravitational acceleration $g = g_0(1 + z/a)^{-2}$ by using a power series expansion about 0. Hint: use the following for the expansion about $x = 0$:

$$\frac{1}{(1-x)^2} = 1 + 2x + 3x^2 + \cdots = \sum_{n=1}^{\infty} n x^{n-1} \tag{0.3}$$

[1] https://en.wikipedia.org/wiki/Finite_difference

(i) What is the relative size of this next/first order correction?

(ii) How does the magnitude of this correction compare to the magnitude of the local acceleration terms from (a)?

(iii) At what altitude in the atmosphere does the correction become appreciable?

(iv) Based on your answers above, what you do think about the conventional approximation of $g \approx g_0$?

(c) Estimate the magnitude of the wind tendencies due to the viscosity in the momentum equations for the atmosphere (look up the value for kinematic viscosity).

(i) How does the tendency due to viscosity compare to the typical values you found in (a)? Feel free to use your own method, or use the fact that diffusive processes relate the time tendency to the Laplacian of the quantity, or use the scaling method in Vallis 1.11 (provided on the course webpage under HW 3).

(ii) Based on this, what do you think about our choosing to neglect viscosity in this course?

**One can calculate a "typical magnitude" in many different ways*. You could provide the mean of the absolute value, provide the most common magnitude, etc. One nice way is to calculate the root-mean-square (RMS) value. That is, first square all of the values of interest, take the mean of those squared values, and then take the square root.

Problem 3: Flying Adiabat(ics)

When air is moved *adiabatically* from outside an aircraft flying at 200 hPa to inside the aircraft, what will its temperature be? You can assume a typical cabin pressure of 750 hPa and an outside temperature of 210 K. What can you infer about the heating/cooling system of the aircraft?

Problem 4: An Adiabatic Atmosphere?

(a) What processes lead to diabatic heating and cooling? Why?

(b) Where do you think the adiabatic approximation ($\frac{D\theta}{Dt} \approx 0$) is most applicable? (Think stratosphere vs. troposphere, low vs. high-latitudes, deserts vs. tropical regions)