Name: ___________________________________

**ATOC/ASTR 5560 Radiative Processes — Lab 5**
September 28, 2001

The purpose of this lab is to run a broadband longwave radiative transfer model and gain an understanding of longwave radiative processes that control spectral radiances and heating rates. You will use MDTERP, which is a narrowband longwave radiative transfer model with a graphical user interface written in IDL. MDTERP has three phases of operation: 1) it sets up one or more atmospheric profiles of temperature and gas concentrations according to user input, 2) it runs the Fortran narrowband radiative transfer model, and 3) it plots the radiative transfer results using the interactive graphical interface. MDTERP was written by Bob Ellingson and Ezra Takara at the University of Maryland. MDTERP is available at `http://metosrv2.umd.edu/~ezra/MDTERP.dir/`.

Copy all the MDTERP files to your lab directory:

```
cp /home/rt/mdterp/* .
```

These include all the IDL files, the Fortran executable, and the band model and standard atmosphere input files (but not the Fortran source code).

1. First practice running MDTERP.
   Type `runMDTERP &` in a Unix terminal window. An IDL window will popup. Click on "Input data" to start the procedure for creating the atmospheric profiles. Choose one profile for practice. Click on "Input sounding data".
   Choose the "Midlatitude summer" sounding, then click on "Done" at the bottom.
   Click on "Compute results" to run the longwave radiative transfer model.
   Click on "Plot results". Use "Save text output" to save the output broadband flux and heating rate profiles to a file. Click on "Select a plot" to choose the type of plot. Explore the various plot options (we will use many of them). You can control the size of the plot with "Resize".

   The only way to save or print plots is to use "Save as", which creates a gif file. It is best to use the 640x480 size. You may wish to save your plots for later reference when completing the lab. These can be converted to Postscript by typing at the Unix prompt:

   ```
   convert plot1.gif plot1.ps
   ```

   MDTERP plots the layer heating rate values at the layer bottom altitude rather than in the middle of the layer. This causes an offset that is noticeable for the higher altitudes. The level spacing is 1 km from 0 to 20 km, 5 km from 20 to 50 km, and then there are levels around 69 and 102 km.

2. a) Plot the upwelling radiance spectrum (at $0°$) for the midlatitude summer atmosphere. Explain the differences between the upwelling radiance spectra at 0 km, 5 km, and the top of the atmosphere. Refer to Planck function curves at the temperature of the surface and current level when interpretting the radiance values. Explain in terms of the absorber distribution, spectral bands of the absorbers, and the physics of thermal radiative transfer.

   b) Plot the downwelling radiance spectrum for the midlatitude summer atmosphere. Explain the differences across the spectrum between the downwelling radiances at 20, 5, and 0 km.

3. a) Plot the spectrally integrated fluxes and heating rate for the midlatitude summer atmosphere. Plot as a function of altitude and use 49 km for the upper level so only the troposphere and stratosphere are plotted. For a different perspective, change the y-axis of the plots to pressure.

   b) Why does the downwelling flux have a change in slope around 200 mb?
   Why is the net flux slope and heating rate fairly constant from 300 to 1000 mb even though the water vapor density increases by two orders of magnitude?

   c) Save the text output and report the upwelling and downwelling fluxes at the surface, tropopause (13 km), and top of atmosphere. Calculate the integrated net flux divergence ($\Delta F_{net}$ in W/m$^2$) in the troposphere and above. Note that the total atmospheric divergence does not equal the flux emitted at the top of the atmosphere – what else is cooling, i.e. what makes the longwave flux balance?

   d) For what layer does the cooling rate peak? Explain, considering the results in c).

4. Look at the heating rate in more detail for midlatitude summer by making a Clough spectral heating rate profile plot (use an upper altitude of 49 km). Explain the variation in height of cooling across the spectrum by major absorption band. Consider the distributions of radiatively absorbing gases and the physics of longwave heating rate. Explain the major locations (wavenumber,height) of heating.

5. Now we'll look at the effect of single level temperature and water vapor perturbations on the heating rate profile. Go back to "Input data" and choose three profiles. Use an unmodified midlatitude summer for profile 1.
   For profile 2, modify the temperature (select T button under Modify). Add 5 K to the 7 km level by choosing "X=X+k", set k to 5, select "Choose levels", select "Individual", click on level 8, then "Done".
   For profile 3, modify the water vapor by doubling the value at 7 km. Use a similar procedure as for modifying temperature, but choose "X=k*X" and set k to 2.
   Run the longwave radiative transfer ("Compute results").
   Go to the plot section and "Save text output", which saves results for all three soundings.

a) Calculate the change in outgoing longwave flux at the surface and top of atmosphere for the temperature and water vapor perturbations. Briefly explain the causes of the TOA flux changes. Why does the downwelling flux at the surface barely change?

b) Plot the broadband heating rate profile of the difference between the temperature perturbed and the original sounding (plot “Sounding 2-1”). Select a altitude range from 0 to 16 km. Explain the change in the longwave heating rate profile using the flux exchange concept. It may be helpful to make a Clough spectral heating rate profile plot of the difference.

c) Plot the broadband heating rate profile of the difference between the water vapor perturbed and the original sounding (plot “Sounding 3-1”). Select a altitude range from 0 to 16 km. Explain the change in the longwave heating rate profile.

6. Now look at the effect of doubling carbon dioxide. Go back to “Input data” and choose two profiles. Use midlatitude summer for the first one. Double the $CO_2$ concentration in the second profile by selecting the “2*X” button (make sure the mass mixing ratio is correct). Run the longwave radiative transfer (“Compute results”).
   Go to the plot section and save the text output for the two soundings.

   a) Calculate the change in outgoing longwave fluxes at the surface and top of atmosphere from doubling $CO_2$. Briefly explain the outgoing flux changes.

   b) Plot the broadband heating rate profile of the difference between the doubled $CO_2$ and original sounding (plot “Sounding 2-1”). Select a altitude range from 0 to 49 km. Explain the change in the longwave heating rate profile.