Radiative Processes in Planetary Atmospheres — Homework 1
Due: September 17, 2001

Please show your work.

1. Assume the Sun radiates as a blackbody at 5783 K and is a uniform sphere with radius 6.96×10^5 km. Calculate the broadband radiance **and** irradiance of sunlight at the orbits of Venus and Earth.

2. a) Ozone amount is measured in Dobson units. A Dobson unit is a milli-atmospheric-cm, where an atm-cm is the thickness of the gas if reduced to standard temperature (273 K) and pressure (101.3 kPa). Find the ozone amount over Boulder (latitude 40.0, longitude -105.0) on September 5, 2001 using the TOMS Web site (`http://jwocky.gsfc.nasa.gov/teacher/ozone_overhead.html`).

   Convert the total ozone in Dobson units to absorber amount in g/cm^2. Hint: a gas at standard temperature and pressure occupies 2.241×10^4 cm^3/mol.

   b) Water vapor amount is measured in precipitable cm or inches, which is the height of the column of water resulting from condensing all of the water vapor out. At 12 GMT on September 5, 2001 the Denver radiosonde recorded 0.56 inches. Convert this to absorber amount in g/cm^2.

   c) Carbon dioxide concentration is measured in parts per million by volume. There are small seasonal and geographic variations and an increasing trend, but the current value is now about 370 ppmv (as measured by the Climate Monitoring and Diagnostic Laboratory at their four baseline observatories; see `http://www.cmdl.noaa.gov/ccgg/insitu/index.html`). Convert this concentration to absorber amount in g/cm^2 above the Mauna Loa observatory (3400 m altitude, 680 mb pressure).

3. A hypothetical Mars lander probe carries a narrow field of view tracking sunphotometer operating at $\lambda = 0.5$ μm wavelength. One morning the instrument measures the following voltages as Sun rises above the horizon.

Solar Zenith Angle	Voltage
75°	1.534
70°	1.937
60°	2.435

   a) What is the aerosol optical depth at 0.5 μm?

   b) What assumptions about the atmosphere did you have to make to derive the aerosol optical depth?

4. The Atmospheric Radiation Measurement program deploys a number of Microwave Water Radiometers (MWR) at its three sites around the world. The MWR measures the zenith viewing brightness temperature at 23.8 and 31.4 GHz looking up from the ground. These two brightness temperatures are inverted to obtain the integrated water vapor and cloud liquid water mass (see http://www.arm.gov/ for more on the MWR). Assume the sky is known to be clear from lidar data, in which case the 23.8 GHz brightness temperature can be related to the integrated water vapor amount.

   a) Derive an equation for the integrated water vapor amount (g/cm^2) from the brightness temperature assuming the mean atmospheric radiating temperature T_{mr} and the mass absorption coefficient k_ν are known. Include the cosmic background, which is blackbody radiation at $T_{cb} = 2.7$ K. Use the Rayleigh-Jeans approximation, i.e. use brightness temperatures for all radiances.

   b) Calculate the water vapor amount corresponding to a 23.8 GHz brightness temperature of 64.3 K if the mean radiating temperature is T_{mr}=288 K and the mass absorption coefficient is k_ν=0.058 cm^2/g. These values are for a tropical atmosphere.

   c) Determine numerically the uncertainty in the water vapor amount from a 0.5 K brightness temperature uncertainty and, separately, from a 5 K mean radiating temperature uncertainty.