Assignment 5 Due Feb 12

1. Consider an air parcel containing $n(a) \, da$ drops $m^{-3}$ with radii between $a$ and $a + da$. The parcel is rising at constant speed $w$ and not mixing with its environment. It can be shown that

$$\frac{dS}{dt} = Aw - S/\tau_D$$

where, $w$ is the updraft velocity, $S$ is the supersaturation, and the second term represents depletion of vapor via condensation on drops.

(a) Explain the physical meaning of $A$

(b) Find $\tau_D$ in terms of droplet spectral parameters. You may ignore heat conduction terms in your expression.

(c) For total drop number concentration = 200 cm$^{-3}$ and mean radius $a = 10 \, \mu m$, estimate $\tau_D$ at $T = 10 \, C$. (the diffusivity $D_v = 2 \times 10^{-5} \, m^2 \, s^{-1}$.)

(d) Sketch $S$ as a function of height in the cloud assuming haze aerosols are rising from below the cloud.

2. Question 1 addresses the time scale associated with the change in the supersaturation field around haze aerosol that grow into activated droplets. There is an implicit assumption in this, namely that the haze aerosol activity is always in equilibrium with its environment, i.e $\rho_v(a) = \rho_v, s(a, x)$, where $x$ is the solute concentration. From the Maxwellian growth equation, calculate the time-scale for a haze droplet to adjust to its environment under a constant updraft. Under what circumstances might this time-scale be long relative to the characteristic time-scale for changes to environmental humidity $\rho_v, \infty$ in a rising air parcel? What are the implications to the atmosphere? For $a < 5 \, \mu m$, you should assume an approximate value for the effective diffusivity of $D_v = 5a$, where $a$ is the droplet radius in meters.

3. Read the paper by Korolev and Mazin 2003 Supersaturation of water vapor in clouds. Describe the major physics discussed in Sections 5 and 6 about mixed-phased clouds. What are the possible implications of these results to real clouds? In particular think about altocumulus clouds as described by Hobbs and Rangno 1985.