Physical Meteorology, MTR3440
Spring 2008
Homework #3
Due Wed., March 19

1. Rogers and Yau, Problem 5.1

2. The 2D-S particle probe is an instrument that can be mounted on research aircraft to take extremely high speed images of cloud particles. From these images, the particle size distribution is calculated. An average particle size distribution from the 2D-S probe taken within so-called "subvisual" cirrus can be found at http://atoc.colorado.edu/~seand/class/MTR3440/hw2prob3.xls. The data are stored in terms of # of particles L^{-1} bin^{-1}. The left column is the bin edge *diameter*. So for example, the first bin goes from 10-20 μm, and the number concentration of particles within that bin is 2.02 L^{-1}.

   a. Calculate the total number concentration (in units # cm^{-3}) from the size distribution.

   b. Assuming these particles are spheres, calculate the extinction coefficient (in units of km^{-1}). You can assume the extinction efficiency is 2. The equation for extinction is $\beta = \int Q_{ext} \pi r^2 N(r) dr$, but you will need the discrete form
   $\beta = Q_{ext} \pi \sum r^2 n(r)$

   c. Assuming these particles are spheres, calculate the ice water content (in units g cm^{-3}). Once again, you will need the discrete form of the equation for IWC, $IWC = \rho_{ice} \int \frac{4}{3} \pi r^3 N(r) dr$. I'll leave this one for you to figure out on your own.

   d. Assuming the cloud is 0.5 km^{-1} thick, calculate the optical thickness of the cloud from your answer in part b. Given that the human eye can detect things with an optical thickness of about 0.03, does this cloud qualify as being "subvisual"?

   e. Plot the dN/d(logD) size distribution on a log-log scale. What are the units of dN/d(logD)?

   f. Are there more particles of size 310 μm or 360 μm? Explain your answer.

3. Using the approximate equation for the saturation ratio 6.6 in your book, show that the critical radius, r^*, and critical saturation ratio, S^*, are given by

$$r^* = \sqrt{3b/a}$$

$$S^* = 1 + \sqrt{4a^3/27b}$$

4. Over the ocean, sea salt aerosol ($NaCl$) is generated when sea spray from breaking waves evaporates. These aerosol particles may act as cloud condensation nuclei when they are lofted to levels at or above saturation. Assume a salt particle of mass 10^{-16} g is at a temperature of 10°C.

a. What radius must the droplet attain to become "activated"?

b. If the supersaturation is 0.5%, will this droplet become activated?

5. Calculate the critical radius of a droplet of pure water at 0°C for saturation ratios of 1.02, 2.5, and 7.5