Homework 3

due Sept. 8, 2017

[50 pts.]

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, 2014 (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 to 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 $x = 0$:

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

(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)?

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

(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. You can do this a variety of ways, some easier than others. I would suggest following the scaling method in Vallis, First Edition that uses the Reynolds number (section 1.11.1 - provided on the course webpage under HW 3), as this will provide a ballpark solution in record time. Alternatively, you can try and calculate the laplacian of the wind on the sphere and compute the actual term (much more difficult).

(i) How does the tendency due to viscosity compare to the typical values you found in (a)?

(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.