Lab 7: Quasigeostrophic Theory I: Traditional form of the omega equation

Objective: To examine the nature of the forcing terms in the QG omega equation while continuing to learning Python.

Materials: Your laptop, Enthought Python, Internet access, pencil, eraser, and colored pencils.

Procedure:

1) Downloads
   (a) Today's Netcdf file is named `gfs_4_20120918_1200_000.nc`. Download it from `http://weather.ou.edu/~metr4424/files/`.
   (b) Updated scripts to download from the class repository (`http://weather.ou.edu/~metr4424/files/`):
      `utilities_modules.py`
      `weather_modules.py`
      `print_netcdf_info.py`
      `plot_diagnostics_forlab.py`

2) Plots

   (a) Today you will begin developing your own Python diagnostics script. A 'skeleton' script has been provided, and is called `plot_diagnostics_forlab.py`. You will be making your own edits and additions to this script to ultimately create a set of custom diagnostic plots. `weather_modules.py` has been updated to include functions that compute geostrophic wind, horizontal advection, and vertical vorticity.
   (b) Produce a set of analyses with the following 3 figures:
      `500 hPa absolute vorticity and geostrophic wind vectors`
      `1000 hPa absolute vorticity and geostrophic wind vectors`
      `700 hPa temperature and geostrophic wind barbs`

   The skeleton script provided computes and plots absolute geostrophic vorticity at 100 hPa and 200 hPa. You can use this as an example to compute vorticity on other isobaric levels. Refer to the Python scripts from your previous lab if you need help determining how to read in temperature, or use `print_netcdf_info.py` (or look at your `gfs_fields` file) to determine variable names and dimensions if necessary. **Hint: When creating additional figures, much of the work can be done by simply cutting, copying, and pasting the code for the first figure. You will then only need to make a few adjustments for the new figures.** Don't forget to set an appropriate title for each of your plots.

   Note that you will need to adjust your colorbar settings for each of your plots (search for 'Colorbar settings' in the skeleton script for the appropriate place to edit). Suggested contour intervals and colormap names are listed in Table 1, but feel free to adjust for your custom script. You can add/remove/change to different colormaps if desired. The current plots use a colormap called `hot_r` for plotting absolute vertical vorticity, which is good for plotting a field that has only one sign. Colormap names are an argument in the matplotlib `contourf` function. For more help and for documentation on Python colormaps, go to `http://matplotlib.org/examples/pylab_examples/show_colormaps.html`.

(c) Once you have made the above figures, print them. Shade areas of cyclonic vorticity advection (label with CVA) and anticyclonic vorticity advection (label with AVA) on your vorticity plots, and warm and cold temperature advection on your temperature plot. Use any colors you desire, just make sure they are clearly labeled.

(d) Now use the function `hadvection_latlon` to compute absolute geostrophic vorticity and thermal advection. These functions are located in `weather_modules.py`. For example, to compute geostrophic absolute vertical vorticity advection on a level you call '1', add:

```
vort_adv1 = wm.hadvection_latlon(uin1, vin1, zeta_a1, lats, lons)
```

Be sure to add

```
vort_adv1, lons = um.addcyclic(vort_adv1, lonin)
```

after you compute the advection but before you plot it, or else you may have inconsistent array dimensions. Remember that the first term on the right-hand side of the omega equation is *differential vorticity advection*. This can be computed by subtracting the geostrophic absolute vorticity advection at 1000 hPa from 500 hPa:

$$\left[\vec{V_g} \cdot \nabla \zeta_{a,g}\right]_{500hPa} - \left[\vec{V_g} \cdot \nabla \zeta_{a,g}\right]_{1000hPa}.$$

Print two plots: differential vorticity advection and 700 hPa temperature advection. Note that you will need to adjust your colormaps in your plots (try using a colormap called `bwr` since you expect values in these fields to be centered about 0). To change colormaps, change one argument in `m.contourf` from `cmap=plt.cm.hot_r` to `cmap=plt.cm.bwr` instead. Feel free to use a different colormap if you desire.

(e) Based on QG theory and the traditional form of the QG omega equation, discuss where you would expect significant vertical motion (both ascent and descent). Keep in mind that the vorticity advection and thermal advection terms can either combine or cancel.

(f) Now plot omega. Note that this is already read in at a certain level in your skeleton script. Make sure you plot it at the same level as your thermal advection plot. It is not required to print this plot. Are your regions of ascent and descent the same? Why or why not?

Hand in all plots required for printing above in this lab with answers to any questions above. This lab is due at the beginning of class on Wednesday October 3.

Calculation	Suggested contour interval value (`cint`)	Colormap suggestion
Absolute geostrophic vorticity	8×10^{-6} s^{-1}	hot_r
Differential absolute geostrophic vorticity advection	6×10^{-11} s^{-2}	bwr
Temperature advection	4×10^{-6} K s^{-1}	bwr
ω	0.2×10^{-1} Pa s^{-1}	bwr

Table 1: Suggested contour intervals and colormap names for plots.