Precipitation

There are many types of precipitation: rain, snow, sleet, and hail, to name a few. In this lesson we will learn about the mechanisms that produce various types of precipitation. It is important to note that the presence of clouds and their associated condensation nuclei alone do not always produce precipitation. Very specific conditions must occur in order for a cloud to produce precipitation.

In order for cloud droplet to form a non-equilibrium condition, where condensation exceeds evaporation, must exist. The curvature of a cloud droplet affects its rate of evaporation. The more curved the droplet, the more evaporation that occurs. Smaller cloud droplets will evaporate quickly unless the air is *supersaturated* (the relative humidity exceeds 100%). Because of the curvature effect, air that is saturated with respect to a flat surface is unsaturated with respect to a curved cloud droplet. An ordinary cloud droplet 100 times smaller than raindrop.

Though super saturation is required in order for cloud droplets to sustain themselves, relative humidity rarely approaches 101%, even in very wet clouds. How do cloud droplets ever grow to raindrop size? The answer lies in the *hygroscopic* nature of certain condensation nuclei. Recall that condensation on hygroscopic particles will commence when the relative humidity is below 100%. This is known as the *solute effect*.

Consider a parcel of air unsaturated air rich with condensation nuclei. As the air cools the relative humidity increases. At some point below 100% saturation, condensation commences on the most hygroscopic of the available nuclei. These nuclei continue to grow as the air cools further and the relative humidity approaches 100%. The curvature effect becomes negligible for larger droplets but

remains appreciable for smaller nuclei. The rise in relative humidity within the air mass is slowed by the fact that the larger particles begin to remove lots of water vapor from the air. Soon, the particles are removing water vapor from the air as fast as it can be replaced from external sources. At this point the relative humidity actually begins to decrease. Condensation in clouds is such an inefficient precipitation producing process that it is very unlikely to produce, by itself, precipitation in any appreciable amount. Another mechanism is clearly responsible for producing precipitation from clouds.

Two additional mechanisms are responsible for producing precipitation from clouds the *collision-coalescence process*, and the *ice-crystal process.*

The collision-coalescence process occurs in warm clouds. As cloud droplets form within clouds they become electrically charged. The cloud droplets grow larger by sticking to each other in the aftermath of collisions due to electrical attraction. As time passes the droplets grow larger and larger. Updrafts help keep the droplets suspended in the cloud longer. If the cloud is thick the droplets will also stay suspended longer. Finally, the droplets will grow large enough that they can no longer remain suspended and will begin to fall. As soon as they leave the cloud base they begin to shrink due to evaporation. Raindrops that reach the ground are smaller than those leaving the base of the cloud.

The ice-crystal process occurs in colder clouds that exist mainly in the middle to high latitudes. Even in these extremely cold clouds there are liquid water droplets (existing well below freezing). These are referred to as *super cooled* water droplets. The temperature of a cloud, in fact, must exceed -40°C in order for it to consist entirely of ice crystals. Such clouds are referred to *glaciated*.

When the temperature drops low enough within a cloud, large numbers of water molecules begin to bond in a rigid form within super cooled liquid water

droplets. This leads to the formation of *ice embryos*, i.e., small ice crystals in the center of super cooled water droplets. The water molecules must have very low rms speeds in order for ice embryos to remain intact since even slight thermal motions disrupt them. Even colder temperatures enable the crystal to become a *freezing nucleus*. The presence of these ice embryos enhances the freezing process. The presence of *ice nuclei* also enhances the freezing process. Ice nuclei may be clay (kaolinite), biological material, or anything that looks like an ice crystal. *Contact freezing* is another important method by which ice crystals to form in a cloud, involving collisions between ice nuclei (freezing nuclei) and super cooled droplets.

Precipitation Types

As we have seen, when precipitation first begins to fall it is usually in a frozen state. Often precipitation begins in the form or either *graupel* or *snowflakes*. Snowflakes are an aggregation of ice crystals. Much precipitation falling at middle latitudes, even in mid-summer, falls as snow flakes in the beginning. Graupel is formed by collisions between super cooled cloud droplets and ice crystals.

In a precipitation theory known as the *Bergeron Process* all raindrops begin as ice crystals. When the ratio of ice crystals to water droplets in clouds is on the order of 1 : 100,000, conditions are right for precipitation to begin. When there are too few ice crystals, the existing crystals grow large and fall out of the cloud, leaving it unaffected. When there are too many crystals, a cloud of ice crystals is formed, and no precipitation occurs because the individual crystals are all too small to fall to the ground.

Cloud seeding is an important process used quite often in the winter to create precipitation. The object is to find clouds that are deficient with ice

crystals and inject artificial ice nuclei to produce the ratio of 1 : 100,000. (Silver iodide is usually the artificial ice nuclei used because it resembles an ice crystal so well.) A cold cloud is needed for this to work effectively. We will study cloud seeding in detail in a later exercise.

Rain is liquid drop precipitation with diameter greater than or equal to 0.5mm. *Drizzle* is a liquid drop with diameter less than 0.5mm. *Virga* is precipitation that doesn't reach the ground. If updrafts in a cloud change to downdrafts rainfall amount may increase to a *shower*. If a shower is excessively heavy it is referred to as a *cloudburst*.

Snow consists frozen ice crystals falling to the ground. Because snow scatters light more effectively than rain one may easily observe where snow changes to rain below a cloud (above the freezing line is darker). If, however, one looks directly up into the precipitation from below the snow appears lighter because it scatters light in all directions below the cloud. As a result the bottom of a rain cloud appears much darker than a cloud with snow in it. *Fall streaks* are a virga-like phenomenon consisting of snow rather than rain. *Flurries* are brief snow showers, typically from cumuliform clouds. A *snow squall* is a more intense snow shower, essentially the equivalent of a cloudburst. Continuous snowfall is associated with nimbostratus and altostratus clouds. A *blizzard* is a snowstorm accompanied by low temperatures, strong winds, blowing and drifting snow.

Sleet is melted snow that re-freezes into a tiny ice pellet. *Freezing rain* occurs when raindrops fall through a freezing layer that supercools them and subsequently freeze on contact with the ground. *Freezing drizzle* is freezing rain with drop diameters less than 0.5mm. *Rime* is an accumulation of small, supercooled cloud droplets that are milky and granular in appearance. *Snow grains* and *snow pellets* are the solid equivalent to drizzle. Snow grains have a diameter of less than

1mm and stick upon hitting a surface, while snow pellets have diameters of greater than 5mm and bounce upon hitting a surface. *Hail* is produced when large, frozen raindrops, graupel, etc. act as accretion nuclei. In order for a hailstone to form, the accretion nuclei must remain in a cloud a long time and thus travel a large distance within the cloud. This process is facilitated by strong updrafts of the type common within cumulonimbus clouds. Hail is most often associated with such clouds and is therefore more common during the spring and summer than in winter. *Hail streaks* are long narrow bands of land struck by hail as the precipitating cloud moves along.