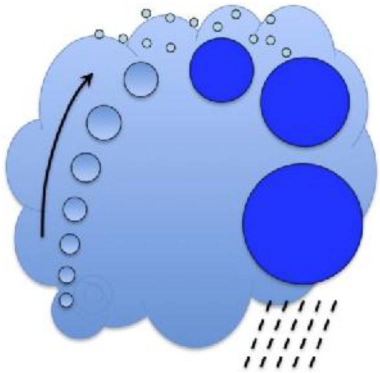
Cloud Physics Lab
LAB 9: Precipitation Growth by Collision-Coalescence

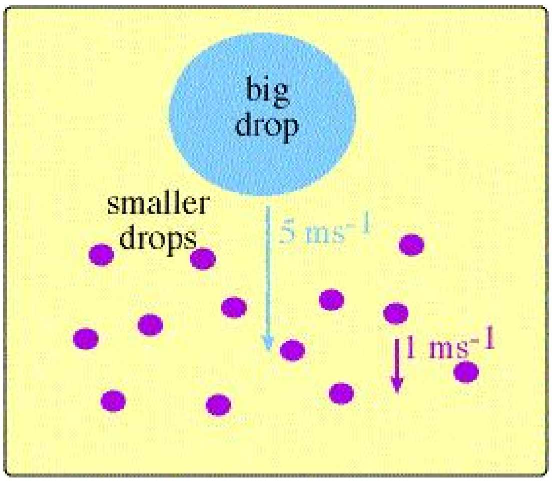
Purpose:

Study the growth precipitation by collision-coalescence process

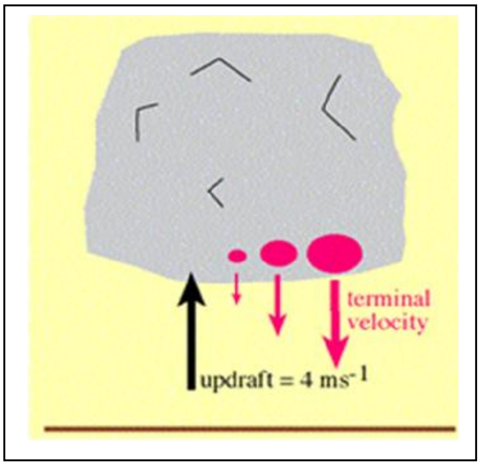
Theory:



- Collision/Coalescence - cloud droplet growth by collision
- This is a dominant process for precipitation formation in warm clouds (tops warmer than about -15°C)
- Some cloud droplets will grow large enough and will start to fall in the cloud
- Since the bigger drops fall faster than the smaller drops, they will "collect" the smaller drops - the bigger drop grows
- Droplet fall speed is called its terminal velocity
- Need droplets of different sizes for this process to really work



What determines the droplets fall speed relative to the ground?
Answer: droplet size and updraft strength



Given a growing cu with an updraft strength of 4 m/s:

if the particle terminal velocity is -2 m/s,
the particles fall speed is: 2 m/s upward

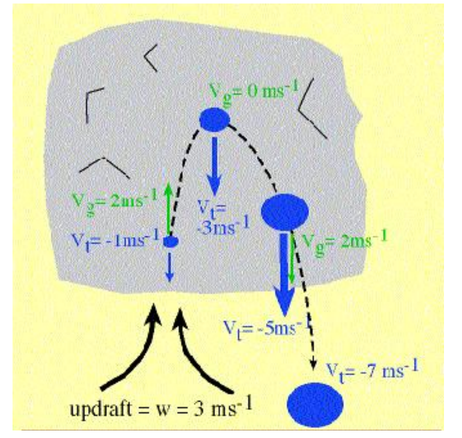
if the particle terminal velocity is -4 m/s,
the particles fall speed is: 0 m/s drop remains suspended

if the particle terminal velocity is -6 m/s,
the particles fall speed is: 2 m/s downward

Life cycle of a droplet

The drop initially forms in the updraft of the cloud near cloud base

It grows in size by collisions



since $V_g = U + u$

V_g = ground relative fall speed of the drop

U= updraft velocity

u = drop's terminal velocity

then the drop will begin to fall when u >U

The Growth Equation is:

$$\frac{dR}{dt} = \frac{EM}{4\rho_L} u(R) \qquad (1)$$

where E is the collection efficiency, M is the cloud liquid water content, ρ_l is the water density, and $u(R)$ is the cloud droplet terminal velocity.

From the chain rule this can be written as:

$$\frac{dR}{dz} = \frac{dR}{dt}\frac{dt}{dz} = \frac{EM}{4\rho_L}\frac{u(R)}{U - u(R)} \qquad (2)$$

where U is the velocity of the updrafts.

Methodology

Assuming that updrafts velocity is very small and equal to 0 then equation (2) becomes:

$$\frac{dR}{dz} = -\frac{EM}{4\rho_L} \tag{3}$$

Integrate this equation the final radius of cloud droplet as it emerges from cloud base:

$$\int_{R_o}^{R_f} dR = -\frac{EM}{4\rho_L}\int_{Z_T}^{0} dz \tag{4}$$

$$R_f - R_o = +\frac{EM}{4\rho_L}(Z_T - 0) = \frac{EM}{4\rho_L}\Delta z \tag{5}$$

$$R_f = \frac{EM}{4\rho_L}\Delta z + R_o \tag{6}$$

To find the time taken by the droplet to fall through the cloud integrate equation (1) assuming $u(R) = kR$, where k $=3\times10^8$.

$$\frac{dR}{dt} = \frac{EM}{4\rho_L}kR \tag{7}$$

$$\int_{R_o}^{R_f} \frac{dR}{R} = \frac{EM}{4\rho_L}k\int_{0}^{t} dt \tag{8}$$

$$\ln\frac{R_f}{R_o} = \frac{EMk}{4\rho_L}\Delta t \tag{9}$$

$$\Delta t = (\ln\frac{R_f}{R_o})\frac{4\rho_L}{EMk} \tag{10}$$

The matlab script *lab9.m* calculates the final radius of the cloud droplet as it emerges from the cloud base and the time taken by the drop to fall through the cloud for given Collection efficiency, cloud thickness, and initial radius of cloud droplet.

Use this program to conduct the following cases:

1. The effect of the initial radius of the cloud droplet (assume M=0.5, Δz = 2 km, and E=1):

R_o (mm)	R_f (mm)	Δt (min)
0.05		
0.1		
0.2		
0.3		

2. The effect of the cloud liquid water content (assume Ro=0.1 mm , Δz= 2 km, and E=1):

M(g/m^3)	R_f (mm)	Δt (min)
0. 5		
1		
1.5		
2		

3. The effect of the cloud thickness (assume R_o=0.1 mm, M=0.5, and E=1):

Δz	R_f (mm)	Δt (min)
1		
2		
3		
4		

4. The effect of the collection efficiency (assume R_o=0.1 mm, M=0.5, Δz= 2 km):

E	R_f (mm)	Δt (min)
0.5		
0.7		
0.8		
1.0		

5. Discuss your results