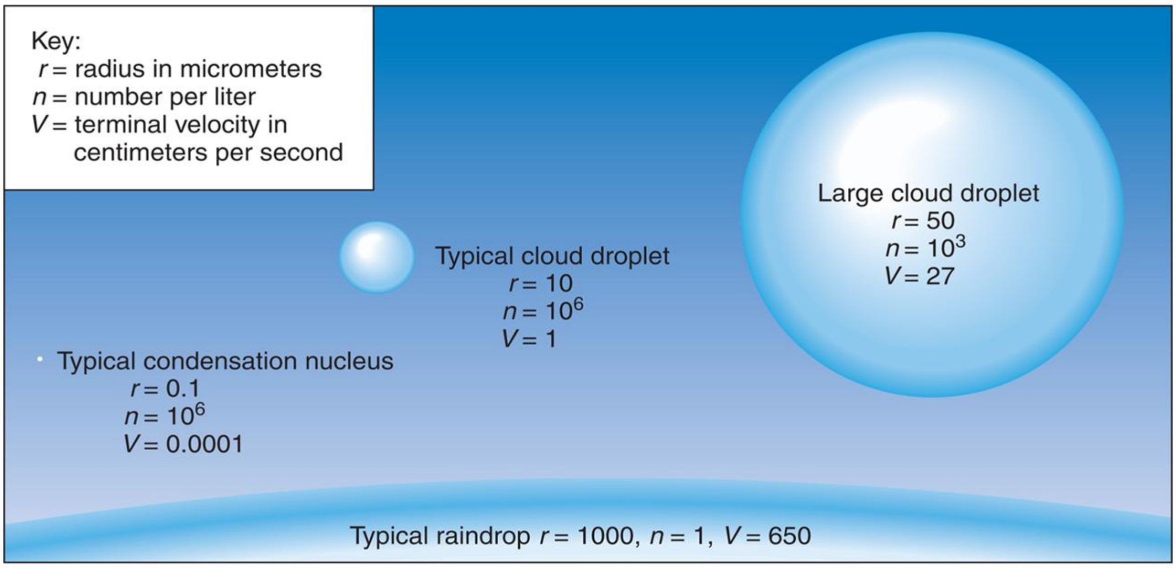
Chapter 7

Precipitation Processes

Clouds

- Clouds are composed of tiny water droplets from condensation onto CCN



Clouds -> Precipitation

Cloud droplet fall speeds are way too low to become precipitation

-→ For clouds to produce precipitation, cloud droplets must get bigger!

Growth of Cloud Droplets

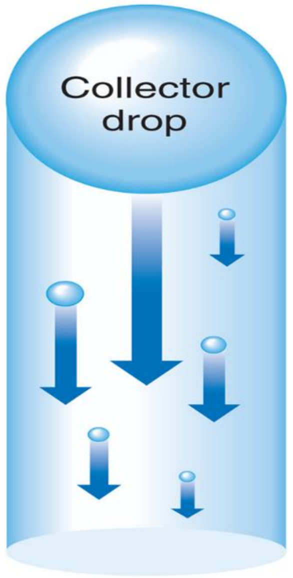
- Condensation is only effective from nucleation up to around radii of 0.02 mm
  → There's just too many drops, too little moisture
- So, for precipitation, we need another mechanism!
- This other mechanism depends on the type of cloud:
  1) Warm clouds (totally > 0°C)
  2) Cool and cold clouds (at least partially below 0°C)

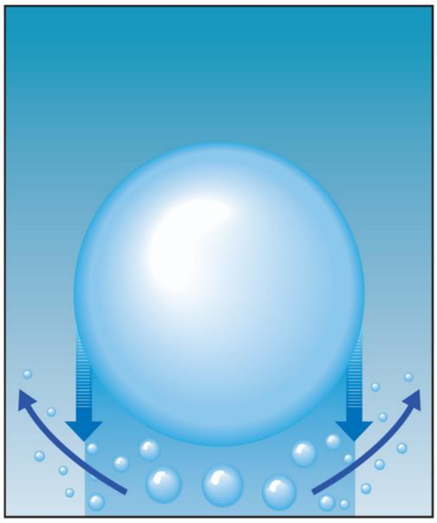
Precipitation in Warm Clouds

- Warm clouds – clouds with only liquid water above 0oC
- 2 processes produce warm cloud precipitation:
  1) Collision
  2) Coalescence

Collision in Warm Clouds

- Collision – when cloud droplets collide with each other
- Collision efficiency depends on relative size of a collector drop and droplets below
    - ➢ Low efficiency for very small drops
    - ➢ Low efficiency for same-size drops
    - ➢ High efficiency for drops in between these sizes





(c)

Coalescence in Warm Clouds

- **Coalescence** – when colliding cloud droplets stick together
- Coalescence efficiency is assumed to be near 100% (all drops stick together if they collide)

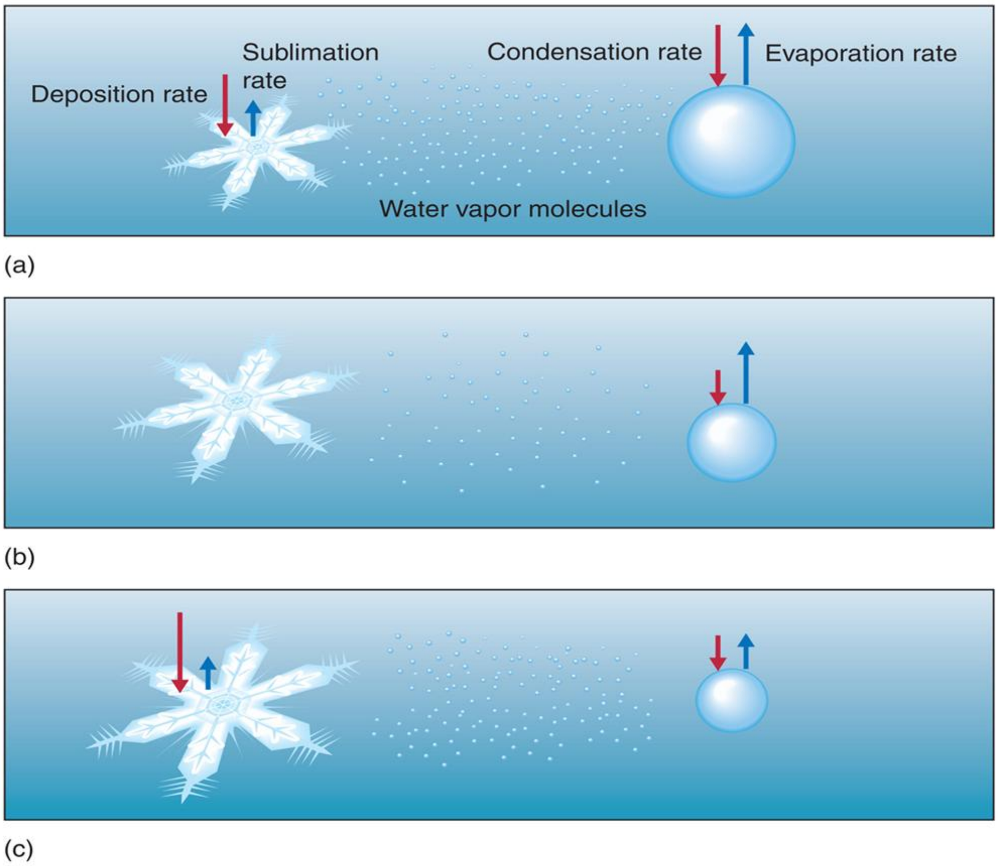
Precipitation in Cool and Cold Clouds

- **Cold cloud** – a cloud entirely below 0^{o}C that may contain supercooled water, ice, or both
- **Cool cloud** – a cloud with regions both above and below 0^{o}C
- Precipitation in cool and cold clouds relies on a mixture of supercooled water and ice

<u>Key Concept</u>

Saturation vapor pressure over ice is less than Saturation vapor pressure over water

→ The Bergeron Process



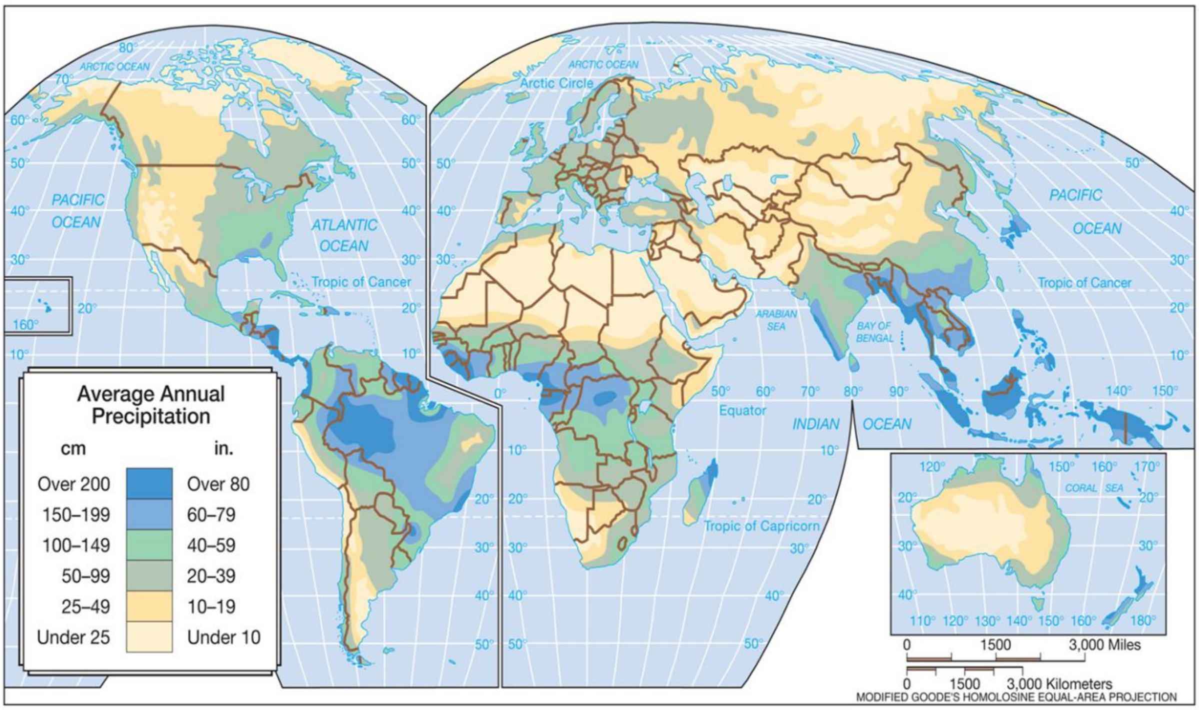
The Bergeron Process

- For air with both supercooled water and ice:
  1) Amount of water vapor is in equilibrium with water (saturated)
  2) Amount of water vapor is not in equilibrium with ice (supersaturated)
  3) Water vapor deposits onto ice, lowering the amount of water vapor, causing evaporation of water
  4) The cycle continues – ice grows and water vanishes

- Once the Bergeron Process takes place, ice becomes big enough to fall, and 2 additional processes occur:
  1) Riming – ice collides with supercooled water which freezes on contact
  2) Aggregation – ice crystals collide and stick together

Precipitation Distribution

- 38.8 in/year annual average precipitation
- Each year (for the last ~100 years) has been within 2 in of this average

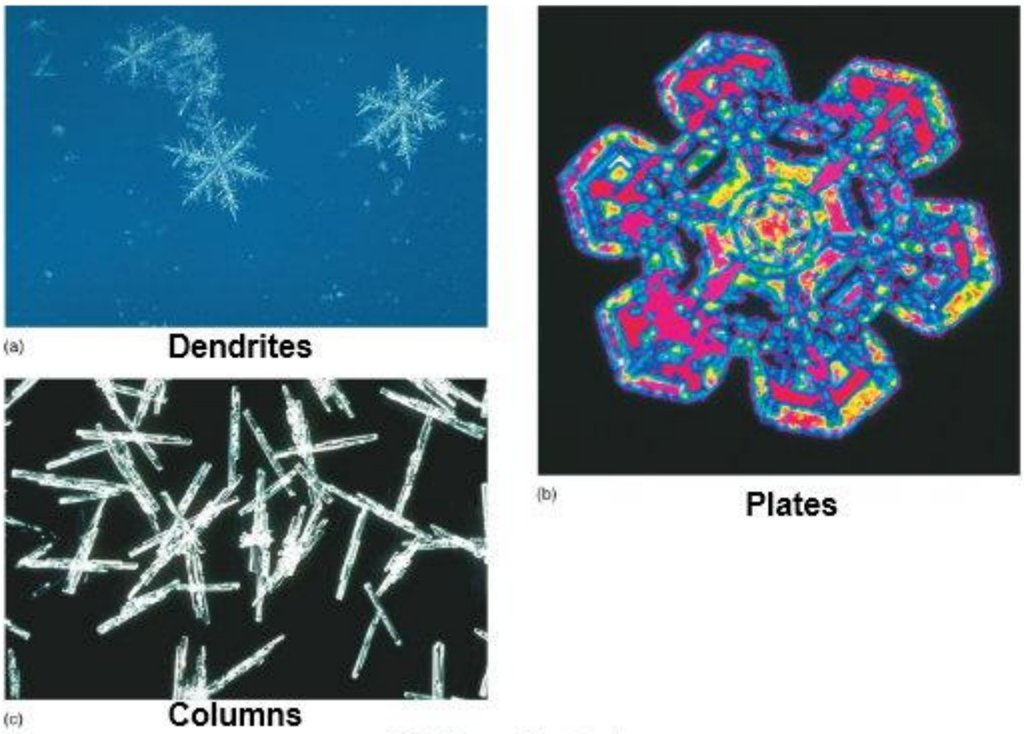


Types of Precipitation

- Several types of precipitation exist and depend on the atmospheric temperature profile:
  1) Snow
  2) Rain
  3) Graupel and hail
  4) Sleet
  5) Freezing rain

Snow

- Snow occurs from the Bergeron process, riming, and aggregation
  - ➢ The nature of snowflakes depends on temperature and moisture content



Rain

- The nature of rain formation typically depends on location:
    1) Tropics – warms clouds - rain forms by condensation, collision, and coalescence
    2) Mid-latitudes – cool clouds – rain forms as snow then melts

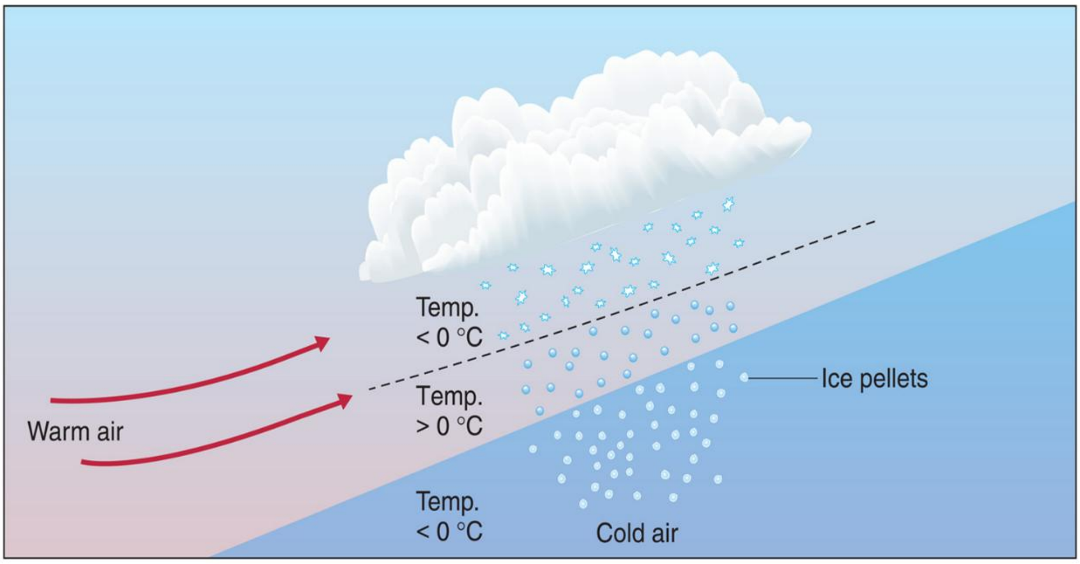
- Rain is also classified in terms of how it lasts in time
    1) Steady (stratiform) rain – rain that lasts for long periods of time (hours)
    2) Showers (cumuliform) rain – rain that is short-lasting (minutes)

Graupel and Hail

- **Graupel** – ice crystals that undergo riming upon collisions with supercooled water
- **Hail** – Severely rimed ice crystals resulting from repeated upward and downward motions in a thunderstorm

Freezing Rain and Sleet

- **Freezing rain** – supercooled rain that freezes on contact or shortly after contact with surface
- **Sleet** – raindrops that have frozen while falling, reaching the surface as ice pellets



Measuring Precipitation

Raingage – A cylindrical container that collects rainfall and measures its depth

(a)

Tipping-bucket gage – a raingage that also measures timing and intensity

(b)

Radar – a very useful tool for measuring rain over large area

Cloud Seeding

Cloud seeding – injecting foreign materials into clouds to initiate precipitation by the Bergeron process

1) Dry ice is used to cool clouds to very cold temperatures, causing ice crystals to form
2) Silver iodide (similar structure to ice) is used as ice nucleii