Chapter 7: Precipitation Processes

- ❑ Growth of Cloud Droplet
- ❑ Forms of Precipitations
- ❑ Cloud Seeding

Precipitations

Water Vapor Saturated

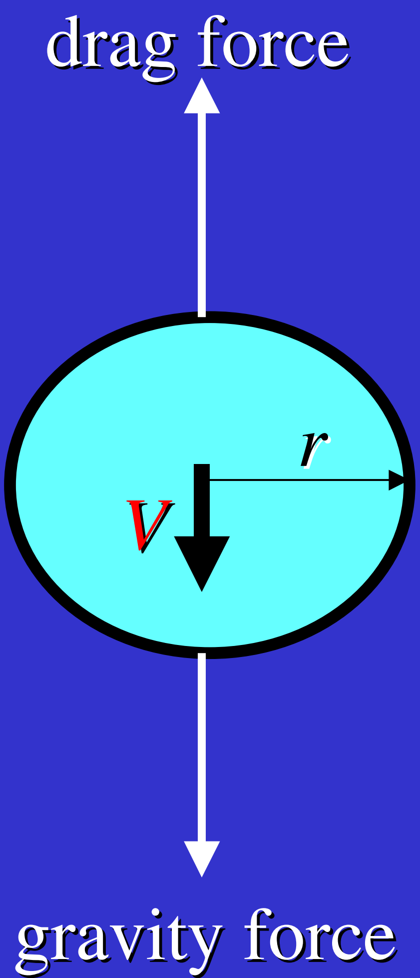
↓ Need cloud nuclei

Cloud Droplet formed around Cloud Nuclei

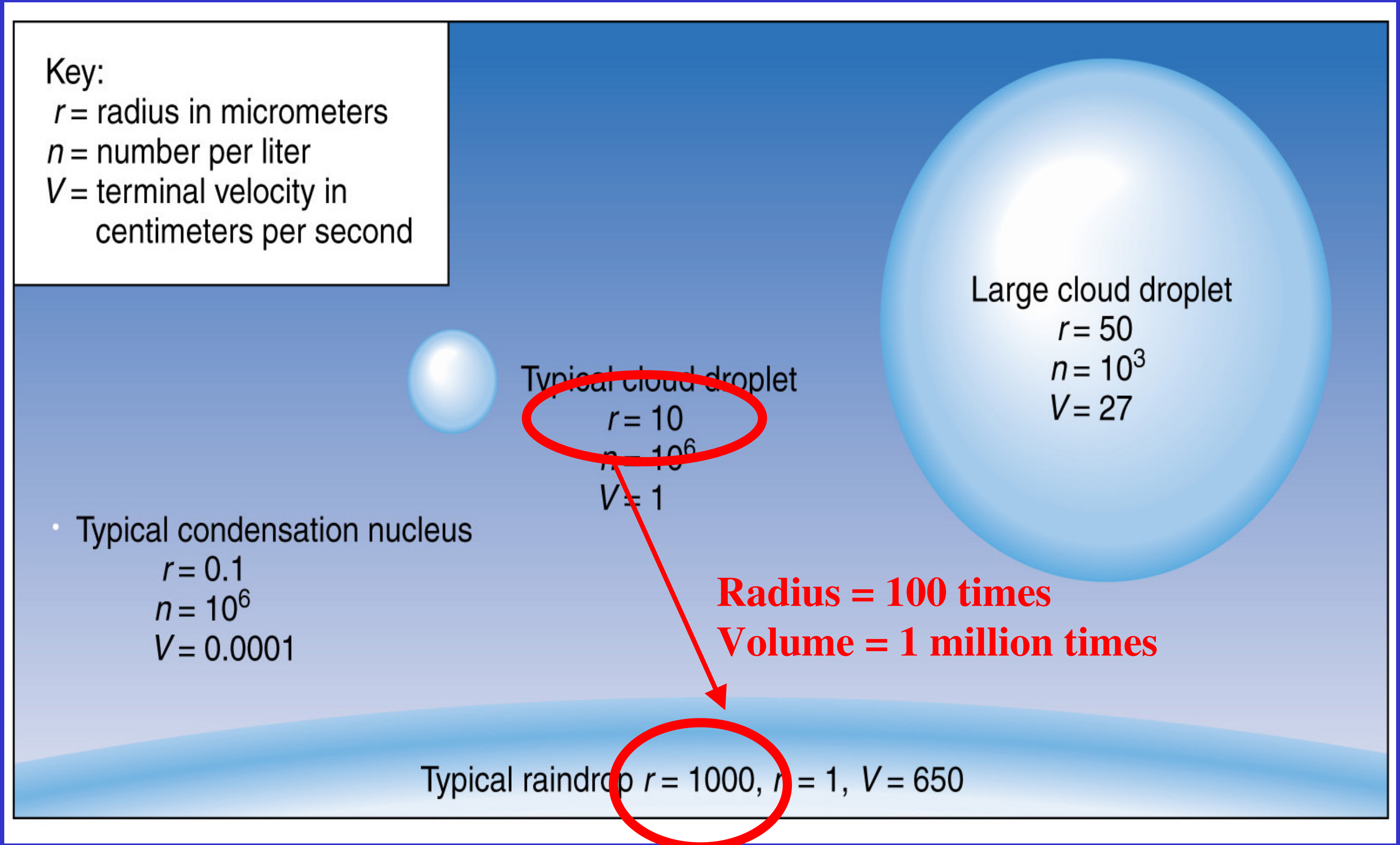
↓ Need to fall down

Precipitation

Terminal Velocity



- Terminal velocity is the constant speed that a falling object has when the gravity force and the drag force applied on the subject reach a balance.
- Terminal velocity depends on the size of the object: small objects fall slowly and large objectives fall quickly.



Key:
r = radius in micrometers
n = number per liter
V = terminal velocity in centimeters per second
Large cloud droplet
r = 50
n = 10^3
V = 27
Typical cloud droplet
r = 10
n = 10^6
V = 1
Typical condensation nucleus
r = 0.1
n = 10^6
V = 0.0001
Radius = 100 times
Volume = 1 million times
Typical raindrop r = 1000, n = 1, V = 650

Raindrops

- Rain droplets have to have large enough falling speed in order to overcome the updraft (that produces the rain) to fall to the ground.
- This means the rain droplets have to ***GROW*** to large enough sizes to become precipitation.

How Raindrop Grows?

- ❑ Growth by Condensation (too small)
- ❑ Growth in Warm Clouds: Collision-Coalescence Process
- ❑ Growth in Cool and Cold Clouds: Bergeron Process

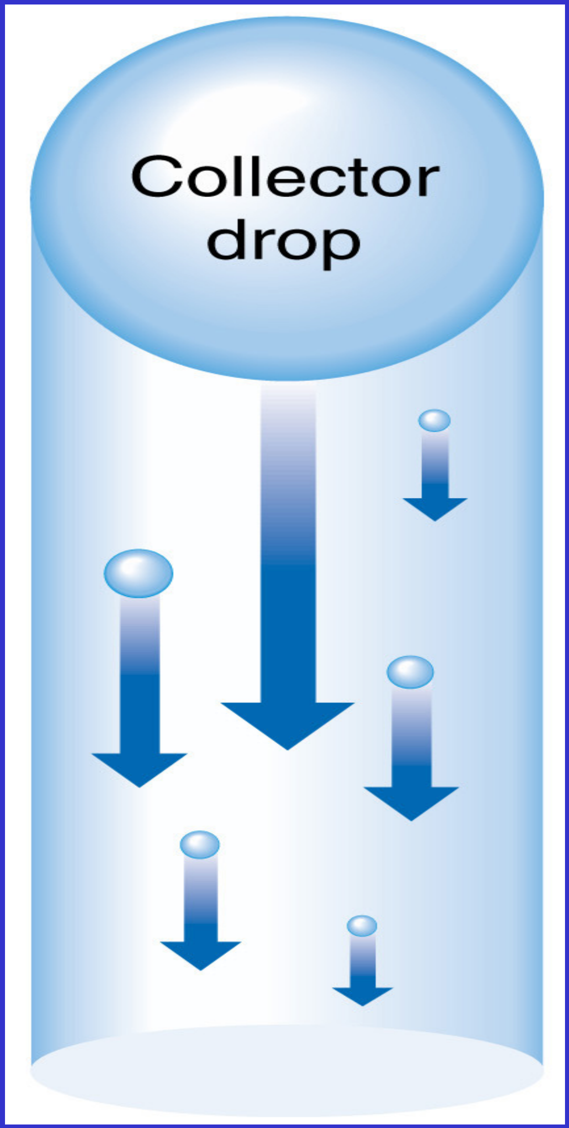
Growth by Condensation

❑ Condensation about condensation nuclei initially forms most cloud drops.

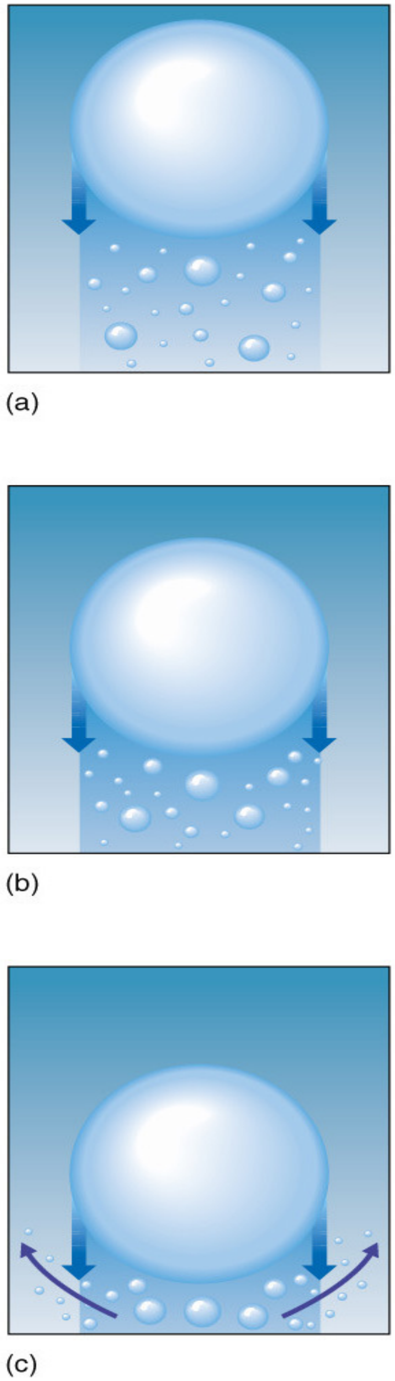
❑ Only a valid form of growth until the drop achieves a radius of about 20 μm due to overall low amounts of water vapor available.

❑ Insufficient process to generate precipitation.

Growth in Warm Clouds



- Most clouds formed in the Tropics, and many in the middle latitudes, are warm clouds.
- Those clouds have temperatures greater than 0°C throughout.
- The Collision-coalescence process generates precipitation.
- This process depends on the differing fall speeds of different-sized droplets.
- It begins with large collector drops which have high terminal velocities.



Collision

- Collector drops collide with smaller drops.
- Due to compressed air beneath falling drop, there is an inverse relationship between collector drop size and collision efficiency.
- Collisions typically occur between a collector and fairly large cloud drops.
- Smaller drops are pushed aside.
- Collision is more effective for the droplets that are not very much smaller than the collect droplet.

Coalescence

- When collisions occur, drops either bounce apart or coalesce into one larger drop.
- Coalescence efficiency is very high indicating that most collisions result in coalescence.
- Collision and coalescence together form the primary mechanism for precipitation in the tropics, where warm clouds dominate.

Cool and Cold Clouds

- A portion of most mid-latitude clouds have temperatures below the melting point of ice.
- Cold clouds are referred to those have temperature below 0ºC throughout and consist entirely of ice crystals, supercooled droplets, or a mixture of two.
- Cool clouds are referred to those have temperatures above 0ºC in the lower reaches and subfreezing condition above.

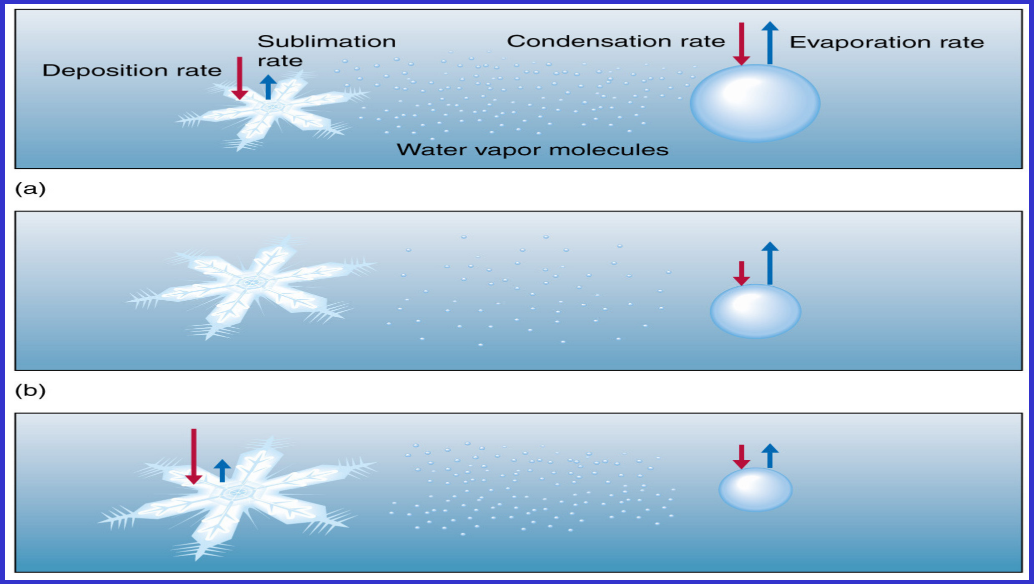
An Example of Cool and Cold Cloud

Cumulonimbus clouds contain both ice (top, fuzzy cloud margins), liquid drops (bottom, sharp margins) and a mix of ice and liquid (middle)

Growth in Cool and Cold Clouds

- ❑ Cool month mid-latitude and high latitude clouds are classified as cool clouds as average temperatures are usually below freezing.
- ❑ Clouds may be composed of (1) Liquid water, (2) Supercooled water, and/or (3) Ice.
- ❑ Coexistence of ice and supercooled water is critical to the creation of cool cloud precipitation - the Bergeron Process.

Bergeron Process



- Saturation vapor pressure of ice is less than that of supercooled water and water vapor.
- During coexistence, water will sublimate directly onto ice.
- Ice crystals grow rapidly at the expense of supercooled drops.
- Collisions between falling crystals and drops causes growth through ***riming*** and ***aggregation***.

Riming and Aggregation

- ***Riming*** = liquid water freezing onto ice crystals producing rapid growth.

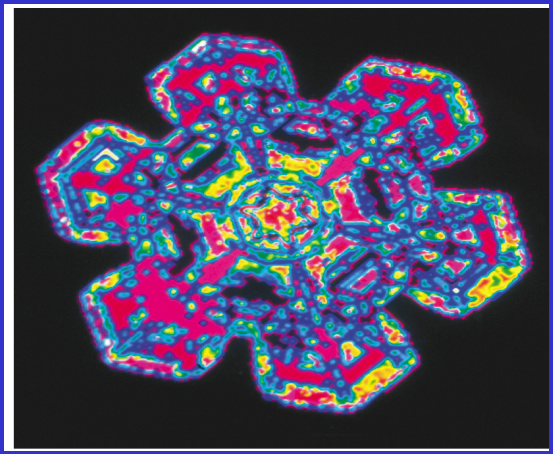
- ***Aggregation*** = the joining of multiple ice crystals through the bonding of surface water builds ice crystals to the point of overcoming updrafts

- Collision combined with riming and aggregation allow formation of precipitation within 1/2 hour of initial formation.

Forms of Precipitation

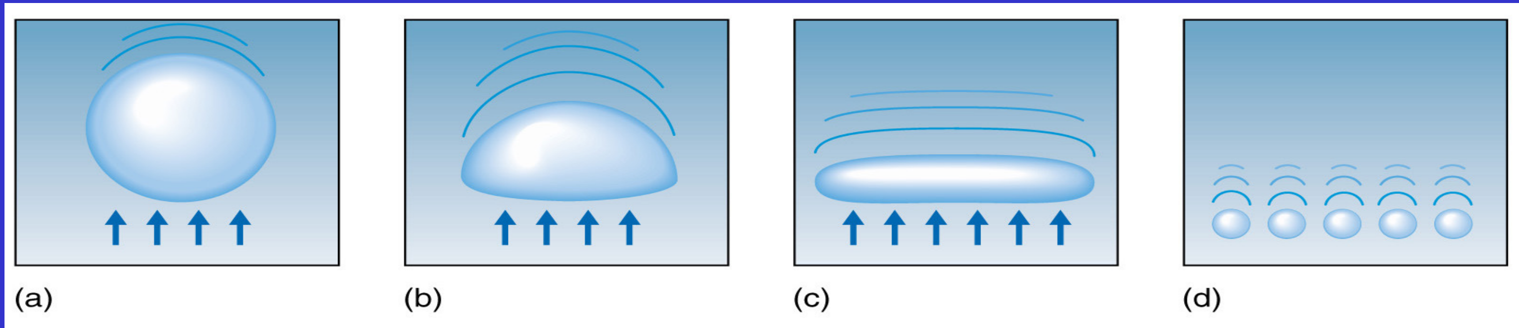
- *Rain*
- *Snow*
- *Graupel and Hail*
- *Sleet*
- *Freezing Rain*

Snow



- Snowflakes have a wide assortment of shapes and sizes depending on moisture content and temperature of the air.
- Snowfall distribution in North America is related to north-south alignment of mountain ranges and the presence of the Great Lakes.
- Lake effect: snows develop as the warm lake waters evaporate into cold air.

Rain

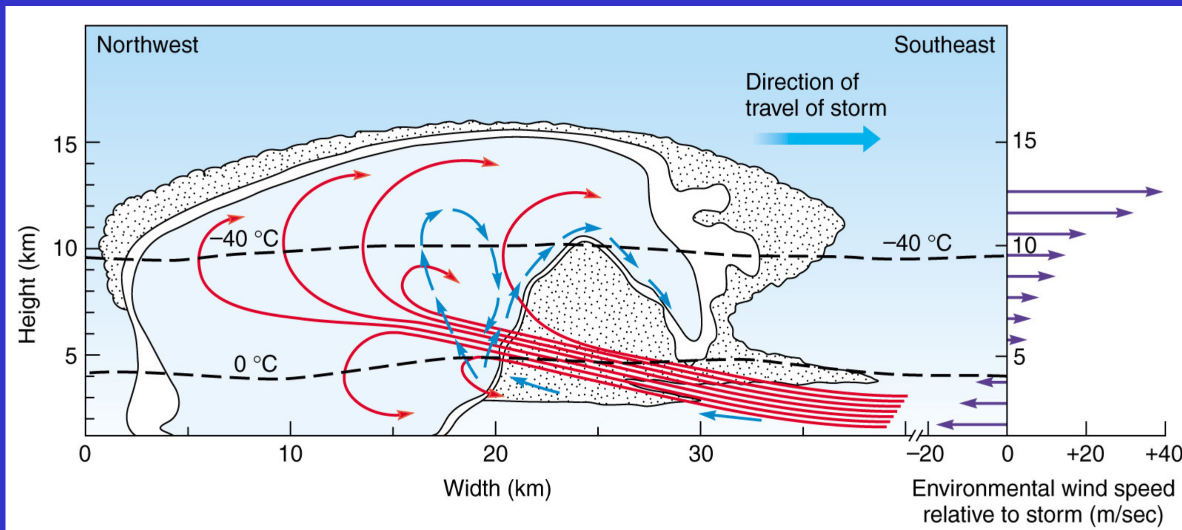


- ***Rain*** is associated with warm clouds exclusively and cool clouds when surface temperatures are above freezing
- ***Rainshowers*** are episodic precipitation events associated with convective activity and cumulus clouds
  - Drops tend to be large and widely spaced to begin, then smaller drops become more prolific
- ***Raindrop Shape*** begins as spherical
  - As frictional drag increases, changes to a mushroom shape
  - Drops eventually flatten
  - Drops split when frictional drag overcomes the surface tension of water
  - Splitting ensures a maximum drop size of about 5 mm and the continuation of the collision-coalescence process

Graupel and Hail

– ***Graupel*** are ice crystals that undergo extensive riming
  - Lose six sided shape and smooth out
  - Either falls to the ground or provides a nucleus for hail

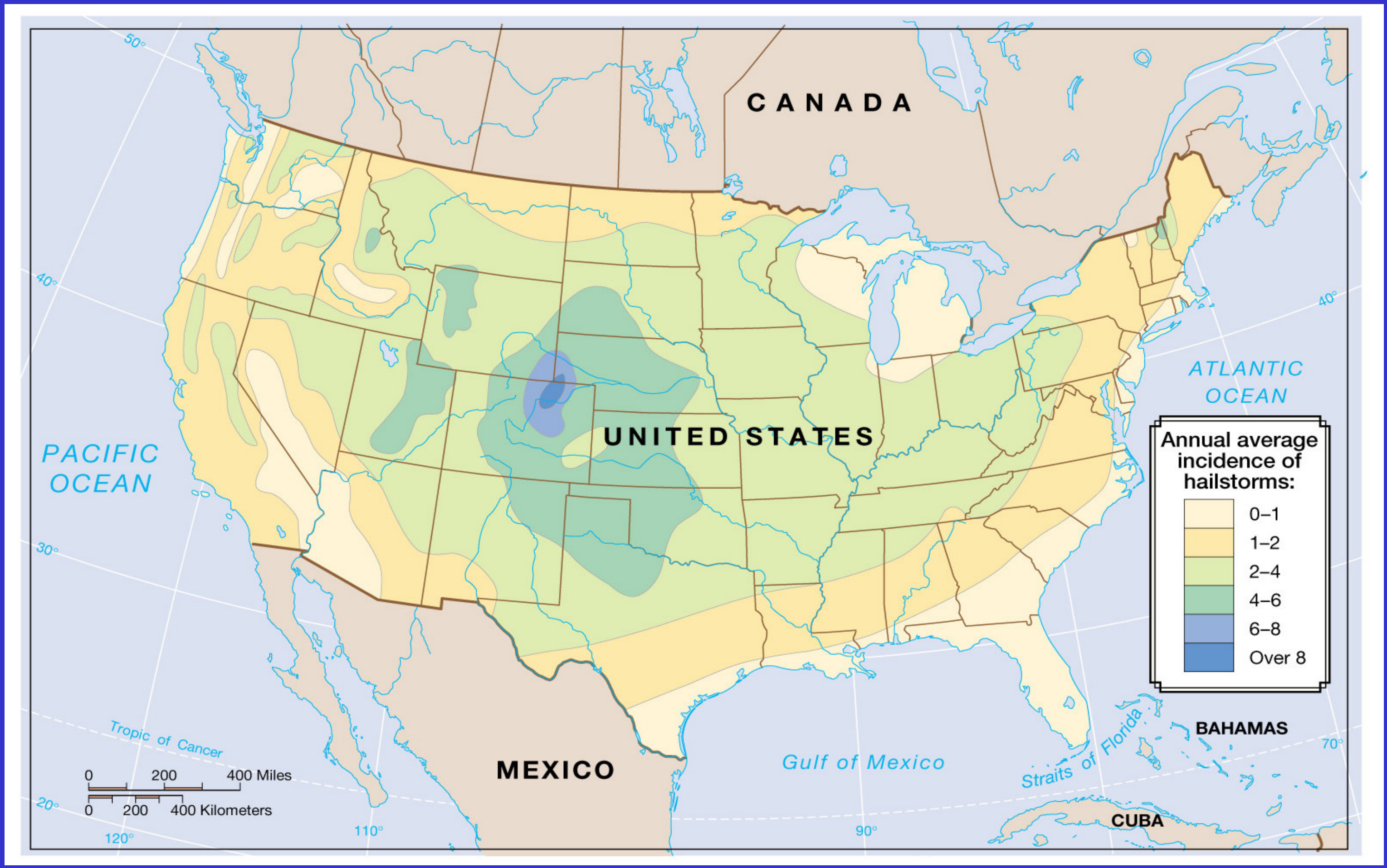
– ***Hail*** forms as concentric layers of ice build around graupel
  - Formed as graupel is carried aloft in updrafts
  - At high altitudes, water accreting to graupel freezes, forming a layer
  - Hail falls but is eventually carried aloft again by an updraft where the process repeats
  - The ultimate size of the hailstone is determined by the intensity of the updraft.
  - Great Plains = highest frequency of hail events



Hail Formation

Concentric layers of ice
in hail indicate the cyclical
hailstone formation process

Hail Frequency in the U.S.



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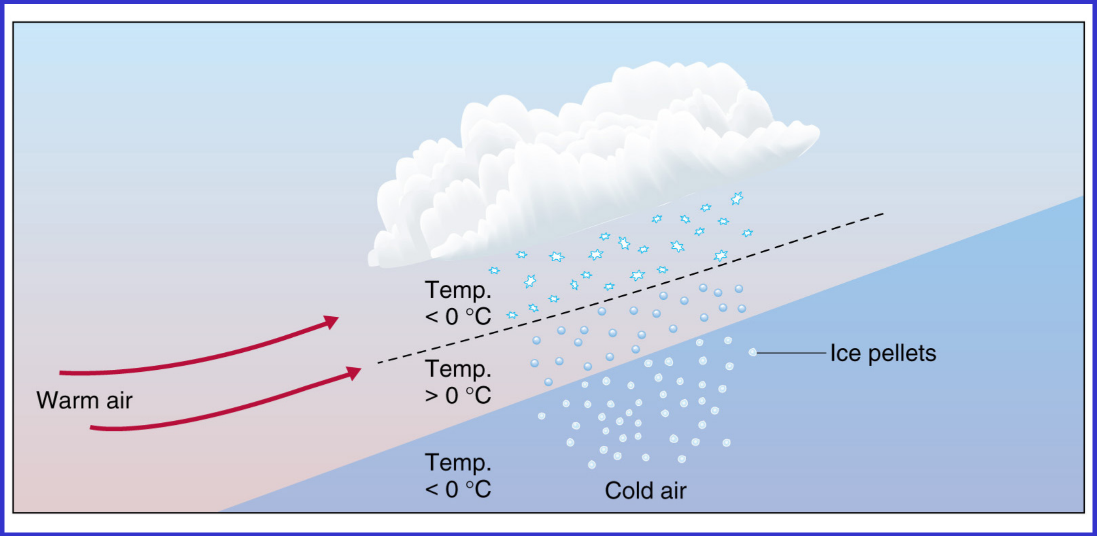
Sleet and Freezing Rain



– ***Sleet*** begins as ice crystals which melt into rain through a mid-level inversion before solidifying in colder near surface air

– ***Freezing Rain*** forms similarly to sleet, however, the drop does not completely solidify before striking the surface

Cloud Seeding

- The objective is to convert some of the supercooled droplets in a cool clouds to ice and cause precipitation by the Bergeron process.
- Two primary methods are used to trigger the precipitation process.
- Dry ice is used to lower cloud temperature to a freezing point in order to stimulate ice crystal production leading to the Bergeron process.
- Silver iodide initiates the Bergeron process by directly acting as freezing nuclei.
- Under ideal conditions, seeding may enhance precipitation by about 10%.

Measuring Precipitation

A raingage


(a)

- Standard ***raingages***, with a 20.3 cm (8”) collected surface and 1/10 area collector are used to measure liquid precipitation
- Depth of water level conveys a tenfold increase in total precipitation
- Automated devices provide a record of precipitation amount and time of the event

Measuring Snow

- Raingages are inadequate for measuring frozen precipitation
- Measurements of accumulated snow are used
- Water equivalent of snow, a 10 to 1 ratio is assumed
- Automated snow pillows are common in many locations
- Detect snow weight and convert directly to water equivalent