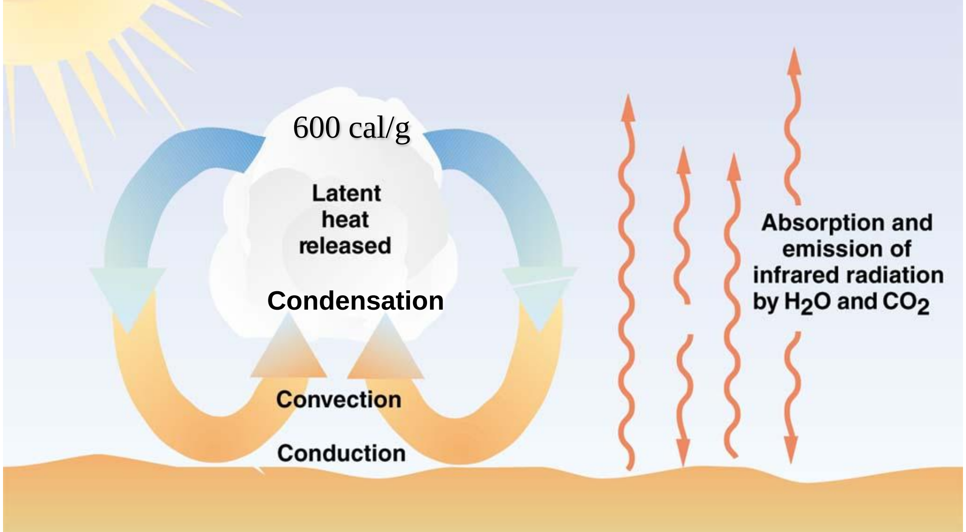
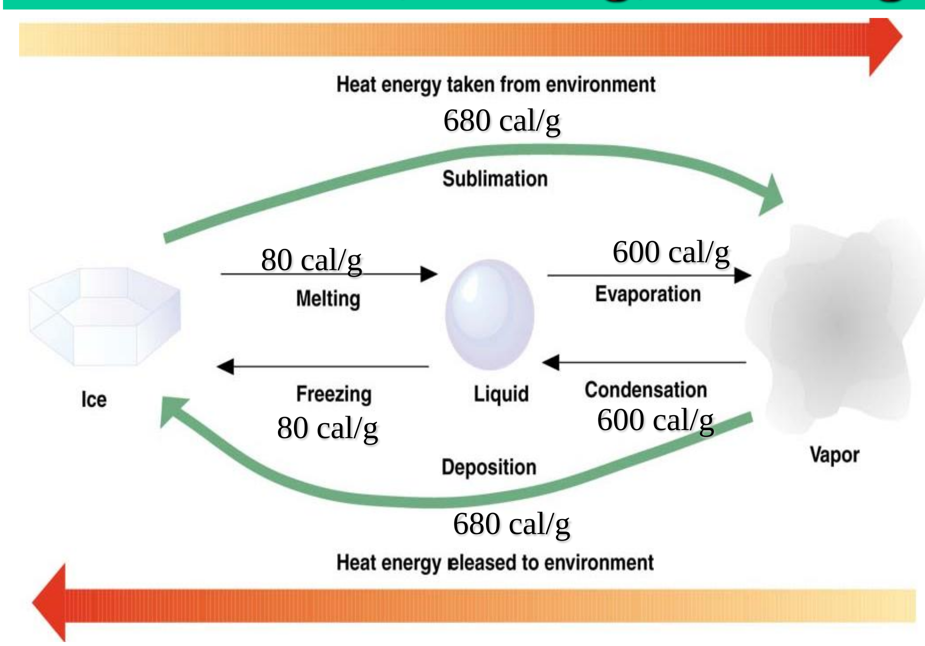
Condensation: process

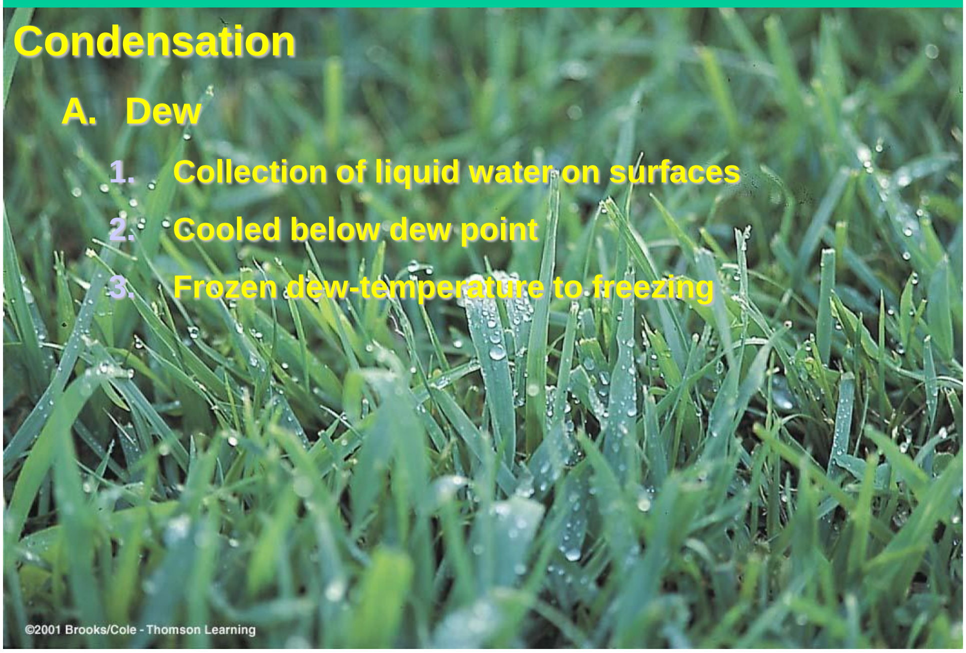
Condensation in atmosphere produces water droplets of less than 10 microns (μ) diameter. Smaller that human hair (75 μ diameter)



Sublimation, Melting, Freezing



Condensation: Dew



Condensation

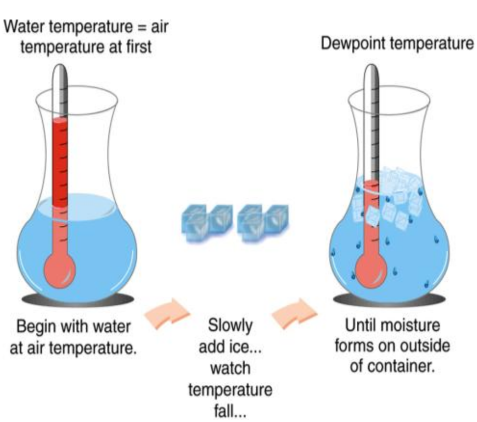
A. Dew

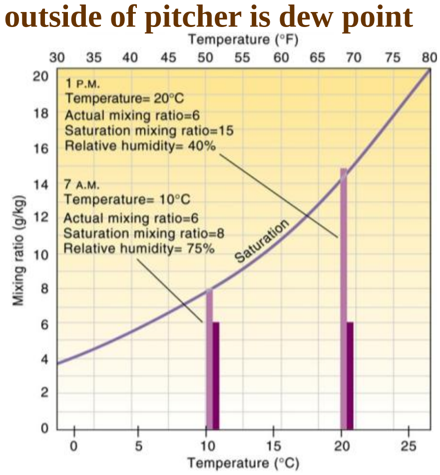
1. Collection of liquid water on surfaces
2. Cooled below dew point
3. Frozen dew-temperature to freezing

Dew Point Temperature

Dew Point: **Temperature at which water vapor begins to condense into liquid (dew, fog, clouds) if the air were to be cooler**

Pitcher of water at air Temperature. Add ice cubes. Temperature that tiny water drops (dew) form on outside of pitcher is dew point





Condensation: Frost

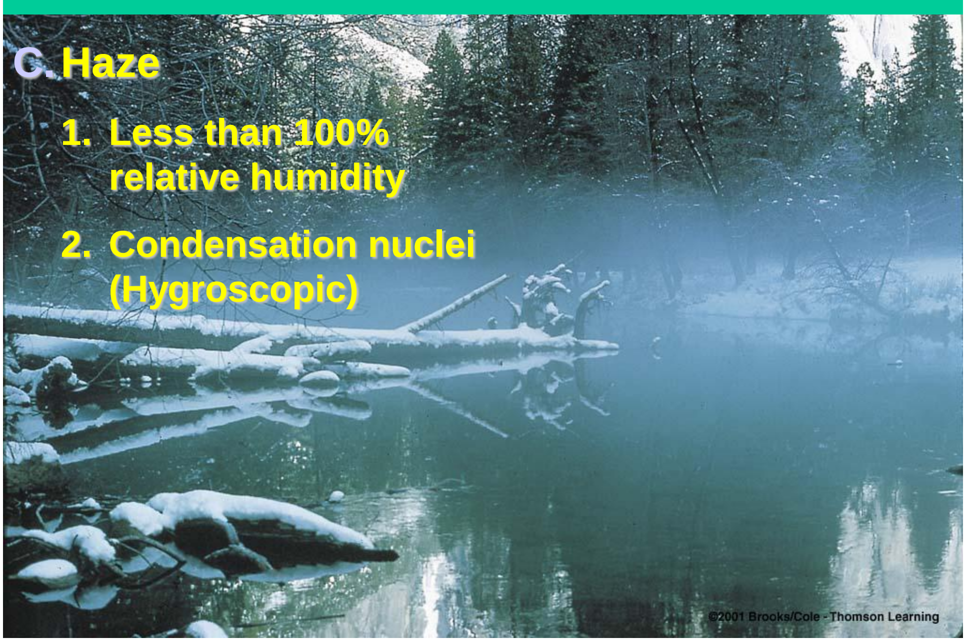
B. Frost

1. Liquid forms first
2. Tree-like branching pattern

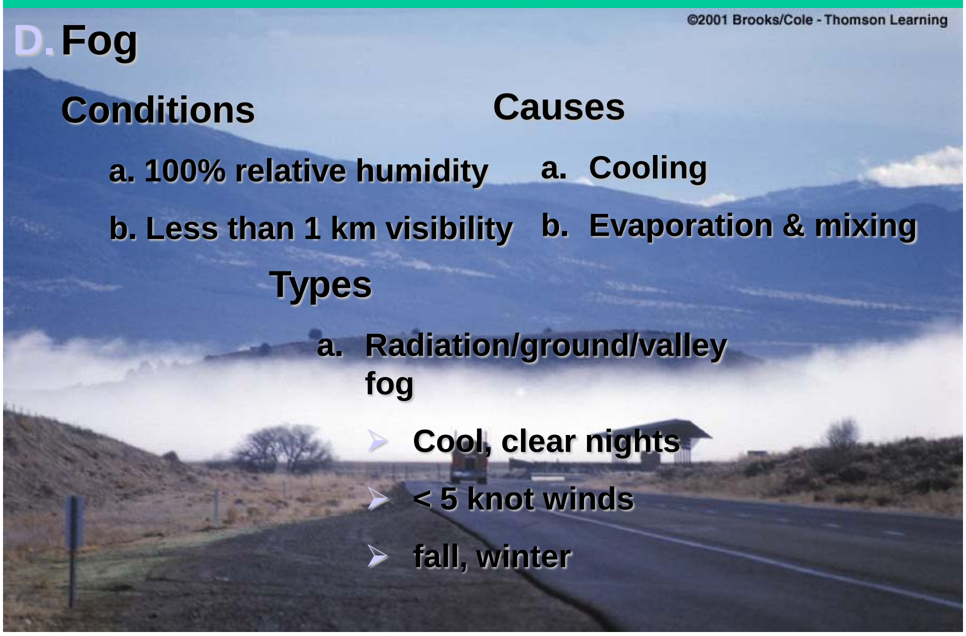
Condensation: Haze

C. Haze

1. Less than 100% relative humidity
2. Condensation nuclei (Hygroscopic)



Condensation: Fog



Fog: Advection & Upslope

b. Advection fog
   1.) Warm, moist air over cold surface
   2.) Coastal areas
   3.) Two ocean currents flow next to one another
   4.) spring, summer, fall, winter

c. Upslope fog
   1.) along slopes, hills, mountains, and elevated plains
   2.) winter, spring

Fog: Evaporative

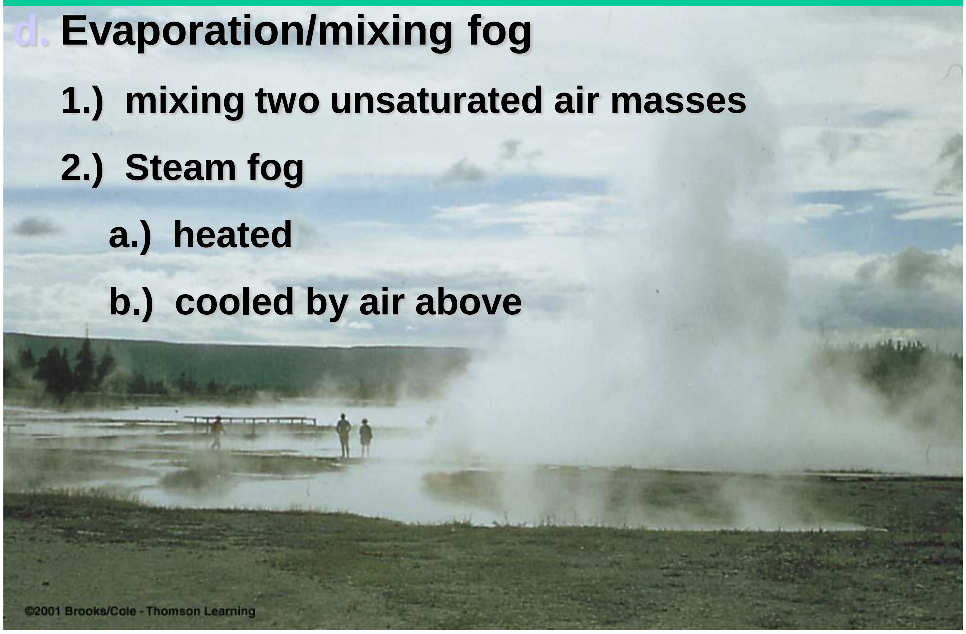
d. **Evaporation/mixing fog**

1.) mixing two unsaturated air masses

2.) Steam fog

a.) heated

b.) cooled by air above



Rime

- Freezing fog
- Formed when wet fog having supercooled droplets immediately freeze on striking objects having temperature below freezing point
- White ice is formed on windward (direction from where the wind is blowing

Mist

•Less densed fog

•Water droplets restricts the visibility between 1100 yards (approx 1 km) to 2200 yards (approx 2 km)

•RH: 75% (at least)

•Mist disappears with rising sun

Condensation: Hailstones

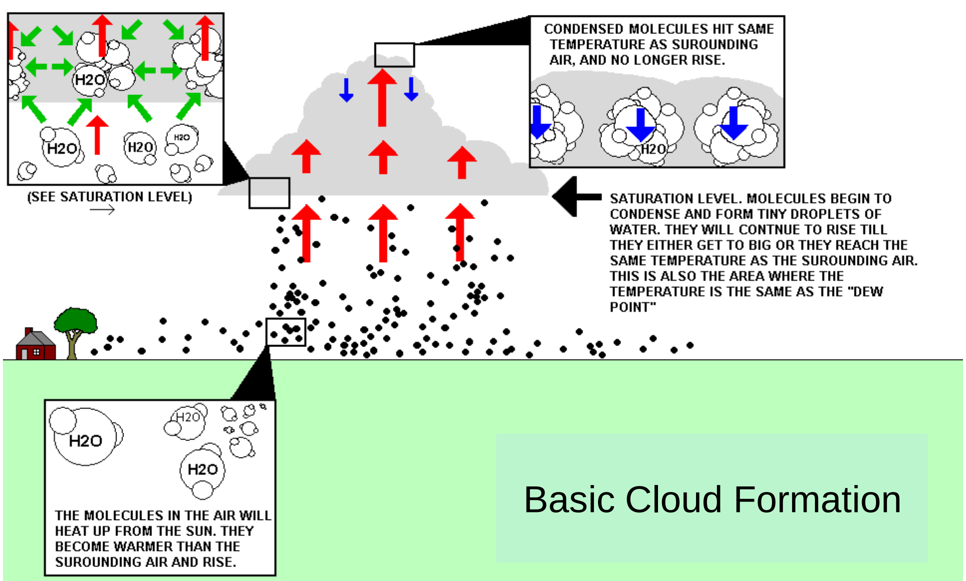
E. Hailstones

1. **Ice**
2. **Size from small peas to golf balls**

Condensation: Cloud

F: Clouds: Aggregate of ice or water droplets

Cloud: Formation



Basic Cloud Formation

Cloud Producing Mechanisms

Upward Motion as a Cooling Mechanism

Upward masses of air (parcel) rise because they are buoyant

Air parcels are buoyant because they are warmer and therefore less dense than the surrounding air

For condensation the temperature must drop

Why Clouds Form in Rising Air

Adiabatic expansion
Cools the air parcel
Must eventually reach dewpoint

Condensation

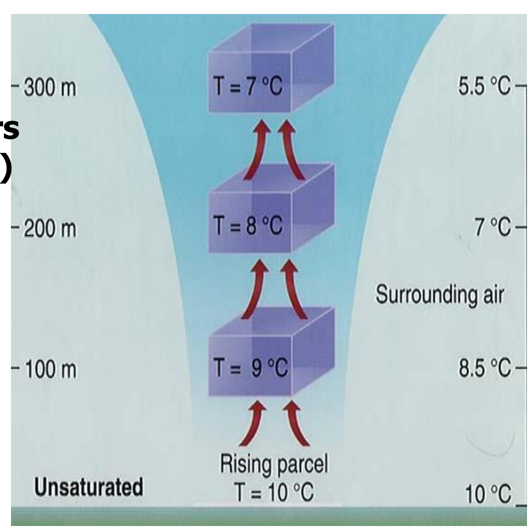
Clouds form

Dry Adiabatic Lapse Rate (DALR)

Unsaturated Air Rises

DALR
≅ -1.0°C per 100 meters
(Constant for Dry Air)
[-0.98°C]

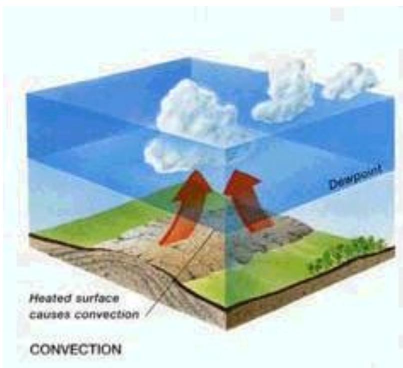
If it starts at 10°C
at 100m drops ≅ 1°C to 9°C
at 200m drops another ≅ 1°C to 8°C
at 300m drops another ≅ 1°C to 7°C

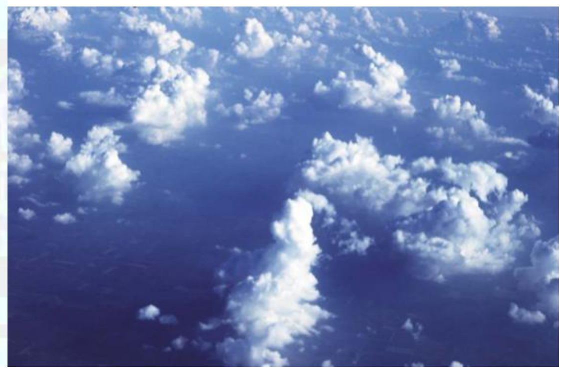


Convectional

Convectional Rainfall

1. Thermal
2. Cumulus cloud
3. Reformation of Cumuliform Clouds
4. Stability controls vertical growth



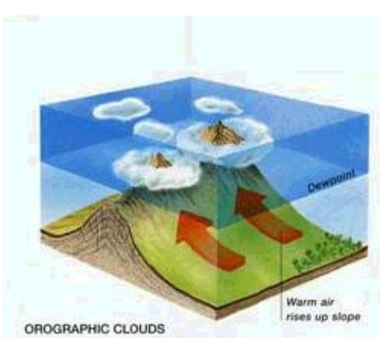


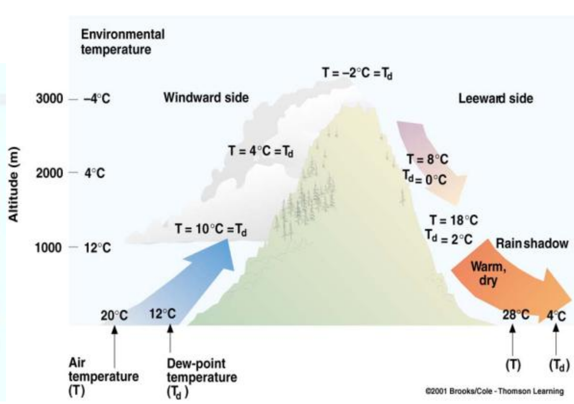
Orographic

Orographic Rainfall

Topographic uplift

- Warmer on leeward side
- Cooler on windward side





Cyclonic

Region characterized by the low pressure area surrounded by high pressure area.

Precipitation characterstics vary according to the pressure gradient

Air ascent through horizontal convergence.

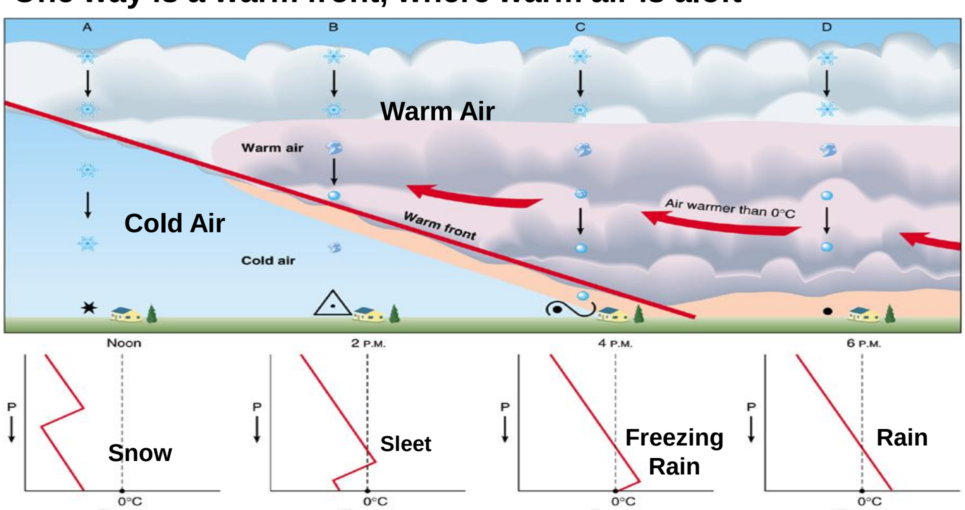
Provide widerspread rainfall.

Spatial Rainfall intensity vary with Moving Cyclone.

Frontal

Change over from snow to sleet to freezing rain and rain is common in any of these sequences

One way is a warm front, where warm air is aloft



How is Precipitation Generated?

Precipitation

Any form of water (raindrops, snowflakes, etc) that falls from the atmosphere and reaches the ground

Excludes:
dew, frost, water vapor
cloud droplets, which are too small to fall

Condensation and Deposition

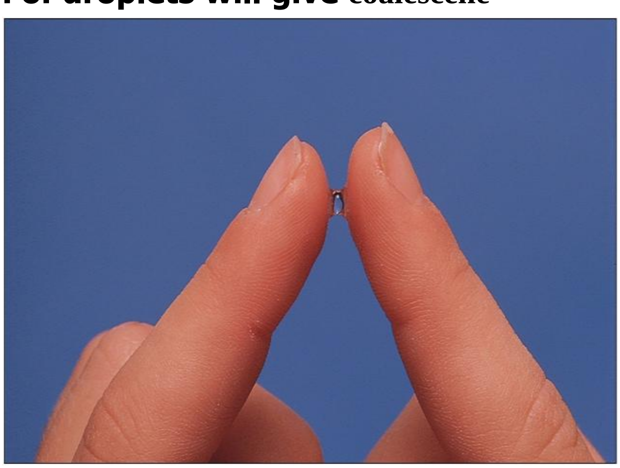
Cloud particles grow as a result of condensation or deposition of water vapor onto appropriate nuclei

High humidity
drop grows to reach precipitation size

Collision and Coalescence

Two droplets of water if placed in contact will join on contact
They will coalesce

Collision of droplets will give coalescene



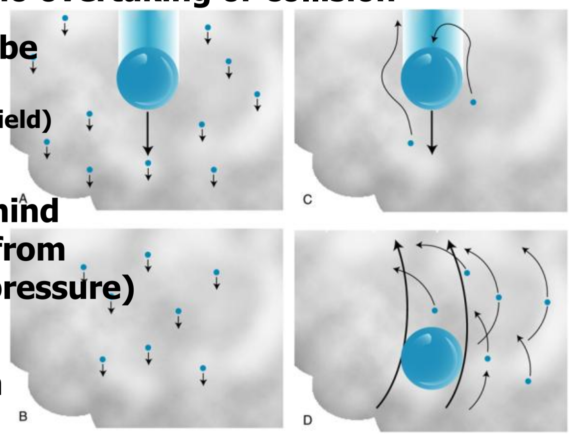
Droplet Collisions Within a Cloud

Larger drops fall faster
- **Can overtake and collide with smaller drops**
- **If the same size, no overtaking or collision**

Small droplets can also be
- **swept aside**
  - **(like water on windshield)**

Wake capture
- **Droplet swept behind**
  - **can collide from**
- **rear (due to low pressure)**

Turbulence
- **Changes direction**

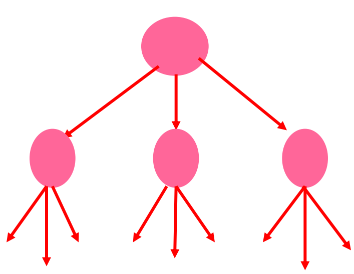


Raindrop Breakup

Maximum size for a raindrop is 5 millimeters
- Breaks into smaller drops (larger than cloud droplets)
  - Due to turbulence

Continues to grow
- Collision and coalescence
  - Breaks up again at critical diameter

Single large drop can be parent to numerous others



How Important is the Collision-Coalescence Process?

Collision and coalescence,

like condensation,

are on going processes in clouds

Warm clouds

Clouds that cause precipitation (rain)

Warmer than 0°C, everywhere

Warm rain process

Almost solely responsible for precipitation in Tropics

The Bergeron Process

Outside the small tropical area

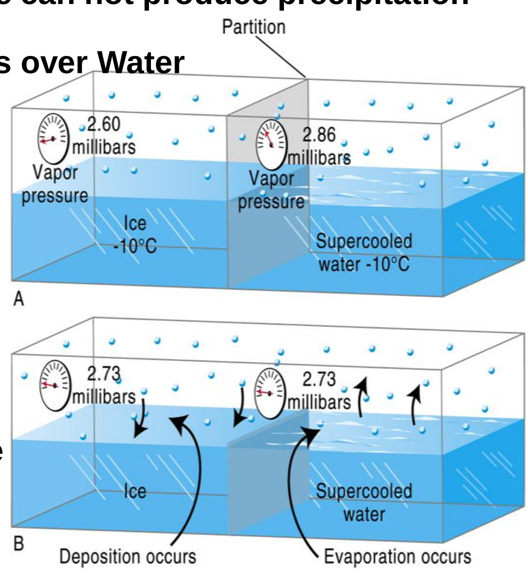
collision- coalescence can not produce precipitation

Ice is needed

Saturation over Ice versus over Water

Equilibrium vapor pressure is less over ice than water

Introduce saturated air over the ice causes supersaturation and deposition of water onto the ice



Saturation Mixing Ratio Curves

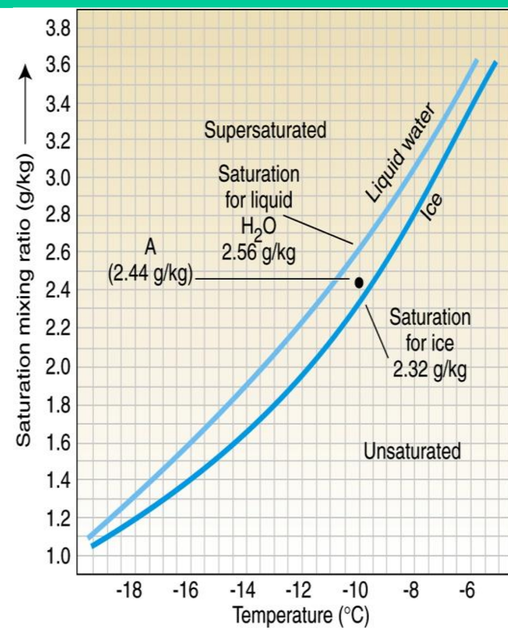
Consider a parcel of air at -10°C Mixing ratio is 2.44 g/kg

RH = [w / w_s] x 100 %

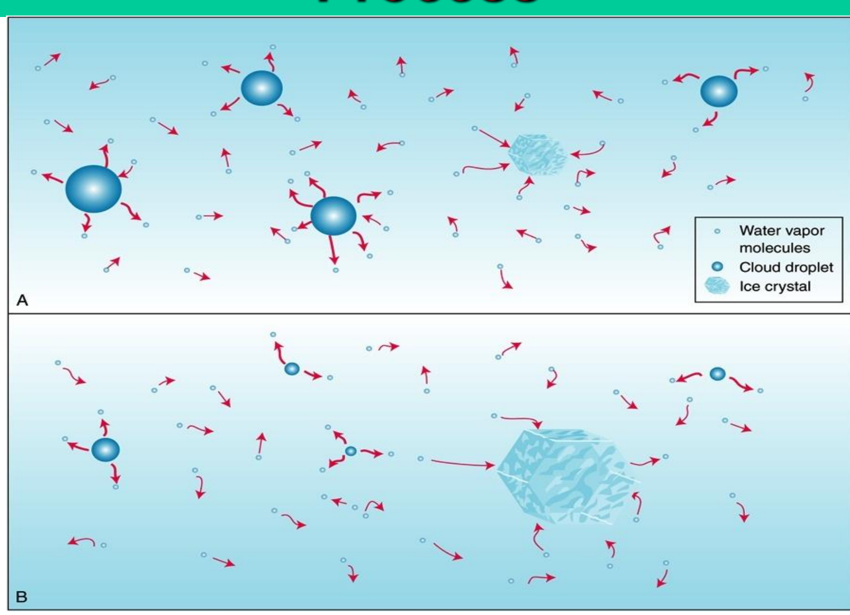
Over water, RH = [2.44g/kg]/[2.56g/kg] x 100% = 95%

Over ice, RH = [2.44g/kg]/[2.32g/kg] x 100% = 105%

Ice crystals will grow, liquid droplets will evaporate



Precipitation Formation/Bergeron Process



Precipitation Formation in Supercooled Clouds

In a supercooled cloud

Air is supersaturated with respect to ice, and at the same time, unsaturated with respect to water

Bergeron process

Water droplets evaporate at the same time that ice crystals grow

Also known as the three-phase process

1. Cloud droplets become smaller as water vapor molecules evaporate
2. Random motions bring them in contact with ice crystals
3. Many are deposited onto ice crystals

Net flux from water droplets to ice crystals

Bergeron Process Makes Precipitation

Ice crystals are rarer than water droplets

1 million to one

But if the water is transferred to a single ice crystal, It will be more than heavy enough to precipitate

Larger crystals fall more rapidly and

collision-coalescence process plays a supporting role

Precipitation's final form depends on the condition

encountered as it falls

How Important is the Bergeron Process?

Responsible for

1. All snow
2. All frontal precipitation
3. All thunderstorm precipitation, except in tropics

Bergeron Process can not operate in warm clouds, which can also produce precipitation

Why Doesn't Every Cloud Generate Precipitation?

Number of factors prevent precipitation

1. Not enough moisture or the height of the cloud (cold)
2. Warm clouds need large drops for collision-coalescence
3. Supercooled clouds
   - Need proper mix of supercooled droplets and ice crystals
   - Bergeron process needs ice crystals but too many and then too few water molecules

Virga – falling precipitation evaporates before reaching ground

Precipitation Types

Snow

Crystals form into Bergeron process, many forms with basic shape 6-sided

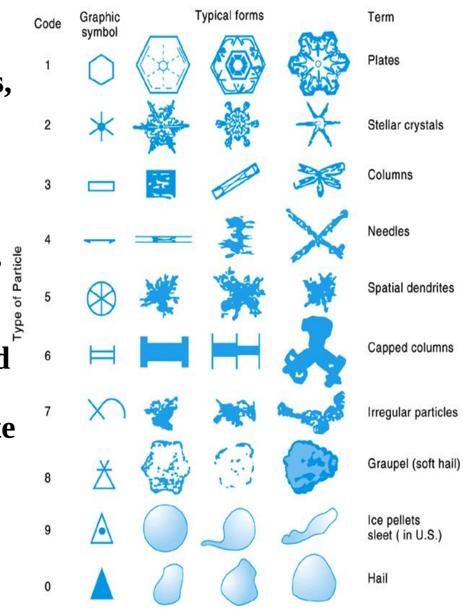
Some reach the ground

Snowflakes

Crystals collide and stick together, a few to a hundred to reach ground

Below cloud base must be moist, and crystals large enough not to evaporate or sublimate

Environment to ground must be below freezing



Temperature Profiles

Snow

Temperature profile is below freezing to ground

Rain

Temperature profile is above freezing at ground

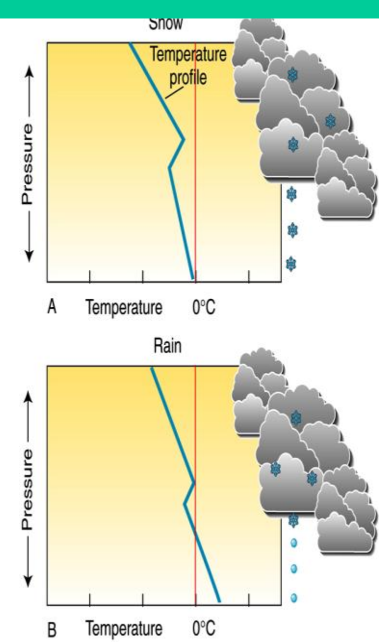
Snow crystals have time to melt size >0.5mm

Drizzle

Distinguishing character is diameter of drops – less than 0.5 mm

Form in thin clouds, total precipitation is small

Thick stratus or fog



Snow Pellets

Snow Pellets or Graupel

Formed by snow crystals falling through

cloud region of supercooled water droplets

Droplets collide with crystals and freeze

Soft and crunchy – “popcorn snow”

Ice Pellets or Sleet

Ice Pellets or Sleet

Formed by snow crystals falling into warmer air, then refreezing

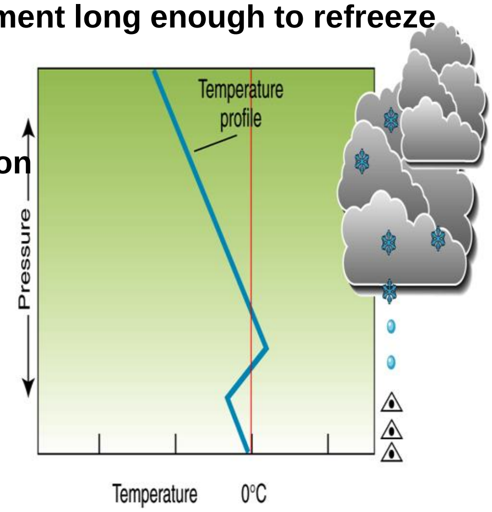
Must be in freezing environment long enough to refreeze

Refreezes as ice pellet, not as crystal

Crystal forms from deposition of water vapor onto *single* freezing nucleus: 6-sided

Rain drop is not a single nucleus get frozen at many points, simultaneously

Small Hail – continued coating of ice

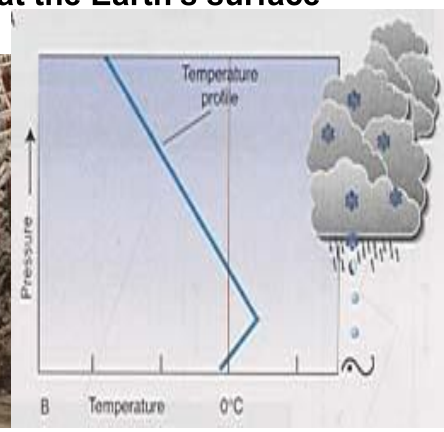


Freezing Rain

Freezing Rain

Rain that freezes when it strikes the ground, trees and structures

Snow crystals must melt to form rain which falls into subfreezing temperatures at the Earth's surface



Hail

Hail

Precipitation in spherical or irregular chunks of ice greater than 5 mm in diameter

Lethal missiles

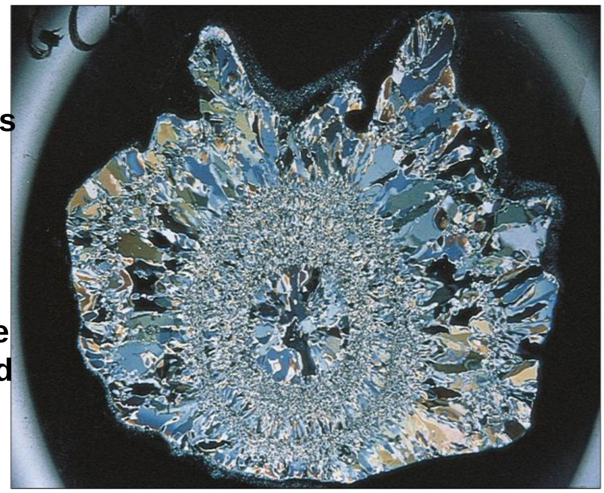
Can injury and kill

Cause hundreds of millions of dollars of damage

Diameter: 140mm (5.5in)
Weight 0.75kg(1.7lbs)
Speed: 45m/s (100mph)

Layered - Hail

Cross-sectional view shows that hail is composed of many layers



When the water freezes quickly on hailstone it is opaque

Colder in cloud

Freezes slowly it is clear

Not as cold with more moisture in cloud

Hail Formation

1. Original particle forms in area of weak updrafts to about 1 mm
2. Begins to fall
3. Swept back up by strong updrafts (greater than terminal velocity
4. Particles collides with supercooled particles that freeze to it
5. Lifting and falling occur many times (layers)
6. Larger may fall or get into downdraft (entrainment)