Radiative Processes in Planetary Atmospheres — Homework 3

Due: October 10, 2001

Please show your work.

1. Use the approximation for the Ladenburg and Reiche function in the notes to calculate the equivalent width of the 183.3 GHz water vapor line for two layers. The first layer (0 to 1 km in a midlatitude summer atmosphere) has $u = 1.15\,\mathrm{g/cm^2}$, pressure $p = 958\,\mathrm{mb}$, and temperature $T = 292\,\mathrm{K}$. For the first layer the line halfwidth is $\alpha = 0.0912\,\mathrm{cm^{-1}}$ and line strength is $S = 2.66\,\mathrm{cm/g}$. The second layer (12 to 13 km in a midlatitude summer atmosphere) has $u = 0.000392\,\mathrm{g/cm^2}$, pressure $p = 194\,\mathrm{mb}$, and temperature $T = 219\,\mathrm{K}$. For the second layer the line strength is $S = 4.29\,\mathrm{cm/g}$. Calculate the line halfwidth, given that the halfwidth temperature coefficient is 0.64.

   What curve of growth regime (limit) is each layer in? How close are the equivalent width formulas for these limits?

2. Show the sensitivity of band mean transmission to pressure by plotting the Goody random band model transmission as a function of pressure. Use the 400 to 500 cm^{-1} portion of the pure rotational water vapor band, for which the band model parameters at 260 K and 1013 mb are $\bar{S}/\delta = 9.0\,\mathrm{m^2/kg}$ and $\bar{S}/\bar{\alpha}\pi = 103\,\mathrm{m^2/kg}$.

   a) Graph the Goody band model transmission as a function of pressure (log scale for p from 1 to 1000 mb) for water vapor absorber amount of $u = 20\,\mathrm{kg/m^2}$ (2 cm). Assume the temperature is fixed at $T = 260$ K.

   b) Explain the change in transmission with pressure in terms of absorption line physics.

3. Band mean transmission profiles from space to height z, $\mathcal{T}(\infty, z)$, and from the surface to z, $\mathcal{T}(0, z)$, for $\mu = 0.6$ have been calculated for bands from 700 to 750 cm^{-1} and from 1000 to 1050 cm^{-1}. These transmission profiles were calculated for the midlatitude summer standard atmosphere using MODTRAN3 and are available via anonymous ftp at `ftp://nit.colorado.edu/pub/transprof3.dat`.

   a) Graph the four transmission profiles. Calculate and plot the weighting function referenced to space and referenced to the surface for both bands.
   Why are the two weighting functions for the 700 to 750 cm^{-1} band so different?

   b) Use the cooling to space approximation to compute and plot the cooling rate profiles in K/day for each band.
   Why was $\mu = 0.6$ chosen for the angle to compute the transmission?
   What absorbing gases are causing the cooling rate features? For which band do you expect the cooling to space approximation to be more accurate? Why?

4. This problem is about calculating the solar flux profile in a tropical atmosphere for 7700 to 14500 cm^{-1} (0.69 to 1.3 μm) using Fu and Liou's k-distribution. A file has been prepared with the water vapor density and k-distribution interpolated to the pressure and temperatures of each altitude level. The k-distribution weights are in the file. The file is available via anonymous ftp at `ftp://nit.colorado.edu/pub/trp_kdist.dat`.

   a) Why do some of the k's decrease with height and some increase with height?

   b) Calculate the band mean transmission and solar flux profile from 0 to 15 km in W/m^2 for solar angles of $\mu_0 = 1.0$ and $\mu_0 = 0.5$. Assume there is no reflection from the surface. For reference, the band transmission to the surface computed by MODTRAN3 for $\mu_0 = 1$ is 0.8393 for water vapor only and 0.8066 for all species.

   c) Calculate the solar heating rate (K/day) in this band for these two sun angles.