Physical Meteorology, MTR3440
Spring 2008
Homework #2
Due Wed., Feb. 20

1. Consider an idealized cloud consisting of spherical droplets with a uniform radius of 20 μm and number concentration of 1.2 cm^{-3}.
   a. How long a path through such a cloud would be required to deplete a beam of visible radiation by a factor of e (neglecting multiple scattering)?
   b. If the cloud layer were 1 km thick, what would be the optical depth at (visible wavelengths) of the layer (again, neglecting multiple scattering)?
   c. Assume that the cloud now has particles of 10 μm radius, but that the liquid water content (LWC, LWC=mass of cloud particles per unit volume) remains unchanged. Calculate the optical depth as in b.
   d. How do your answers in b and c compare? That is, for a cloud with a fixed LWC, which cloud attenuates more visible radiation? Why?

2. Calculate the radiative heating rate (in °C hr^{-1}) within the 650-500mb atmospheric layer, given the following flux densities at the top and bottom of the layer.

$F\downarrow = 780\ Wm^{-2}$	$F\uparrow = 420\ Wm^{-2}$	500 mb
$F\downarrow = 700\ Wm^{-2}$	$F\uparrow = 680\ Wm^{-2}$	650 mb

3. The Solar Radiation and Climate Experiment (SORCE, http://lasp.colorado.edu/sorce/) satellite has been making measurements of the solar input into the Earth system from low earth orbit since 2003. One of the instruments aboard SORCE is the Spectral Irradiance Monitor (SIM). SIM measures the solar spectral irradiance (i.e., the monochromatic irradiance impinging on a surface at the mean Earth-Sun distance and oriented perpendicular to the Earth-Sun direction) from 300 to 2400 nm.
   a. Using SIM data, compute the solar irradiance (normal to the surface of the Earth) in the near IR band (0.7 – 1.5 μm) at the top of the atmosphere over Denver at solar noon on Dec 21, 2007. On this day, the Earth is at 0.984 Astronomical Units (AU, 1 AU = the mean Earth-Sun distance). SIM data can be downloaded from http://lasp.colorado.edu/cgi-bin/ion-p?page=input_data_for_spectra.ion. Note that these data follow the definition of solar spectral irradiance given above. Use a program such as MATLAB, IDL, or Excel to compute your answer, and attach any relevant code or data to show your work.
   b. Water vapor accounts for most of the absorption in the near IR due to the many rotational-vibrational lines in this region. Assume that for the near IR band, a representative value for the absorption coefficient for water vapor is 0.5 $cm^2\ g^{-1}$. Determine the optical depths for water vapor in the 0-500mb and 500-840mb layers. Assume that the mean value of the mass mixing ratio is 0.1 g kg^{-1} for the upper layer and 2.5 g kg^{-1} for the lower layer.
   c. Determine the near IR band solar irradiance reaching 500 mb and 840 mb, ignoring all other mechanisms for attenuating the beam.
   d. Calculate the heating rate (K day^{-1}) in each of the two layers due to absorption of water vapor alone.