Condensation: Dew, Fog, and Clouds

Formation of Dew and Frost

As we have already learned, objects near the ground cool rapidly at night through emission of infrared radiation. The ground and objects near the ground are often much cooler than the surrounding air. Air in contact with these objects cools by *conduction*, eventually reaching the dew point. As water vapor condenses on these surfaces *dew* begins to accumulate. Dew evaporates rapidly in dry climates or windy conditions. Dew is most likely to form on calm clear nights where infrared radiation is at a maximum and movement of chilled air away from the ground is at a minimum.

Frost forms when the dew point temperature is below freezing (a.k.a. *frost point*). When the air temperature cools to the frost point, and further cooling occurs, water vapor can change directly to ice without becoming a liquid first in a process known as *deposition.*

Condensation Nuclei

Just as dew and frost need a surface upon which to condense, there must be airborne particles upon which water vapor can condense to produce cloud droplets. As noted in the last chapter, particles known as *condensation nuclei* fulfill this role. Condensation nuclei provide surfaces upon which water vapor can condense to create cloud droplets. Condensation nuclei are very small (about 0.2 – 10.0 microns) particles light enough to remain suspended in the air. Condensation nuclei are formed from a variety of sources including dust, pollen, smoke, salt from ocean spray and sulfates, produced by phytoplankton, in marine environments.

There are two broad categories of condensation nuclei: *hygroscopic* and *hydrophobic*. Hygroscopic nuclei are "water seeking" nuclei. Water vapor condenses on hygroscopic surfaces readily even when the relative humidity is considerably lower than 100 percent. Salt is an example of a hygroscopic particle. Hydrophobic nuclei are water repelling. Water vapor will condense on hydrophobic surfaces only at relative humidity's greater than 100 percent, and even then with great difficulty. Examples of hydrophobic nuclei are oil, gasoline, and paraffin wax. Since air usually has a mixture of both hygroscopic and hydrophobic nuclei, condensation usually occurs at relative humidity of less than 100 percent.

Haze

Haze forms when a layer of dust or salt particles is suspended in the air. In areas where haze regularly forms, visibility is enhanced when relative humidity is low because less condensation occurs on the haze particles. This keeps the particles relatively small even as the number of haze particulates remains constant. As air cools the relative humidity increases. In such an environment, when the relative humidity reaches about 75 percent, condensation begins producing a *wet haze*. As water collects on the available nuclei, their size increases to the point that they become effective scatterers of light, thus producing haze.

Fog

When relative humidity nears 100 percent, haze particles grow larger and condensation occurs on less active nuclei. When visibility diminishes to < 1 km, *fog* occurs. As fog droplets increase in size they begin to settle toward the ground. This process is fairly rapid (approx. 5 cm/sec). How then, is fog maintained? Fog forms when air is either cooled (cooled below its saturation or dew point) or by evaporation and mixing (water vapor enters the air by evaporation and the moist air

mixes with relatively dry air). Once fog forms it is maintained by the continuous formation of new fog droplets on fresh condensation nuclei that replace those settling to the ground, as long as the cooling/mixing mechanism is also maintained.

Radiation or Ground Fog is a fog produced by the earth's radiational cooling. It forms best on cold, clear nights where a relatively thin layer of moist air close to the ground is overlain by drier air. The moist, shallow layer does not absorb much of the outgoing infrared radiation. The ground and the air directly above it cool rapidly, creating a surface inversion. The moist, lower layer quickly becomes saturated by this rapid cooling and fog forms. Radiation fogs are most common in late fall and winter due to long nights (allows for longer cooling time) and cool air. A light breeze of less than five knots enhances the formation of radiation fog. This occurs because the slight breeze brings more moist air in contact with the cool ground, thus cooling the moist air layer more efficiently. A strong breeze squelches this process by mixing the moist surface air with the drier air above.

You may have noticed that fog tends to dissipate or "burn off" after the sun has been up for a short while. This occurs because some sunlight penetrates the fog and begins to warm the ground thus disrupting the fog creating cycle.

Advection fogs form as the result of wind moving moist air from above a warmer surface to a region above a cooler surface. The moist air cools to its dew point after coming in contact with the cooler surface producing fog. Advection fogs are typical in most coastal regions. During summer months, moist air is carried by the wind from warmer waters (near the surface) offshore. When this warm air reaches cooler surface waters near the coasts the air cools and condenses creating a fog. Advection fogs often provide an important moisture source for surrounding biological systems in coastal regions.

Upslope fogs form when moist air flows upslope in mountainous regions. With

this upward movement the air cools to its dew point causing condensation and fog formation. Upslope fog is common on the eastern side of the Rocky Mountains. Upslope fogs can persist for many days in some regions.

Evaporation or Mixing fog is the mixing of two unsaturated air masses to produce a fog. If moist air meets and mixes with cooler air resulting in saturation, a fog forms. Mixing fogs are common in ski areas during times of rainfall. As rain falls onto the snow it begins to melt. The melting process extracts heat from the surrounding environment, including the air close to the ground. For readily forms in the cool, rain-saturated air. When you breathe condenses in front of your face on a cold morning you are staring at another example of a mixing fog.

Foggy Weather

In the U.S., heavy fog is more prevalent in coastal regions than in the center of the continent. Three major regions stand out as having the most days with heavy fog:

1. Pacific Coast region
2. Appalachian Highlands
3. New England region

Fog often causes poor visibility. Driving from a clear area into fog on a major freeway can be extremely dangerous. This problem is exacerbated when driving at night with high-beam lights on. This is because the light from lamps is reflected backward by the fog droplets. It is much better to use low beams in this situation to change the angle of the reflected light away from the level of the driver's eyes. People who frequently drive in foggy areas often install fog lamps. Fog lamps direct light downward toward the road surface. In addition to solving the reflection

problem, fog lamps illuminate a drier layer of air that typically exists within a foot or so of the road providing better visibility.

Be sure to view the Photo Gallery cloud photographs.

Clouds

There are ten basic types of clouds categorized by both their appearance and their height above the earth's surface. The four major cloud groups are *high*, *middle* and *low* clouds, and clouds with *extensive vertical development*.

High Clouds

High clouds generally form above 6000 m. Because the air is cold and dry, high clouds are composed almost exclusively of ice crystals. These clouds also tend to be very thin. *Cirrus* (Ci) clouds are the most common of this group and can be blown into long, wispy streamers often called mare's tails. Cirrus clouds have little vertical development.

Cirrocumulus (Cc) clouds are an infrequently seen type of high cloud. These clouds can occur individually or in long rows and often have a "rippled" appearance. This rippling looks like fish scales in the sky and the appearance of Cc clouds is sometimes referred to as a *mackerel sky*. These clouds are composed mainly of ice crystals and have little vertical development.

Cirrostratus (Cs) clouds are common high clouds that have a sheet like appearance. Cs clouds have varying vertical development and are cold and dry. Thick cirrostratus clouds indicate impending bad weather.

Halos are usually associated with cirriform clouds

Middle Clouds

Middle clouds have bases between 2000 and 7000 m. These clouds are composed of water droplets and ice crystals (if temperature is low enough). *Altocumulus* (Ac) clouds are puffy and can be found in varying shades of gray. They are mostly water droplets and have moderate vertical development.

Altostratus (As) clouds are a combination of water droplets and ice crystals that are gray to blue gray in color. Altostratus clouds usually block out a majority of sunlight light and result in gray, dreary days.

Low Clouds

Low clouds, with their bases lying below 2000 m, are almost always composed of water droplets. The *Nimbostratus* (Ns) clouds are dark gray and are associated with continuously falling rain or snow. Nimbostratus clouds can occupy the entire sky and have moderate vertical development. Ns clouds are associated with stratus, fractus, and scud clouds.

Stratocumulus (Sc) clouds are low, rounded, and "lumpy" with small patches of blue sky in between. These clouds are much larger elements than altocumulus but are not associated with precipitation.

Stratus (St) clouds are typically a uniform grayish color covering over the entire sky. These clouds are often mistaken for a fog, but they do not touch the ground. They may be associated with small amounts of precipitation such as a drizzle, but do not produce larger precipitation.

Clouds with Large Vertical Development

The puffy, "floating cotton" appearance of the *cumulus* (Cu) cloud is a common sight. These clouds can be distinguished from a stratocumulus cloud by the large amounts of sky visible between each cloud, compared to the relatively small space between the Sc clouds. There are three sub-groups of the cumulus cloud group:

1. *Cumulus humulis*- has little vertical development
2. *Cumulus congestus*- is a towering cumulus
3. *Cumulonimbus* (Cb)- has a great deal of vertical development, also known as thunderstorm clouds

Other miscellaneous cloud types include:

Lenticular clouds- mountain waves, banner clouds

Pileus clouds- these clouds are formed when moist winds are deflected up and over cumulus clouds

Mammatus clouds- produced by moist, sinking air cooler than the surrounding air mass

Contrails- sometimes produced by aircraft

Nacreous clouds- found in the stratosphere

Noctilucent clouds- clouds found in the upper mesosphere