Name: ______________________________________

ATOC/ASTR 5560 Radiative Processes — Lab 2
September 7, 2001

The purpose of this lab is to learn how to code multilayer thermal emission radiative transfer and understand how the resulting emergent radiance behaves. Log in to nit and copy the IDL file to your directory for this lab: `cp /home/rt/thermalrt/thermalrt.pro .` . Turn in all the plots and a listing of the IDL file along with the answers to the questions.

1. Code the brightness temperature function at the beginning of the file.

2. At the beginning of the IDL file are function definitions for upwelling and downwelling radiance calculations. We will assume the volume extinction has an exponential profile

$$\beta(z) = \frac{\tau_{tot}}{z_0} e^{-z/z_0}$$

where τ_{tot} is the total optical depth, z_0 is the extinction scale height, and z is the height above the surface. By integration this gives an an exponential optical depth profile:

$$\tau(z) = \tau_{tot} e^{-z/z_0}$$

We will also assume that the atmospheric temperature is determined from the surface temperature T_s and the lapse rate Γ:

$$T(z) = T_s - \Gamma z$$

Code the discrete multilayer thermal radiative transfer solutions for upwelling and downwelling radiance.

Test the code using $\lambda = 10.0\,\mu\mathrm{m}$, $\mu = 0.8$, $T_s = 300\,\mathrm{K}$, $\Gamma = 6.0\,\mathrm{K/km}$, $\tau_{tot} = 1.0$, $z_0 = 2.0\,\mathrm{km}$. The upwelling radiance for this case is $I_\lambda = 8.358\ \mathrm{W\ m^{-2}\ sr^{-1}}\ \mu\mathrm{m}^{-1}$ and $T_b = 289.7\,\mathrm{K}$. The downwelling radiance is $I_\lambda = 6.180\ \mathrm{W\ m^{-2}\ sr^{-1}}\ \mu\mathrm{m}^{-1}$ and $T_b = 273.2\,\mathrm{K}$.

3. a) Use section `Plotvstau` to plot zenith upwelling intensity and brightness temperature at $10.0\,\mu\mathrm{m}$ as a function of total atmosphere optical depth for three cases:
i) $T_s = 300$ K, $\Gamma = 6.0$ K/km, $z_0 = 2.0$ km ii) $T_s = 300$ K, $\Gamma = 6.0$ K/km, $z_0 = 5.0$ km
iii) $T_s = 300$ K, $\Gamma = 0.0$ K/km, $z_0 = 2.0$ km

b) Explain the dependence of radiance on total optical depth and the differences between the three cases.

c) For the first two cases calculate the heights and optical depths where the atmospheric temperature matches the brightness temperature for a total optical depth of 10. (Use IDL `print, taugrid` to find the array location `i` for $\tau = 10$ and then use `print, Tbup[i,0], Tbup[i,1]` to get the brightness temperatures).

4. a) Use section `Plotvsmu` to plot upwelling and downwelling intensity and brightness temperature at $10.0\ \mu\mathrm{m}$ as a function of direction μ for the following case:
$\tau_{tot} = 1.0$, $T_s = 300$ K, $\Gamma = 6.0$ K/km, $z_0 = 2.0$ km.

   b) List the upwelling and downwelling brightness temperatures for $\mu = 1$ and $\mu = 0.3$. Briefly explain the radiance behavior with μ. What is this effect called for the upwelling and downwelling cases?

5. a) Use section `ComputeFlux` to calculate upwelling flux by integrating the radiance using Double-Gaussian quadrature with four discrete angles per hemisphere. Compute the flux for $\lambda = 10.0\ \mu\mathrm{m}$, $T_s = 300$ K, $\Gamma = 6.0$ K/km, $z_0 = 2.0$ km with $\tau_{tot} = 1.0$ **and** $\tau_{tot} = 5.0$.

   b) For the two cases in a) find the approximate $\bar{\mu}$ that gives the same flux.