Cloud Physics Lab

LAB 11: Growth of Ice Crystals II

Growth by Aggregation

Introduction:

Diffusional growth of ice crystals is faster than diffusional growth of water droplets. Unlike diffusional growth of water droplets, diffusional growth of ice crystals can explain how very small precipitation consisting of single crystals (the frozen equivalent of drizzle) can form. In order to get larger precipitation such as snowflakes or graupel, additional processes such as *aggregation* or *accretion* are still required. In this lab, student will explore the growth of ice crystal by aggregation.

Objective:

a) Plot and study the growth of ice crystal aggregation for different ice contents.
b) Plot and study the growth of ice crystal aggregation for different collection efficiencies.
c) Plot and study the growth of ice crystal aggregation for various differences between speeds of large and small crystals.

Theory:

Aggregation is the frozen equivalent of collision-coalescence. Larger crystals fall and overtake smaller crystal, which then stick to the larger crystal. This can be described by an equation similar to that, for collision-coalescence,

$$\frac{dm}{dt} = \overline{E} M_{ice} \pi R^2 \left(u_L - u_s \right) \tag{1}$$

where m is the mass of the ice crystal, over bar E is the average collection efficiency, M_{ice} is the mass of ice contained in the small crystal, R is the effective radius of large crystal, u_L is the fall speed of the large crystal, and u_s is the fall speed of the small crystal.

Assuming a spherical snowflake, so that:

$$m = \frac{4}{3} \pi R^3 \rho_{ice} \tag{2}$$

From equations (1) and (2) it can be shown that:

$$\frac{dR}{dt} = \frac{\overline{E} M_{ice}}{4 \rho_{ice}} (u_L - u_s) \tag{3}$$

Integrating equation (3) results in:

$$R_f = R_o + \frac{\overline{E} M_{ice}}{4 \rho_{ice}} (u_L - u_s) \Delta t \tag{4}$$

Materials and Procedures:

1. Run the Matlab script **Lab11a.m** to plot the growth of ice crystal by aggregation for different ice contents.
2. Run the Matlab script **Lab11b.m** to plot the growth of ice crystal by aggregation for collection efficiencies.
3. Run the Matlab script **Lab11c.m** to plot the growth of ice crystal by aggregation for various differences between speeds of large and small crystals.

Analysis and Conclusions:

1. Use figure 1 to describe how the ice content can affect the crystal growth by aggregation.
2. Use figure 2 to describe how the collection efficiency can affect the crystal growth by aggregation.
3. Use figure 3 to describe how the differences between speeds of large and small crystals can affect the crystal growth by aggregation.

Questions:

1. By completing this Lab, what did you learn about the growth of ice crystal by a aggregation?
2. Explain why the results you obtained show that the crystal growth by aggregation is always linear.
3. From your results can you determine the most effective parameter in the crystal growth by aggregation
4. Derive equation (4).