Tropical Meteorology – Homework #7

Due Date: Monday, 16 May 2016

In this assignment, you will explore sensitivities in secondary circulation responses within the Sawyer-Eliassen model framework. To begin, log on to a Mac in EMS W434. Use the Application Launcher to open a Terminal window. Next, issue the following command:

wget http://derecho.math.uwm.edu/classes/TropMet/assignments/hw7/semodel.tar

This will download a file named semodel.tar to this directory. Expand the archive by issuing the following command in the Terminal:

tar -xvf semodel.tar

This will result in sixteen new files being created within this directory. You may list them by typing 'ls' (without the quotes). Together, the .f90 files represent a Fortran program to diagnose the secondary circulation response to specified heat and momentum flux forcing for an idealized tropical cyclone vortex. The model domain extends out to 1500 km from the cyclone's center (Δr = 15 km) and up to 10 km from the sea surface (Δz = 0.5 km).

Parameters controlling the heat flux, momentum flux, and horizontal idealized vortex structures are set in lines 19-21 of the common.f90 file. Specifically,

- Idealized vortex (line 19)…
  - rmw = radius of maximum winds (in m; default: 50,000 m)
  - vmax = maximum sustained 10-m winds (in m s^{-1}; default: 42.5 m s^{-1})
- Idealized heat source forcing (line 20)…
  - fluxmax = magnitude of the maximum heat flux forcing (in K s^{-1}; default: 1 x 10^{-3} K s^{-1}); positive values denote warming
  - r_o = radius from the center of the vortex at which the maximum heating is located (in m; default: 50,000 m)
  - z_o = altitude at which the maximum heating is located (in m; default: 5,000 m)
  - r_d = radial distance from r_o over which the heating decays to zero (in m; default: 25,000 m)
  - z_d = vertical distance from z_o over which the heating decays to zero (in m; default: 2,000 m)
- Idealized momentum source forcing (line 21)…

- momfluxmax = magnitude of the maximum momentum flux forcing (in m s^{-2}; default: 1 x 10^{-3} m s^{-2}); positive values denote cyclone momentum flux forcing
- ro = radius from the center of the vortex at which the maximum momentum forcing is located (in m; default: 500,000 m)
- zo = altitude at which the maximum momentum forcing is located (in m; default: 7,000 m)
- rd = radial distance from r_o over which the momentum forcing decays to zero (in m; default: 250,000 m)
- zd = vertical distance from z_o over which the momentum forcing decays to zero (in m; default: 1,000 m)

Parameters controlling the static stability and vertical idealized vortex structure are set in the vortex.f90 file. Specifically,

- Static stability (Nsq; line 95): default 1.44 x 10^{-4} s^{-2}
- Vertical vortex structure (lines 39, 41)…
  - Barotropic vortex (constant intensity with height): uncomment (remove leading !) in line 39, comment out (add leading !) in line 41
  - Baroclinic vortex (decreasing intensity with height): uncomment (remove leading !) in line 41, comment out (add leading !) in line 39. This is the default setting.

Note, however, that the baroclinic vortex is only very weakly baroclinic; there is no outward tilt of the radius of maximum winds with increasing height, for instance.

Use your favorite text editor to edit any desired parameters within these files. I recommend using nano within the Terminal window, i.e.,

```
nano common.f90
```

In nano, the arrow keys are used to move from one line to the next, or to the left or right on one line. To save, use Ctrl-O, then hit Enter. To exit, use Ctrl-X.

Once common.f90 and vortex.f90 have been edited to reflect the desired values of the above variables, issue the following command (all on one line) to compile and run the model:

```
rm *.o ; make ; ./a.out
```

This will remove any old model code that may exist, re-compile all of the model code, and then execute it. Successful execution should only take a few seconds. If they did not exist already, a series of .dat files will be created by this program.

To view model output, the output data must first be converted from text format to binary format. To do so, issue the following command:

```
gfortran -o binaryconvert binaryconvert.f ; ./binaryconvert
```

Next, to display the data, simply run the provided seplot.gs script:

```
grads -clb seplot.gs
```

This script will create six PNG images...

- hflux.png: displays the vertical and radial structure of the specified heat forcing
- mflux.png: displays the vertical and radial structure of the specified momentum forcing
- psi.png: displays the streamfunction resulting from the heat and momentum forcing
- u.png: displays the radial wind (positive outward) resulting from the streamfunction
- vbar.png: displays the vertical and radial structure of the vortex's tangential wind
- w.png: displays the vertical velocity (positive upward) resulting from the streamfunction

These can be displayed using any image viewer on the Macs. After each run of the model code, create a new directory in which to store these images, then move the images to that directory:

```
mkdir <name>

mv *.png <name>
```

where <name> is replaced by the name of the new directory. Do not include < or > at the end of this name. Naturally, you will probably want to choose some descriptive name. If you do not save the images after each run of the model code, they will be overwritten!

If you run into any technical issues in running the code, please let me know as soon as possible. Note that you do not need to include images with your answers to the questions below.

1. (27.5 pts) In this question, you will examine the basic streamfunction response to idealized heat and momentum flux forcing.
    a. (10 pts) Edit common.f90 and set momfluxmax to 0.0d-3. Compile the model code and visualize the output. Describe the secondary circulation response (*u* and

w) to the specified heat flux forcing. Physically, why do you think this response takes the form that it does?

b. (10 pts) Edit common.f90 and set momfluxmax back to the default 1.0d-3. Set fluxmax to 0.0d-3. Compile the model code and visualize the output. Describe the secondary circulation response (*u* and *w*) to the specified momentum flux forcing. Physically, why do you think this response takes the form that it does?

c. (7.5 pts) Edit common.f90 and set fluxmax back to the default 1.0d-3. Compile the model code and visualize the output. Describe the secondary circulation response (*u* and *w*) to the specified heat and momentum flux forcing.

2. (20 pts) In this question, you will explore the sensitivity in the secondary circulation response to the magnitude of the heat and momentum flux forcing.

    a. (10 pts) Repeat Question 1a, except with fluxmax set to 2.5d-3. Describe the secondary circulation response (*u* and *w*) to the specified momentum flux forcing. Physically, why do you believe this response differs from that in Question 1a?

    b. (10 pts) Repeat Question 1b, except with momfluxmax set to 2.5d-3. Describe the secondary circulation response (*u* and *w*) to the specified momentum flux forcing. Physically, why do you believe this response differs from that in Question 1b?

3. (15 pts) In this question, you will explore the sensitivity in the secondary circulation response to the radii at which the heat and momentum flux forcing are applied.

    a. (7.5 pts) Repeat Question 1c, except with r_o (the heat flux forcing radius) set to 500.0d3. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c.

    b. (7.5 pts) Repeat Question 1c, except with ro (the momentum flux forcing radius) set to 50.0d3. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c.

4. (7.5 pts) In the preceding questions, an idealized vortex that is weakly baroclinic has been used. Repeat Question 1c, except for the Gaussian barotropic vortex instead of the Gaussian baroclinic vortex. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c. How does this compare to theoretical expectations (e.g., Slide 20 of the TC Structure slide deck)?

5. (15 pts) In this question, you will explore the sensitivity in the secondary circulation response to the inertial stability, as manifest by the idealized vortex's horizontal structure.

    a. (7.5 pts) Repeat Question 1c, except with rmw set to 200.0d3 and vmax set to 12.5d0. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c. How does this difference compare to theoretical expectations (e.g., Slide 20 of the TC Structure slide deck)?

b. (7.5 pts) Repeat Question 1c, except with rmw set to 20.0d3 and vmax set to 75.0d0. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c. How does this difference compare to theoretical expectations (e.g., Slide 20 of the TC Structure slide deck)?

6. (15 pts) In this question, you will explore the sensitivity in the secondary circulation response to the static stability. Note that in this model, static stability is constant over the entire domain, rather than varying with height as is seen in the real atmosphere.

   a. (7.5 pts) Repeat Question 1c, except with static stability set to 14.4d-4. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c. How does this difference compare to theoretical expectations (e.g., Slide 21 of the TC Structure slide deck)?

   b. (7.5 pts) Repeat Question 1c, except with static stability set to 0.14d-4. Describe how the secondary circulation response (*u* and *w*) differs from that in Question 1c. How does this difference compare to theoretical expectations (e.g., Slide 21 of the TC Structure slide deck)?