Physical Meteorology, MTR3440
Spring 2008
Homework #4
Due Wed., April 9

1. Consider an activated cloud droplet with a radius of 1.5 μm in a cloud that is at 700 mb and 10°C, with a saturation ratio of 1.005.
    a. How long (in days) would it take this droplet to grow to be a precipitation-sized droplet 1 mm in radius (Hint: Use Figure 7.1, R&Y)? Given this amount of time, do you expect that condensational growth can account for the formation of precipitation in clouds?
    b. How long would it take this droplet to grow to a radius of 20 μm? For particles around 20 μm, the collision-coalescence process starts to be an efficient mechanism for particle growth. Does the time for the drop to grow to 20 μm make you think that the precipitation will be able to form in a reasonable amount of time?

2. A drop with an initial radius of 100 μm falls through a cloud containing 100 droplets per cubic centimeter that it collects in a continuous manner with a collection efficiency of 0.8. If all the cloud droplets have a radius of 10 μm, how long will it take for the drop to reach a radius of 1 mm? You may assume that for the drops of the size considered in this problem the terminal fall speed v (in m s^{-1}) of a drop of radius r (in m) is given by $v = 8 \times 10^3\, r$. Assume that the cloud droplets are stationary and that the updraft speed in the cloud is negligible.

3. If the raindrop in the question above exits the cloud base, which is located 5 km above the ground, what will be its radius at the ground and how long will it take to reach the ground if the relative humidity between cloud base and ground is constant 60%? To calculate this, you will use the growth equation, assuming $\xi_1 = 700\ \mu m^2\ s^{-1}$. Use the equation in problem 2 for the terminal velocity.

4. In this problem, you will estimate the mass of precipitation between the ground and cloud base (per unit surface area on the ground), assuming a cloud with a base 5 km above ground. To do this, consider a 1 m^2 patch of ground. Imagine you are watching this patch during a rainstorm. Based on your experience, how many drops per second will hit this patch? This number gives you the "flux" of raindrops, in # m^{-2} sec^{-1}. You will then divide this number by the terminal velocity of the raindrops (look it up in a table, using a reasonable size for raindrops) to obtain the concentration of raindrops per unit volume (# m^{-3}). Using an appropriate size for raindrops, convert this concentration to a LWC (g m^{-3}). Finally, multiply this by the volume of air (between the ground and cloud base) per unit surface area on the ground (units of this are m^3 m^{-2}). This final number is the mass of precipitation between you and the cloud, per unit surface area on the ground (g m^{-2}). How does this mass compare to the mass of air above you? To do this you will need to calculate the mass of atmosphere per unit surface area (g m^{-2}).