Homework #1/2: ATM OCN 718
Assigned: Tuesday 6 February 2018
Due: Thursday 15 February 2018

1. Given the basic system of equations for deep convective motions being used in this class, what modifications must be made for the system to be Boussinesq or anelastic? What types of atmospheric motions are eliminated by using these approximations? In what situations would the Boussinesq or anelastic approximations be appropriate simplifications? Provide a paragraph or two explaining these concepts.

2. The basic system of equations for deep convective motions, including those used in CM1, are often formulated using *non-dimensional pressure*, π, with the *Exner function*, defined as,

$$\pi = \left(\frac{p}{p_o}\right)^{R/c_p}$$

where p_o = 1000 hPa. This allows the basic equations to be written in terms of π and θ. Show how the vertical momentum equation, as in the form of (2.74) in M&R, can be rewritten as (using the perturbation decomposition for π and θ),

$$\frac{dw}{dt} = -c_p\theta\frac{\partial\pi'}{\partial z} + g\frac{\theta'}{\bar{\theta}}$$

3. Beginning with (2.125) in M&R, show all the steps in deriving the diagnostic pressure equation in the form presented in (2.128). *Hint:* Use the Boussinesq momentum equation to simplify.

4. Starting with (2.128), come up with an analytical formula for the Laplacian of the pressure perturbation field for solid-body rotation in a two-dimensional (X and Y) flow. In other words, reduce the right-hand side of (2.128) using simple equations that describe the u and v velocity components within solid-body rotation (they will have similar forms to u = ax or v = ay). Neglect the beta and Coriolis terms. What is the sign of the pressure perturbation associated with two-dimensional solid-body rotation?

5. Download and compile CM1
    a. Login to Cheyenne using "ssh –Y USERNAME@cheyenne.ucar.edu",
    b. Run "wget http://www2.mmm.ucar.edu/people/bryan/cm1/cm1r19.tar.gz" at prompt in your home directory on Cheyenne to download CM1.
    c. Untar/zip cm1r19.tar.gz by running "tar xzvf cm1r19.tar.gz"
    d. In ./cm1r19/src, using your favorite text editor (e.g., vi or emacs), modify CM1 Makefile by uncommenting two blocks 1) top block associated with netcdf output and 2) block associated with **single core** compilation options for Cheyenne (we want to run CM1 as a single core job with netcdf output).
    e. Run "make" in ./cm1r19/src/ directory to compile CM1. Confirm **cm1.exe** is created in ./cm1r19/run after compilation is finished (compilation may take 10-15 minutes).

6. Configure CM1 and run test supercell simulation using Cheyenne queuing system
    a. Move into the ./cm1r19/run directory and copy the example submission script from CM1 website into a new file called "run_cm1.csh". This c-shell script will be submitted to the PBS queuing system to run CM1.
    b. The "#PBS" lines in run_cm1.csh provide information about the job to PBS. We need to make changes to this script to run our single core CM1 job in a single core queue. To do so, replace the following: "-A Pxxxxxxxx" with "-A UWIS0029", "-l select=4:ncpus=36:mpiprocs=36" with "-l select=1:ncpus=1:mpiprocs=1", "-l walltime=12:00:00" with "-l walltime=01:00:00", and "-q regular" with "-q share". Also remove "mpiexec_mpt" from the beginning of the last line.
    c. Copy the namelist.input from ./cm1r19/run/config_files/supercell into the ./cm1r19/run directory. namelist.input contains all the configuration options for CM1.
    d. Make the following changes to namelist.input: set "nodex" and "nodey" to 1, set output_type to 2, and set output_pdcomp to 1 (this will run CM1 with a single core with netcdf output, producing pressure decomposition fields in the output file).
    e. Submit script using qsub by running "qsub run_cm1.csh".
    f. Check status of job by running qstat –u USERNAME
    g. After job is finished (should take ~25 minutes to run, potentially longer if your job is in the queue but not running), confirm cm1out.nc is produced.

7. Visualize CM1 output (using both ncview and python code).
    a. Use ncview to view cm1out.nc by running "module load ncview", then "ncview cm1out.nc". Look at the "dbz" (reflectivity) field to confirm the storm was produced.
    b. Save an image of the final output time "dbz" field by selecting "Print" and then "File". Turn this image in with your assignment.