Tropical Meteorology – Homework #6

Due Date: Thursday, 26 April 2018 (via e-mail)

Learning Objectives: In this assignment, you will use a numerical maximum potential intensity routine to *analyze* sensitivities in maximum potential intensity to variable air-sea disequilibrium.

At http://derecho.math.uwm.edu/classes/TropMet/assignments/hw6/, you will find a Fortran program named mpi.f and four input files (mpi-dunion2011mt, mpi-dunion2011sal, mpi-dunion2011mldai, and mpi-jordan1958). These represent the mean soundings across the tropical North Atlantic basin from Dunion (2011) that we discussed in our Tropical Climatology lecture. Respectively, these represent the "moist tropical," "Saharan air layer," "mid-latitude dry air intrusion," and "overall tropical mean" soundings. The first line of each of these files is the sea level pressure (hPa); subsequent lines contain the pressure (hPa), temperature (°C), and mixing ratio (g/kg), with data on selected isobaric surfaces between 1000-50 hPa. Hard-coded into mpi.f is the sea-surface temperature (26.0°C).

Download the code and all four input soundings. For this task, I recommend using the Macs in EMS W434; however, you are free to use any machine on which you can compile FORTRAN 77 code. I have attempted to describe each of the necessary steps in detail below. If you run into any technical problems with anything that is being asked, please ask me for help as soon as possible. Please think critically over each question, giving particular focus to connecting MPI theory to both necessary conditions for tropical cyclogenesis and the WISHE paradigm. Only a limited number of points are associated with your successful execution of the model code.

1. (28 pts) The default configuration for the MPI program utilizes the Jordan (1958) mean sounding. In a terminal window, compile the mpi.f code as follows: "gfortran -o mpi mpi.f" (without the quotes). Next, run the code using "./mpi" (again without the quotes).

    a. (4 pts) What are the maximum sustained surface winds (kt) and minimum sea level pressure (hPa) resulting from this routine for this sounding?

    b. (4 pts) Examine the mpi-jordan1958 sounding in a text editor. What are the pressure (hPa), temperature (°C), and mixing ratio (g kg^{-1}) closest to the surface?

    c. (12 pts) Specific enthalpy is defined as $h = c_p T + l_v q$ + const. Assuming hydrostatic balance, the first law of thermodynamics can be written as:

$$\frac{Dh}{Dt} + g\frac{Dz}{Dt} = Q_{net}$$

    Where Q_{net} is the net diabatic heating rate: $Q_{net} = Q_{rad} + Q_{mech} = Q_{rad} + Q_{sen} + Q_{latent}$, and Q_{rad}, Q_{sen}, and Q_{latent} are radiative heating, sensible heat flux, and latent heat

flux, respectively. If $z = 0$ following the motion and we assume no radiative heating, then the first law of thermodynamics can be written as:

$$\frac{Dh}{Dt} \approx Q_{sen} + Q_{latent}$$

Thus, specific enthalpy changes following the motion due to sensible and latent heat fluxes. For air parcels along the air-sea interface, specific enthalpy changes following the motion due to surface sensible and latent heat fluxes.

We wish to approximate the surface sensible and latent heat fluxes by the specific enthalpy difference between the air and the underlying ocean; e.g., $h_{ocean} - h_{air}$.

First, compute the saturation mixing ratio for the assumed sea-surface temperature:

$$q_s = 621.97 * \left(\frac{e_s}{p_{sfc} - e_s} \right) \text{ , where } \ln\left(\frac{e_s}{6.11} \right) = \frac{l_v}{R_v} \left(\frac{1}{273} - \frac{1}{T_{SST}} \right)$$

where q_s is in g kg^{-1}, p_{sfc} and e_s are in hPa, and T_{SST} is in K. Show all work, including units. Next, compute the specific enthalpy difference as described above, showing all work including units. What is the inferred direction of enthalpy transport? Would you characterize this transport as small, medium, or large, and why?

d. (7 pts) Compute the efficiency (ε) for this sounding. Show all work.

2. (33 pts) We now wish to consider the Dunion (2011) moist tropical, Saharan air layer, and mid-latitude dry air intrusion soundings. This requires editing the file name (given by FILE='mpi-jordan1958') in Line 44 of mpi.f. Note that each time that you change the file name, you must re-compile and re-execute the code.

   a. (8 pts) Consider the Dunion (2011) moist tropical sounding. Repeat Question 1, parts (a) through (d), for this sounding, noting that you do not have to recompute quantities that have not changed from Question 1 (q_s and h_{ocean}).

   b. (8 pts) Consider the Dunion (2011) Saharan air layer sounding. Repeat Question 1, parts (a) through (d), for this sounding, noting that you do not have to recompute quantities that have not changed from Question 1 (q_s and h_{ocean}).

   c. (8 pts) Consider the Dunion (2011) mid-latitude dry air intrusion sounding. Repeat Question 1, parts (a) through (d), for this sounding, noting that you do not have to recompute quantities that have not changed from Question 1 (q_s and h_{ocean}).

   d. (9 pts) Interpret your answers to parts (a) through (c). Why do you believe the maximum potential intensities obtained for these soundings to vary as they do?

3. (20 pts) In which of the Dunion (2011) environments would you expect the intensity of a given tropical cyclone to reach closest to its maximum potential intensity? Conversely, in which environment would you expect the intensity of a given tropical cyclone to be kept furthest from its maximum potential intensity? Physically, why?

4. (20 pts) Change the 1000 hPa temperature in the Dunion (2011) mid-latitude dry air intrusion sounding to 25.3°C. Re-compile mpi.f, first editing the file name if needed, and re-execute the mpi program.

    a. (4 pts) What are the maximum sustained surface winds (kt) and minimum sea level pressure (hPa) resulting from this routine for this sounding?

    b. (8 pts) Describe how these estimates of maximum potential intensity compare to those obtained in Question 2(c). Are the results what you expected? Discuss why.

    c. (8 pts) Would you expect tropical cyclone formation to require somewhat less, about the same, or somewhat more time in the modified or unmodified Dunion (2011) mid-latitude dry air intrusion environment? Discuss why.