Mechanism and Forms of Precipitation

Part II (1+1+1 System) Geography Hons.
Paper: IV
Module: V
Topic: 3.2

Mechanism of precipitation

1. Bergeron-Findeisen Process

The Bergeron-Findeisen process is based on two facts.

(a) Co-existence of water vapour, ice crystals and super cooled liquid water droplets, and

(b) Different values of saturation vapour pressure.

In cold clouds, where the ambient temperatures are below freezing point, the condensation products can be both liquid water and ice crystals. Below - 40°C all the products are ice crystals and all the cloud is said to be glaciated. Between 0°C and - 40°C water and ice coexist giving a mixed cloud.

The Bergeron-Findeisen Process is concerned with the growth of raindrops out of mixed clouds. In mixed clouds, the initial growth phase depends on the co-existence of ice and water.

The super cooled water droplets freeze when –

(i) they are disturbed or

(ii) they come into contact with a freezing nuclei .

The nuclei that form water droplets far outnumber the nuclei that form ice crystals so at cloud temperatures above - 20°C, (the activation temperature for many deposition nuclei), super cooled water droplets are initially much more abundant than ice crystals. In fact, single ice crystals may be surrounded by thousands to hundreds of thousands of super cooled water droplets. Thus, when ascending air currents rise, the temperature in the ascending air currents drops well below - 20°C and the super cooled droplets freeze. This single ice crystal has the capability to change the whole of the cloud to an ice cloud. This is because the saturation vapour pressure over ice is lower than over water at the same temperature. This means that when air is saturated with respect to water, it is super saturated with respect to ice. At a temperature of - 10°C this vapour pressure translates into a relative humidity of 100 per cent (saturation) for the air surrounding water droplets and a relative humidity of 110 per cent (super saturation) the air surrounding ice crystals. In response to super saturated conditions water vapour migrates towards ice crystals and deposition starts on ice crystals (sublimation nuclei) and the ice crystals grow and collect together to form snowflakes. Deposition removes water vapour from the clouds and thereby, lowers the relative humidity. The relative humidity of the air surrounding water droplets goes below 100 per cent and the droplets vaporise. Under these conditions snowflakes grow at the expense of super cooled water droplets. In addition, the growing ice crystals may come into contact with super cooled liquid water droplets, which will freeze onto or around the crystals immediately in contact. This type of growth process is known as riming. Riming is a primary mechanism of hail formation.

As the crystals grow larger and heavier, they begin to fall. These falling ice crystals also increase in number because small splinters become detached from large dendritic crystals and act as fresh nuclei. The whole process is thus repeated again. If the air temperatures are below freezing point, most of the way to the ground, the crystals reach the earth surface in the form of snowflakes. If the air below the cloud is above freezing point, snowflakes melt and reach the ground as water droplets.

However, the process may not always operate. Rain in tropical regions is observed from clouds only about 2 km deep, where at the top of the cloud, the temperature is above 0°C. In these conditions, it is impossible for ice crystals to develop for Bergeron-Findeisen process to operate.

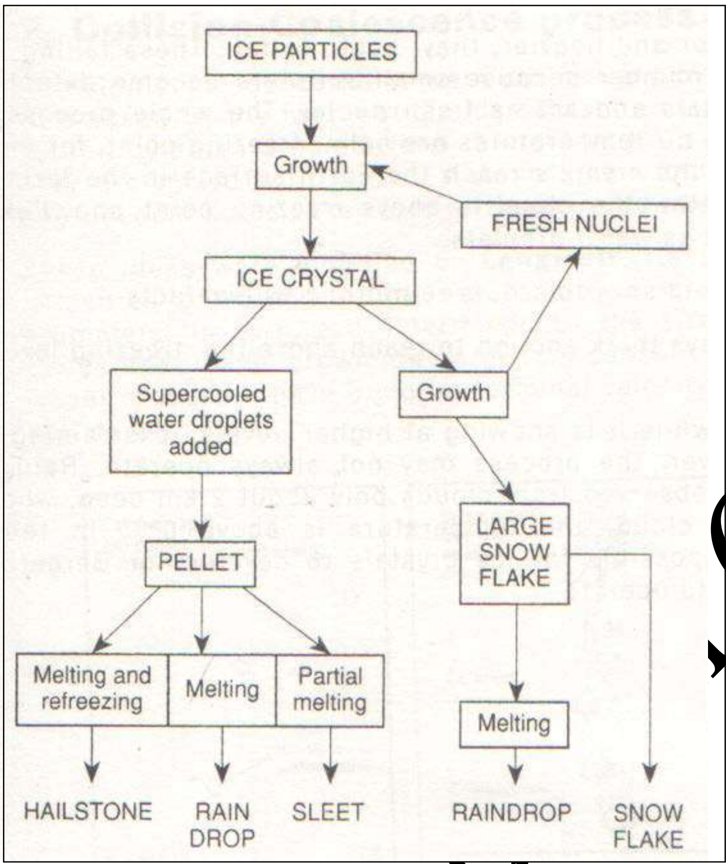

Fig. 1: Bergeron-Findeisen process

2. Collision-Coalescence process

Collision coalescence ideas were put forward by George Simpson and Mason. It is based on the fact that clouds contain a variety of sizes of water droplets. Uniformly small droplets tend to move at the same speed in the cloud but if they are mixed with larger, slow moving droplets that have formed around hygroscopic nuclei, then this will encourage collisions and amalgamations.

These ideas were modified by Langmuir. He pointed out that the terminal velocities of falling drops are directly related to their diameters. These diameters, in turn, are determined by the size of the condensation nuclei. Drops that have grown on large condensation nuclei become larger. The larger drops will have a higher terminal velocity than the smaller ones and so collide with them.

Raindrops or ice crystals often stick after colliding and thus, grow in finite steps, i.e., collide and coalesce. The larger drops then fall faster, as they overcome air resistance more easily. By falling faster, they are able to catch up even more rapidly with other droplets and crystals so that the larger they grow, the faster they grow. For collision to occur, several conditions are necessary.

(a) The smaller droplets must be close to the axis of fall of larger drop, otherwise it will follow the air currents around the falling drop and there will be no impact. As the larger droplets descend, they produce an air stream, a miniature air current that blows the small particles out of their path, i.e., smaller drops are swept away.

(b) Colliding ice crystals bounce off each other when they are plane in shape and dry and cold. In other words, colliding droplets may bounce away from each other as there is little surface tension.

(c) Even with collision, growth will only occur if the two drops coalesce. This will occur most readily if

(i) the drops are of considerably different sizes, and

(ii) atmospheric electricity is present to hold the droplets together. If a droplet with a negative charge should collide with a positively charged droplet, their electrical attraction will bind them together.

Continued collision, thus, leads to coalescence resulting in many large unstable drops which on further disruption produce several large drops and its continued coalescence and further disruption leads to many larger drops.

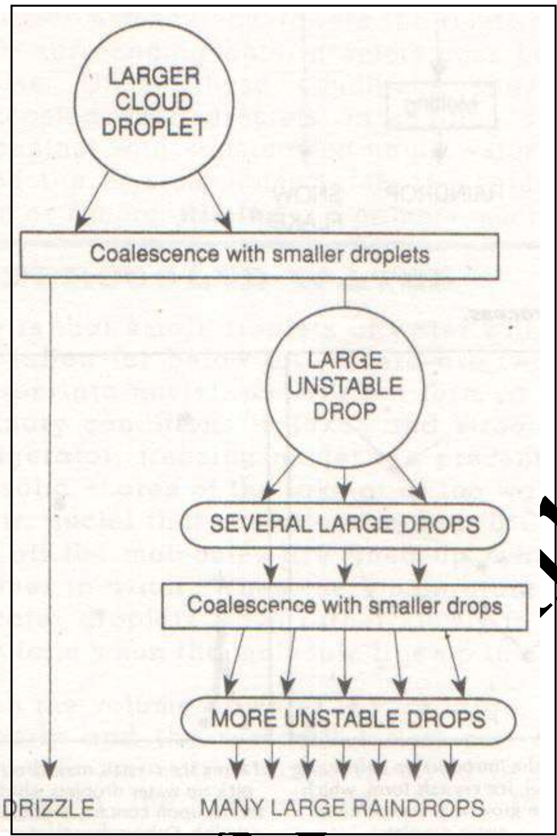

Fig. 2: Collision-Coalescence process

Forms of precipitation

Precipitation includes all forms of water particles that fall to the ground (Fig.3).

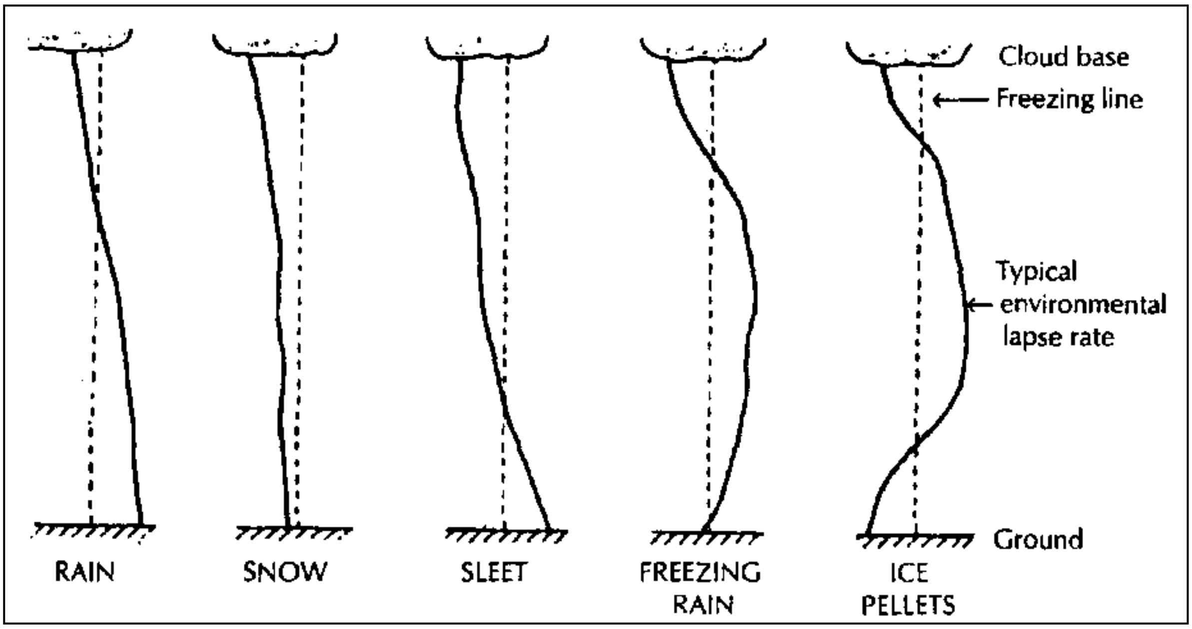

Fig. 3: Types of precipitation

Drizzle: Drizzle consists of small rain drops from 0.2 to 0.5 mm in diameter that drifts very slowly towards the ground. The amount of precipitation resulting from drizzle is very small, accumulating at most at the rate of 1 mm/hr.

Rain: Rain is the name given to all liquid precipitation other than drizzle. Most rain drops originate as snowflakes and melt on their way down as they encounter air that is above 0°C. Because rain originates in thicker clouds having higher bases, raindrops travel farther than drizzle and undergo growth. When the diameter increases more than 5 mm, the drops tend to break up.

Snow: Snow is the general name for precipitation of opaque and semi-opaque ice crystals in the form of individual crystals, small pellets or flakes formed by aggregation of crystals. Snow begins as ice crystals that form a cloud when water vapour freezes around minute solid particles in the middle and upper levels of the atmosphere, where the temperatures are well below 0°C. The individual ice crystals gradually bound, forming snowflakes. Once the snowflakes are heavy enough, they fall on the ground. Ice crystals form in a vast array of shapes depending on the temperature and humidity of the surrounding air mass. The ideal condition for snow temperatures is close to and just below zero, rather than colder temperatures. This is because the warmer the snow, the more moisture it will contain, and hence, the bigger flakes will be; and because a temperature close to 0°C will allow the snow to melt, they refreeze and combine in larger flakes. A combination of heavy snow and strong winds causes blizzards. An associated phenomenon is white-out, when heavy snow and low clouds by multiple reflections render the ground and sky indistinguishable.

Freezing rain: In wintry conditions, when temperatures at cloud level are below zero, any water droplets that fall from clouds will be super cooled. This means that they are likely to freeze as soon as they encounter a colder layer of air or a surface whose temperature is below 0°C. Precipitation that freezes in either of these ways is called freezing rain. The greatest associated hazard with freezing rain is accretion of ice on aircraft and boats. If an aeroplane flies through a super cooled cloud, ice will quickly form on its body and wings.

Ice pellets: Ice pellets (in Australia and the United Kingdom), also called sleet, are actually frozen rain drops. They freeze when falling from warm mass of air through a cold layer. They develop in a manner similar to freezing rain; the only difference is that the surface layer of the air is so deep that the rain drops freeze before striking the ground. Sleet is different from freezing rain in that sleet bounces when it strikes the ground and freezing rain does not.

Glaze: When large super cooled droplets strike sub-freezing ground, they tend to spread out on impact before freezing, coating the surface with a layer of clear ice known as glaze. This type of ice can produce hazardous conditions making it very difficult to walk or drive. Once formed, glaze can thaw quickly or even persist for days. The accumulation of glaze on exposed objects, as a result of an ice storm can cause significant structural damage, and has been known to bring down overhead wires and tree branches.

Hail: Hail is rounded or jagged lump of ice having concentric layers like an internal structure of onions. Hail develops within intense thunderstorms as strong convection currents transport ice pellets upwards, into the middle and upper reaches of a thundercloud. Along the way, the ice pellets grow by collecting super cooled water droplets. Finally, the hailstones become too heavy to be supported by convective updrafts and fall to earth. Hail stones are large enough to survive the trip to the ground as ice, even though surface temperatures are well above freezing point.

Snow pellets: Snow pellets are white opaque spherical particles of ice less than 1cm in diameter. They are crunchy and crushed easily in contrast to ice pellets and hail, which are hard ices.

Rime: When very small super cooled droplets strike subfreezing ground they tend to freeze immediately on impact, trapping air between them. Thus, rime accumulates as deposit of opaque, white, rough textured ice crystals. Rime ice builds up most rapidly in cool humid conditions on surface exposed to the wind. It can accumulate as large cauliflower-shaped growths.