MEA712: Mesoscale Modeling
Class mesoscale model (CMM) project, assignment 5
Due at 5 PM on Friday, 13 November.

We will be adding a Rayleigh damping layer and a sponge lateral boundary condition to CMM. When you are done, the processes in the model should occur in this order...

variables are updated using equations implemented in assignment 3
apply computational diffusion to "dry" variables
apply Rayleigh damping to "dry" variables
(microphysics routines are called... to be done in CMM assignment 6)
(apply computational diffusion to moisture variables... CMM6)
(apply Rayleigh damping to moisture variables... CMM6)
apply Asselin filtering to all variables
apply boundary conditions to all variables
write new variable values to your "history" file

1. Implement a Rayleigh damping layer ("sponge") in the top part of the model. The basic formulation should have these components:

```
!  compute local damping coefficient
     coef = raydmpcoef*0.5 &
          *(1.-cos(trigpi*(zu(k)-raydmpz)/(zu(nz-1)-raydmpz)))

!  apply sponge to slowly remove perturbations
     up(i,k) = up(i,k) - coef*(up(i,k)-ub(k))
```

where I have used Fovell's convention for `up`, and `ub` is the base state u–wind (we will allow it to vary in the vertical in future exercises). In the above sample, `coef` is what we referred to in class as R_D, and `raydmpcoef` is what we referred to in class as α_R. The damping should be applied to all the predicted variables as a part of each time step, but only for physical points that fall within the damping layer. The goal is to damp the perturbations toward 0, so for w, θ', and π', the form will instead be:

```
     wp(i,k) = wp(i,k) - coef*wp(i,k)
```

Note that `zu(k)` is the correct height for u and the scalars, but you should use `zw(k)` when you are working with w. For starters, set your damping layer to extend upward to the model top from `raydmpz`=12km, and use a value of `raydmpcoef` equal to 1/100 (it is unitless, so this value corresponds to the complete removal of a perturbation in 100 timesteps/applications of the filter).

2. Implement a sponge lateral boundary condition. The width of the damping zones should be 10% of the domain's total width (i.e. extending from the eastern and western boundaries to a distance of 10% of the domain's width). Remember that you will need a damping zone on both the eastern and western edges of the domain. Unlike the Rayleigh damping layer, we wish to totally extinguish any perturbations before they reach the lateral boundary. Thus, while the shape function for the damping will be the same as in problem 1 (but, of course, the function will be a cosine in x, not z), the maximal damping coefficient at the edge points will be 1 (instead of `raydmpcoef`). The damping should be applied to all the predicted variables as a part of each time step.

(Continues)

3. Rerun the warm thermal simulation from CMM assignment 4, problem 3 (including the default computational diffusion and Asselin filtering setup), but with the addition of your new damping layer and sponge lateral boundary conditions, as described above. Submit plots of θ' valid at 1200 and 2400 s, and comment on the differences that you observe (as compared to the original run).

4. Redo problem 3 again but add in a mean westerly wind of 5 m s^{-1} throughout the depth of the model domain. Submit plots of θ' valid at 1200 and 2400 s, and comment on the behaviors that you observe (both the thermal and the lateral boundary). Note that, in order to isolate the role of the wind vs. the role of the boundary condition, you may want to perform a control simulation using the original periodic boundary condition for comparison.

5. Finally, let us return to an experiment that we tried at the end of assignment 4, namely, introduction of a cold bubble. We wish to test the response of the model atmosphere to this bubble in states with different vertical stratification, and also to see what happens at our lateral sponge boundaries when perturbations with large amplitudes arrive there. To better resolve the behavior of our "outflow", we will use a higher–resolution version of the model. Use the following parameters:

· nz=82, dz=200.0 m
· nx=163, dx=200.0 m
· dt=1.0 s
· make the bubble's initial perturbation θ'=-6K
· use the sponge lateral boundary condition and Rayleigh damping layer as described above

Run the model for 2400 s in each of the following configurations:

a) the adiabatic base state
b) the Weisman-Klemp (1982) sounding from the very first CMM assignment

For both runs, you should report on the nature of the response to the cold anomaly (what is the physical process called? what is its propagation speed?) and on what happens when the disturbances get to the lateral boundary. Conclude with some summary statements on the physical part of the problem (the "sensitivity") and on the performance of the sponge boundary for various propagating phenomena. For each experiment, you should also submit a plot showing θ' contoured (or shaded) with the 2D wind vectors plotted overtop, valid 900 s into your run.