ESCI 241 – Meteorology
Lesson 10 – Precipitation

Reading: *Meteorology Today*, Chapter 8

GENERAL

- **Cloud droplets are very small (diameter of about 0.02 mm), and do not fall very fast.**
  - **Terminal velocity – The maximum speed of fall of an object**
- **The terminal velocity for cloud droplets is usually smaller than the updraft velocity, so cloud droplets remain suspended in air.**
- **In order to form precipitation, the cloud droplets must somehow grow heavy enough to fall. A typical raindrop has a diameter of 2 mm.**
- **The cloud droplet must somehow grow from .02 mm to 2 mm.** ***This represents an increase of a million times in volume!***

DIFFUSIONAL GROWTH

- **Cloud droplets initially grow by diffusion.**
  - **Water vapor diffuses from the air to the cloud droplet.**
- **In order for diffusional growth to occur, the vapor pressure of the air must exceed the saturation vapor pressure.**
- **The saturation vapor pressure over a curved surface is much greater than that over a flat surface (the** ***curvature effect*****).**
  - **This effect decreases exponentially with increasing radius**
  - **The smaller the droplet, the greater that saturation vapor pressure.**
  - **This means that we need relative humidities greater than 100% or the droplet will evaporate!**
  - **Since relative humidity is rarely much greater than 100%, there must be something else we need to consider for droplet growth.**
- **It turns out that by adding a non-volatile compound (such as a salt) to a liquid will lower the saturation vapor pressure (the** ***solute effect*****).**
  - **This effect decreases with decreasing radius.**

- **For small droplets the saturation vapor pressure can be much less than 100%**

- **The solute effect more than offsets the curvature effect for small radii, and allows small droplets to grow at relative humidities less than 100%.**
  - **This is how *haze* is formed**
- **Droplets cannot grow infinitely large via diffusion**
  - **There is competition for available water among the droplets. The more droplets, the smaller each droplet will be.**
  - **Diffusional growth is slow.**
- **Diffusion can only grow a droplet to up to 50 μm, which is too small to be precipitation.**

FORMATION OF PRECIPITATION FROM CLOUD DROPLETS

- **Growth of a cloud droplet into precipitation is accomplished through two main ways.**
  - **The *Bergeron* process**
    - **The formation mechanism in *cold clouds***
    - **Liquid water exists in the atmosphere at temperatures as low as –40°C.**
    - **Freezing doesn't occur unless there are *freezing nuclei* present.**
    - **Freezing nuclei are not very abundant.**
    - **The saturation vapor pressure over ice is less than that over liquid water.**
    - **Once ice forms in the presence of *supercooled* liquid water, the ice crystals will grow at the expense of the cloud droplets.**
    - **The ice crystals continue to grow until they are heavy enough to fall to the ground.**
    - **If the temperature at the ground is near freezing, the snowflakes will reach the ground as snow.**
    - **If the temperature at the ground is above about 39 degrees F, the snowflakes will have melted to form rain.**
    - **The Bergeron process is the primary mechanism for forming precipitation in storms in the middle latitudes.**

- **The *collision-coalescence* process**
  - **How precipitation is formed in *warm clouds*.**
  - **For the collision-coalescence process to work, at least a few cloud droplets must be as large as 20 microns (.02 mm).**
  - **These larger drops fall and collide with smaller droplets. Some of the smaller droplets will just bounce off, but some will stick, or *coalesce*.**
  - **The drop continues to grow through collisions. As it reaches a size of greater than 4 mm, it becomes unstable and breaks apart into smaller droplets. These smaller droplets can continue the process of collision with even smaller droplets, and can continue growing.**
  - **The collision-coalescence process is the main means of precipitation formation in the Tropics, as well as in stratus clouds.**

FORMS OF PRECIPITATION

- ***Rain* – Drops of water falling from a cloud, and having a diameter of greater than 0.5 mm**
- ***Drizzle* – Liquid water drops having a diameter of less than 0.5 mm. You can often tell the difference between rain and drizzle because drizzle usually doesn't cause ripples in standing water puddles.**
- ***Snow* – Ice crystals or aggregates of ice crystals. The shape of snowflakes varies with the temperature at which they are formed.**
- ***Snow grains* – frozen equivalent of drizzle (from stratus clouds). Diameter < 1 mm.**
- ***Sleet* (also called *ice pellets*) – Sleet is frozen raindrops. If greater than 5 mm in diameter, it is called *hail* (see note under hail).**
- ***Snow pellets* (also called *graupel*) – larger than snow grain, but have diameter < 5 mm. Snow pellets are crunchy and break apart when squeezed. Usually fall in showers from *cumulus congestus* clouds. If greater than 5 mm they are called *hail* (see note under hail).**
- ***Hail* – Hail begins as a snowflake that partially or completely melts, and then refreezes. But, instead of immediately falling to the ground, it gets caught in an**

updraft and can make several trips up and down through the cloud, each time accumulating more ice. Hail is only formed in very strong thunderstorms (*cumulonimbus* clouds). Hail has diameters > 5 mm. If smaller, it is either snow pellets or ice pellets, depending on its hardness and crunchiness (see note below).

  - **U.S. record hailstone fell in Aurora, Nebraska on June 22, 2003. It was at least 7 inches in diameter and had a circumference of 18.75 inches!**

U.S. record hailstone. *NOAA Photo used with permission.*

  - **NOTE: It is sometimes difficult to differentiate between hail, snow pellets, and sleet. Here are some rules to follow:**
    - **If it has a diameter larger than 5 mm it is *hail*.**
    - **If it has a diameter less than 5 mm, and is transparent and solid it is *sleet*.**
    - **If it has a diameter less than 5 mm, is not transparent, and crunches when squeezed, it is *snow pellets*.**

- ***Glaze* – Also called *freezing rain*, glaze forms when supercooled raindrops strike an object and instantly freeze on impact.**
- ***Rime* – Forms in a manner similar to glaze, only it is caused by the freezing of supercooled cloud droplets rather than supercooled raindrops. It often forms feathery ice crystals on trees.**

MEASURING PRECIPITATION

- **Rainfall is measured in inches (or millimeters) per hour. Any flat bottomed, vertically sided container can be used as a rain gage.**
- **Rainfall rate is classified as**
  - **Trace – less than 0.01 inches per hour**
  - **Light – between 0.01 and 0.1 inches per hour**
  - **Moderate – between 0.1 and 0.3 inches per hour**
  - **Heavy – greater than 0.3 inches per hour**
- **Snowfall is measured in one of two ways. Either the depth of the snow, or the depth of the liquid water content.**
  - **Liquid water content is measured by melting the snow and then measuring the height of the resulting water.**
  - **On average, 10 inches of snow is equivalent to 1 inch of rain. But, heavier snow has more water, and light, powdery snow has less water.**
  - **The temperature at which the snowflakes formed determines how much water they contain.**
- **Radar can also be used to estimate precipitation rates and amounts.**

WEATHER MODIFICATION

- **Attempts have been made to "seed" cold clouds with dry ice or silver iodide crystals in order to enhance the Bergeron process. This is done to either enhance precipitation, or to disperse fog. It can be somewhat successful on a small scale (such as trying to clear fog at an airport).**
- **Warm clouds are seeded with salt particles in an effort to get a few large drops to form to initiate the collision-coalescence process.**
- **Inadvertent weather modification occurs when man's activities seed clouds. There is evidence that this is occurring near industrial areas.**
- **The jury is still out on how effective cloud seeding is. There are also legal and ethical issues involved.**