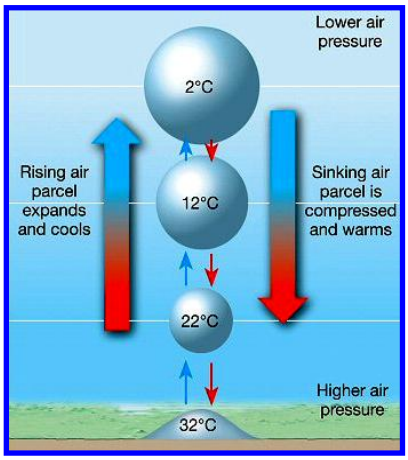
Chapter 5:
Condensation and Precipitation

- Formation of Condensation
  - Saturated Air
  - Condensation Nuclei
- Results of Condensation
  - Clouds
  - Fog
  - Dew
- Clouds
  - Cloud Classification
  - Cloud Descriptions
- Types of Fog
  - Formed by Cooling
  - Formed by Evaporation
- Precipitation Formation
  - Collision/Coalescence
  - Bergeron Process
- Types of Precipitation

Condensation

The most important cloud formation process is Adiabatic Cooling

- **As a parcel of air moves upward it experiences successively lower and lower pressure…**
- **And because the pressure is lower, the air expands…**
- **As air expands, it cools (lower internal density)**
- **Adiabatic Cooling: AIR RISES → EXPANDS → COOLS**



Adiabatic Cooling

- **Adiabatic Cooling:**
  - **AIR RISES → EXPANDS → COOLS**
- **[*Adiabatic Warming*]:**
  - **AIR SINKS → COMPRESSES → WARMS**
- ***The Rate is NEGATIVE as you rise (it gets cooler)***
- ***The Rate is POSITIVE as you descend (it gets warmer)***

– **Dry Adiabatic Rate:** **(this happens both rising and descending)**
10°C / 1000m or 5.5°F / 1000'
- **Dry rate = NO CONDENSATION OCCURING**

– **Wet Adiabatic Rate (average):** **(this happens while RISING ONLY)**
4°C / 1000m or 2.3°F / 1000'
- **Wet Rate = Dry rate + RELEASE OF LATENT HEAT (*from CONDENSATION*)**
- **The wet rate VARIES with the latent heat content of the air**

Condensation

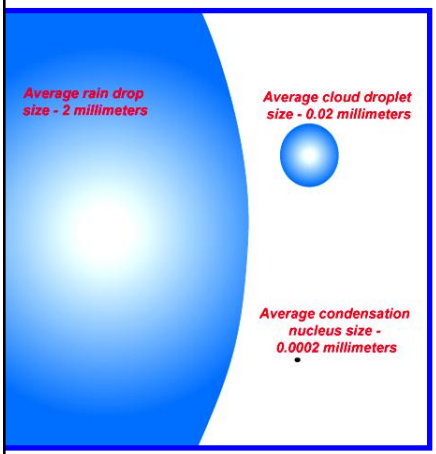
1) The Air must be SATURATED

- **Condensation Lifting Level**
- **Dew Point Temperature**
- **100% Relative Humidity**
- **Saturation**

2) Condensation Nuclei are needed

Cloud Condensation Nuclei

It takes 1,000+ cloud droplets to make one raindrop

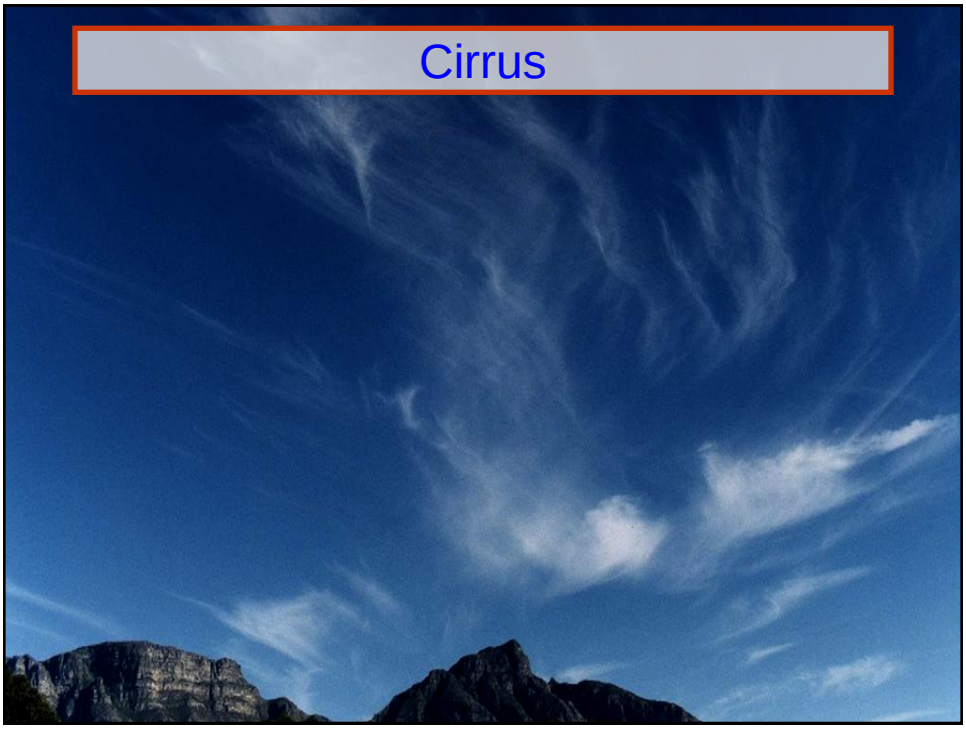


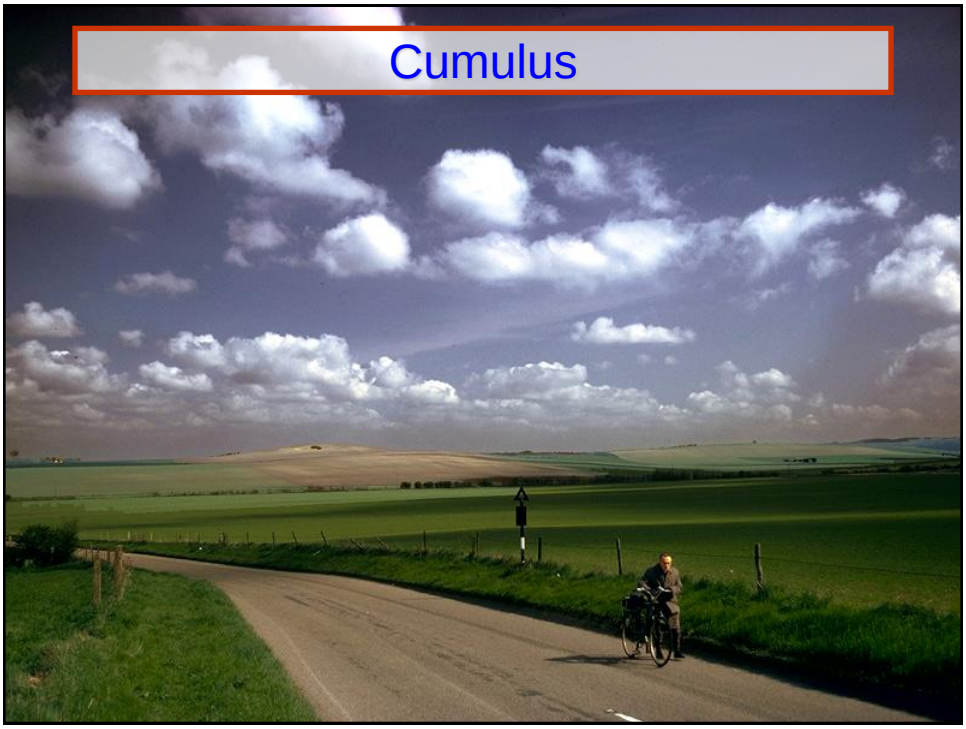
- **There needs to be a SURFACE onto which water vapor (gas) can condense.**
- **On the ground, dew forms when condensation forms on blades of grass**
- **In the atmosphere, tiny particles known as Condensation Nuclei serve as these "surfaces"**
- **Condensation Nuclei include:**
  - **Microscopic dust**
  - **Smoke**
  - **Salt**
  - **Bacteria (*recently reported in Science*)**

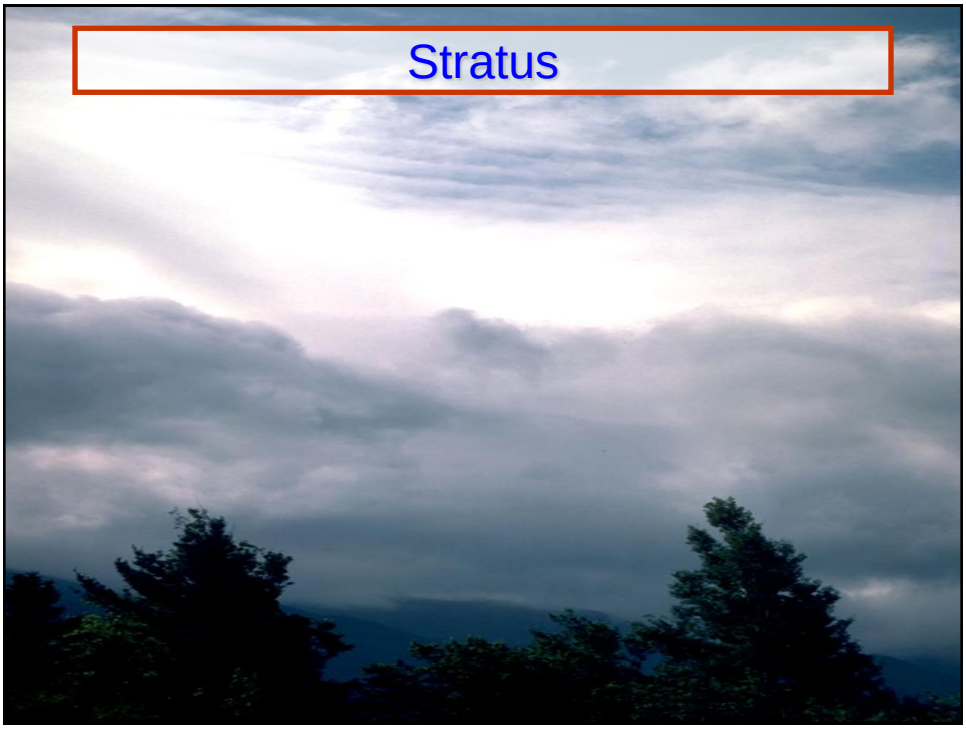
Cloud Classification: Form

- **Cirrus Clouds**
  - High, white and thin.
  - Separate and detached
  - Form delicate streaks or “wispy” fibers
  - Seem to have a feathery appearance
- **Cumulous Clouds**
  - Globular individual cloud masses
  - Often having a flat base and rise in towers
  - Seem to look like mashed potatoes
- **Stratus Clouds**
  - Look like sheets or layers
  - Most often cover the entire (or most of) the sky
  - Can be minor breaks, appear to be one continuous formation

Cirrus




Cumulus


Stratus

Cloud Classification: Height

- **High Clouds**
  - Bases at or above 6,000m (20,000 ft)
    - Cirrus
    - Cirrostratus
    - Cirrocumulus
  - Low temperatures and little water vapor
  - Clouds appear thin and white
  - Composed mostly of Ice Crystals
- **Middle Clouds**
  - Bases between 2,000 – 6,000m (6,500 – 20,000 ft)
  - All have ALTO as a prefix (middle)
    - Altocumulus
    - Altostratus
  - Similar to high clouds, but mostly composed of liquid water (not ice)

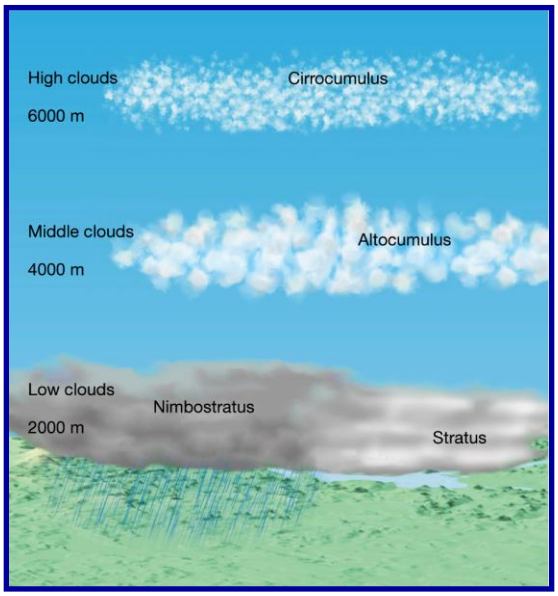
- **Low Clouds**
  - Bases below 2,000m (6,500 ft)
    - Stratus
    - Stratocumulus
    - Nimbostratus
  - More turbulence near surface produces a more chaotic mix
- **Clouds of Vertical Development**
  - Bases in low range, but extend upward into middle or high ranges
    - Cumulus
    - Cumulonimbus
  - Associated with instability, these clouds continue to rise and often are accompanied by precipitation
  - Nimbus = Rain

Cloud Descriptions

High Clouds (over 6,000m)

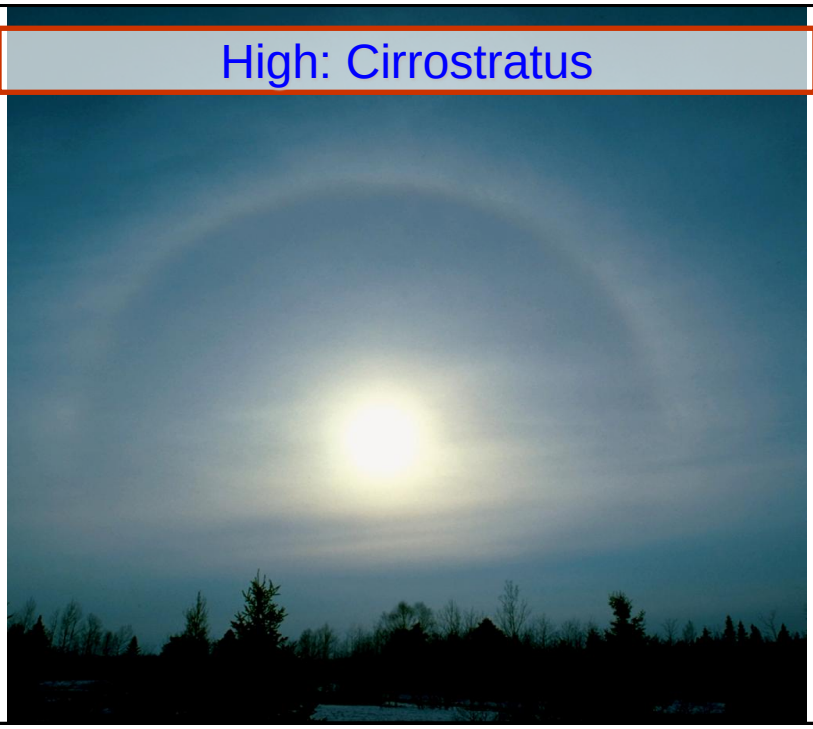
Middle Clouds (2,000-4,000m)

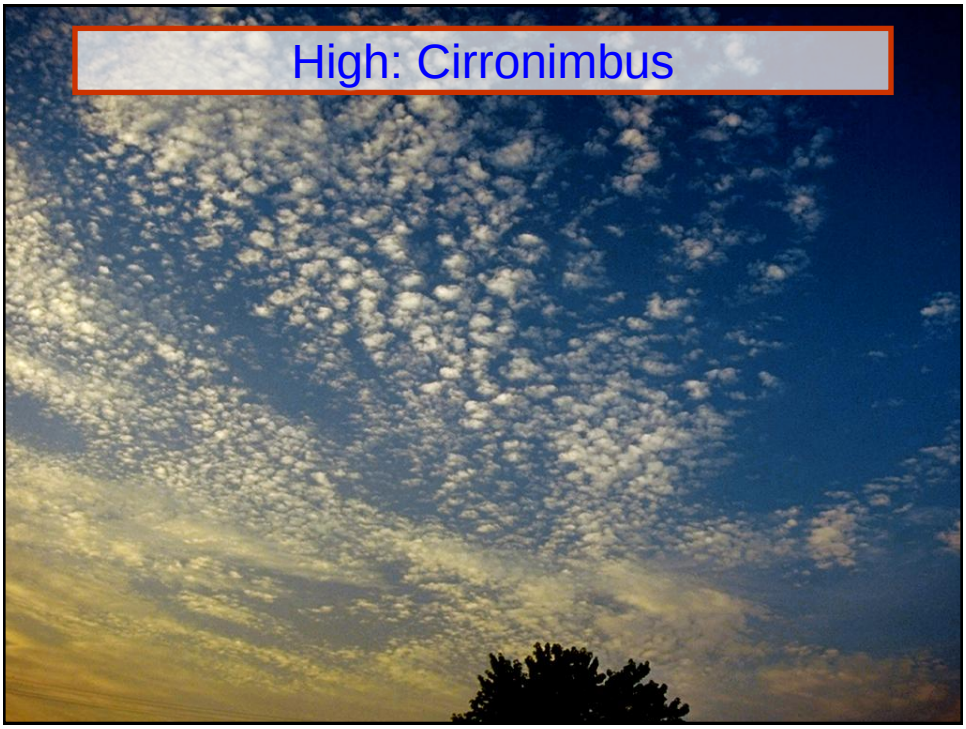
Low Clouds (under 2,000m)

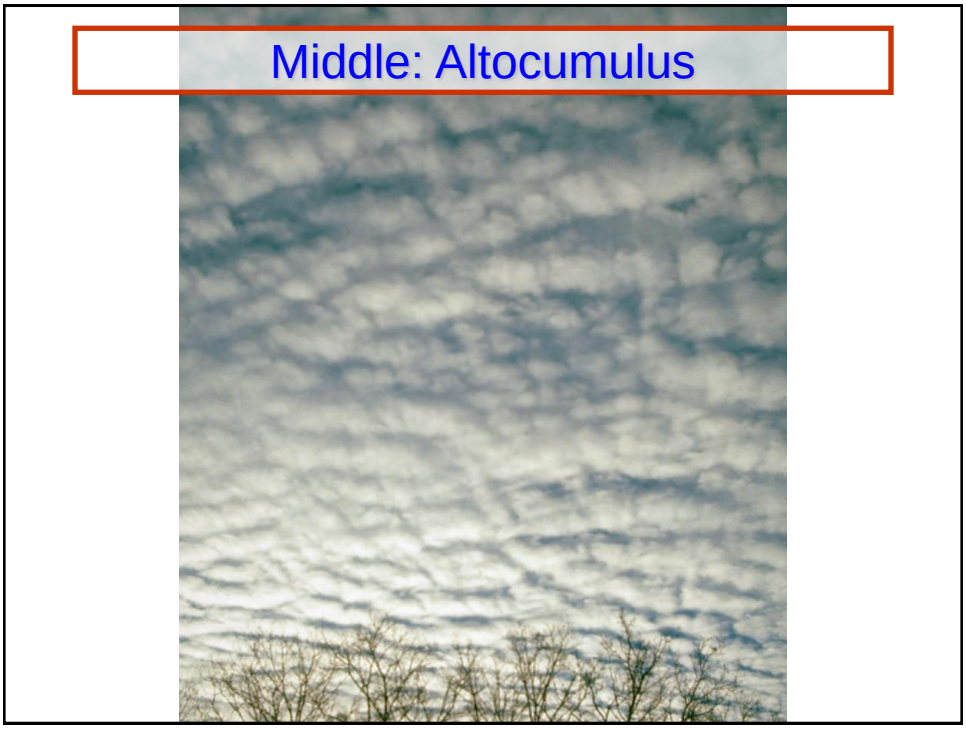


High: Cirrus

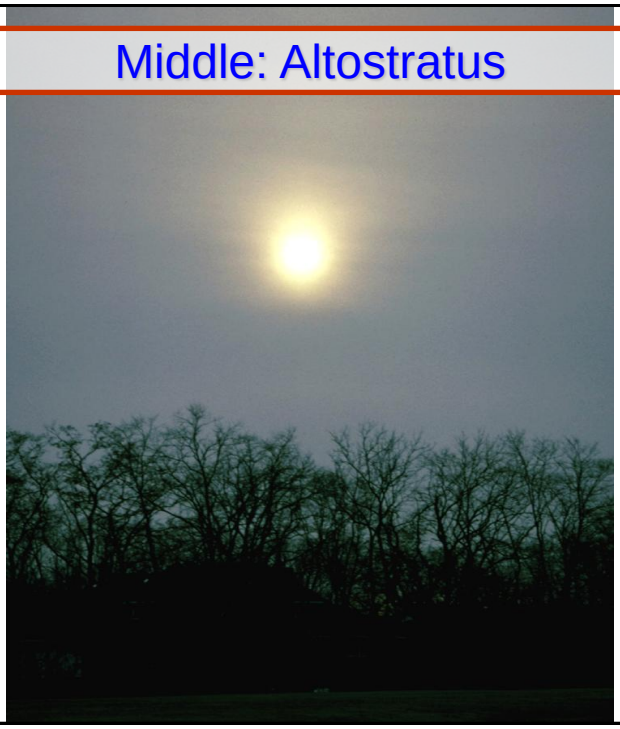
High: Cirrostratus



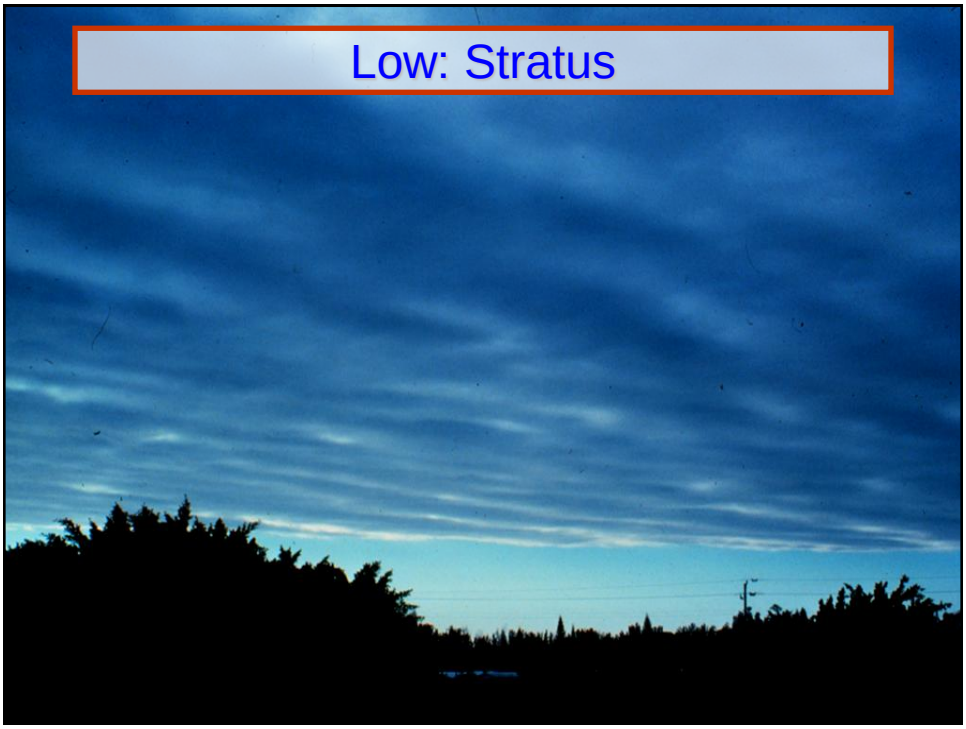

High: Cirronimbus


Middle: Altocumulus

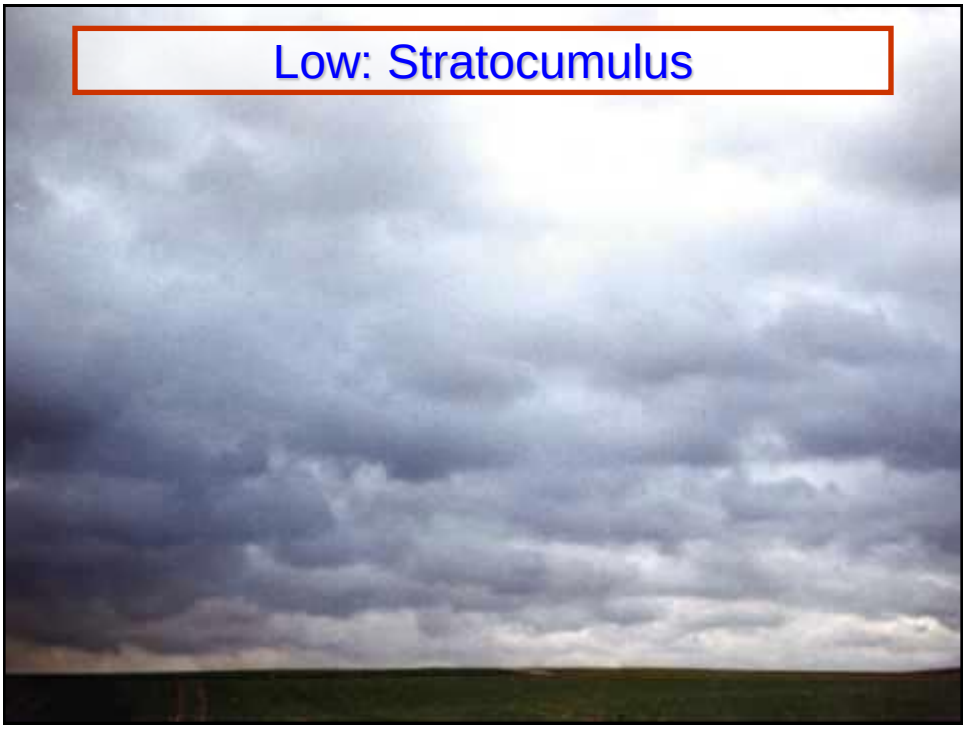
Middle: Altostratus



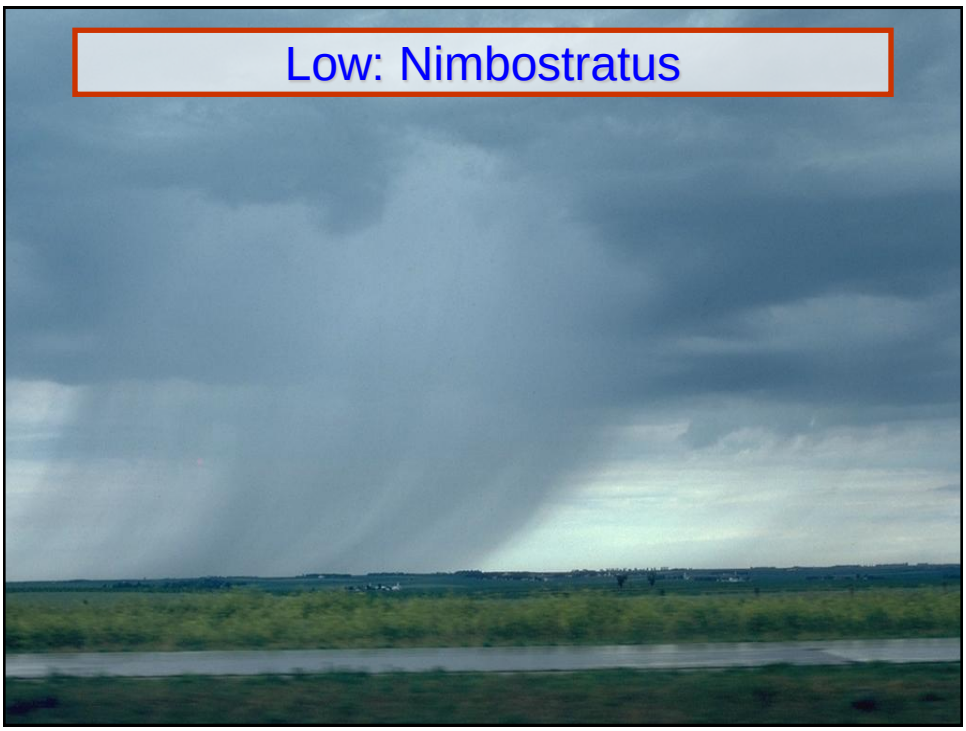
Low: Stratus

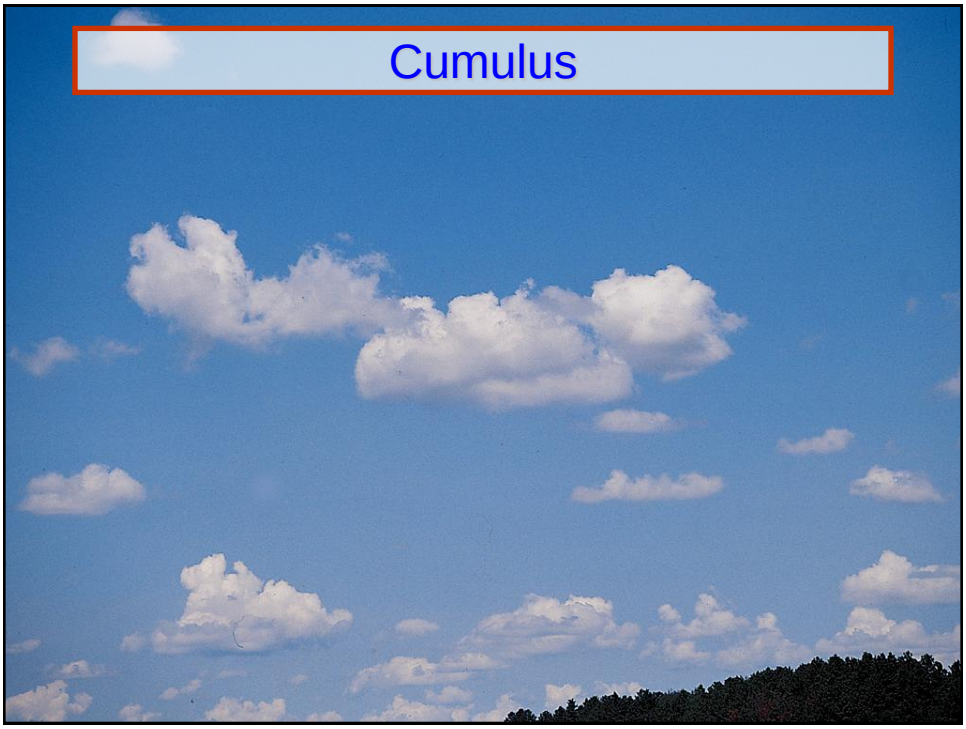


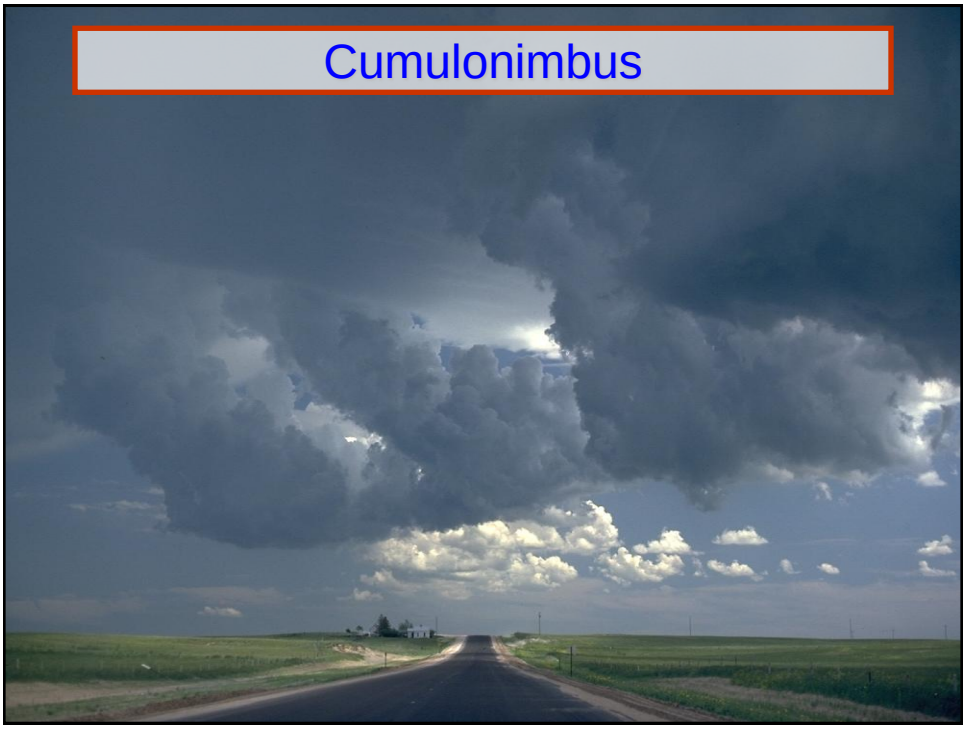
Low: Stratocumulus



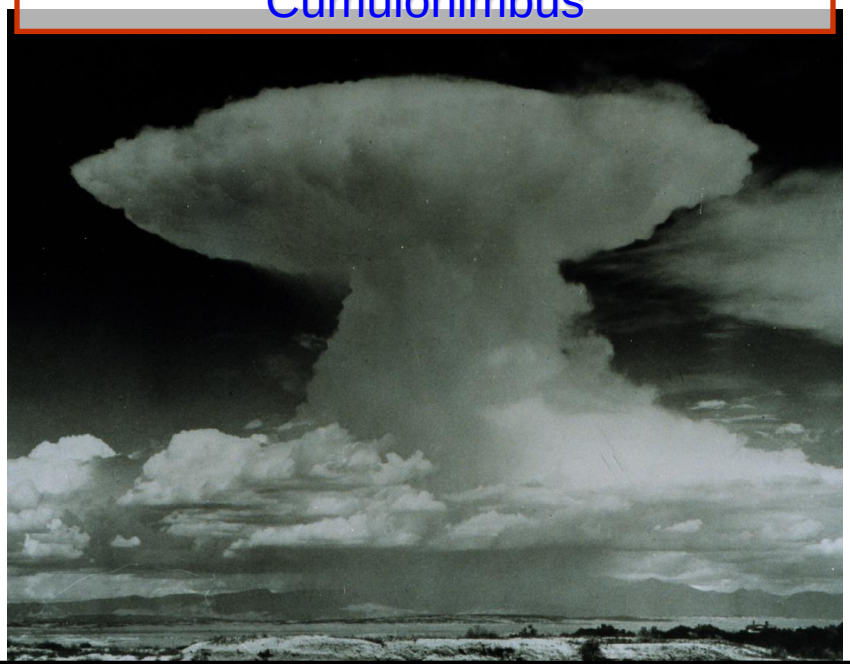
Low: Nimbostratus

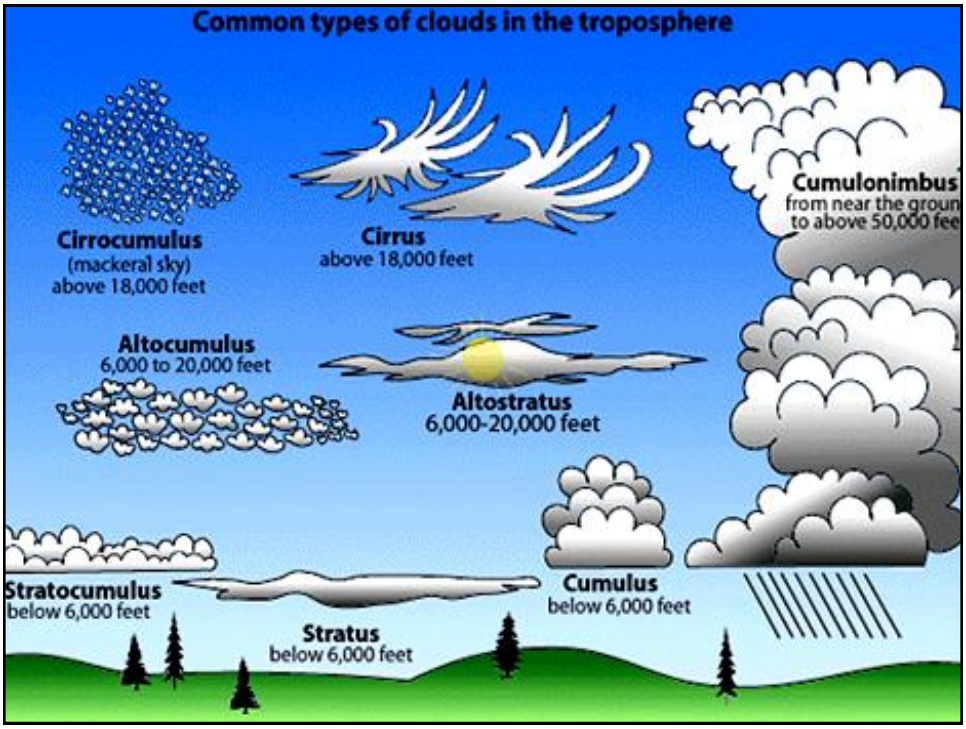


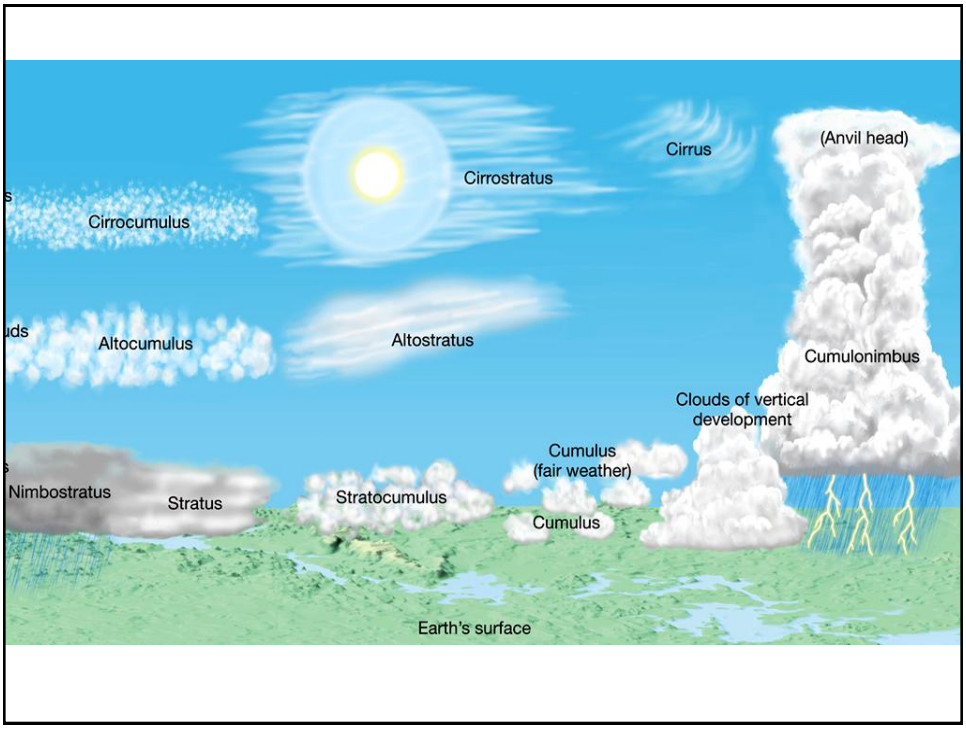

Cumulus

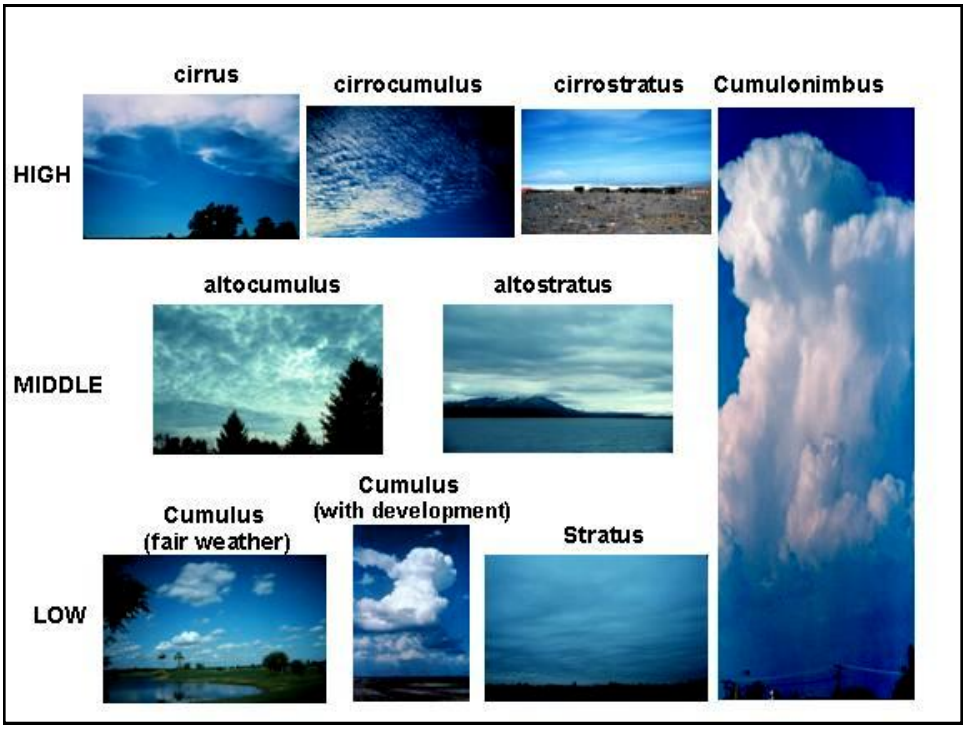

Cumulonimbus

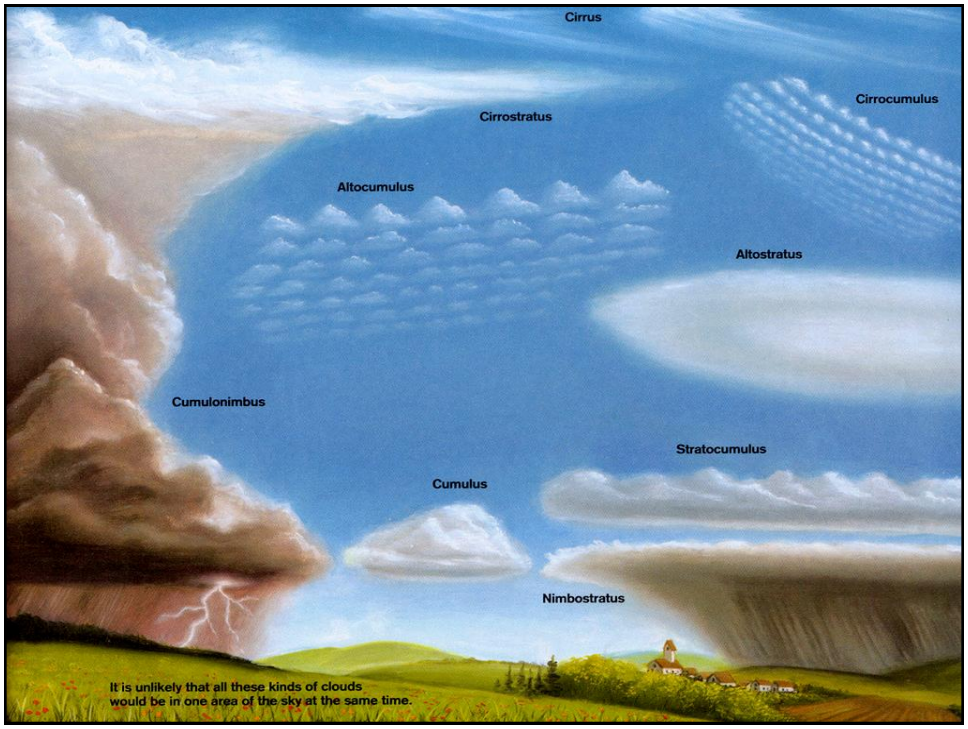
Cumulonimbus

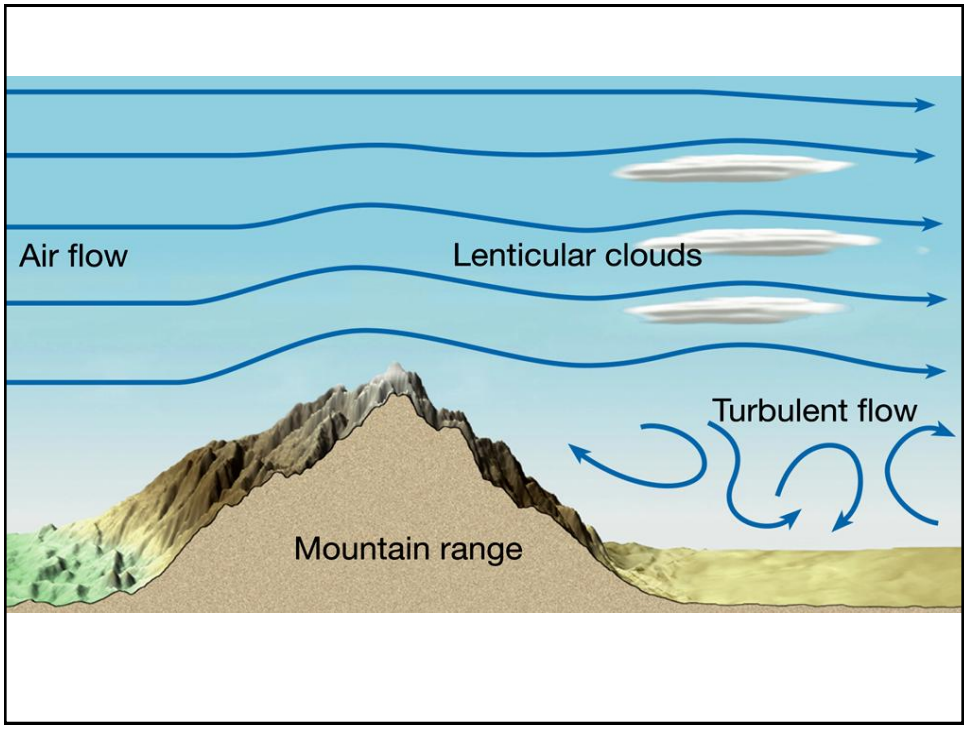





Cirrus
(Anvil head)
Cirrostratus
Cirrocumulus
Altocumulus
Altostratus
Cumulonimbus
Clouds of vertical development
Cumulus (fair weather)
Nimbostratus
Stratus
Stratocumulus
Cumulus
Earth's surface


cirrus
cirrocumulus
cirrostratus
Cumulonimbus
HIGH
altocumulus
altostratus
MIDDLE
Cumulus (with development)
Cumulus (fair weather)
Stratus
LOW


Cirrus
Cirrocumulus
Cirrostratus
Altocumulus
Altostratus
Cumulonimbus
Stratocumulus
Cumulus
Nimbostratus
It is unlikely that all these kinds of clouds would be in one area of the sky at the same time.


Air flow
Lenticular clouds
Turbulent flow
Mountain range

Types of Fog

- Types of Fog
  - Formed by cooling
  - Formed by evaporation
- Dew and Frost
- Precipitation Formation
  - Collision / Coalescence
  - The Bergeron Process
- Forms of Precipitation

Rain	**Snow**	**Hail**
Sleet	**Glaze**	**Rime**

- Weather Modification

Fog

Fog: A cloud with its base at or very near the ground

Fogs formed by Cooling:

Radiation Fog: Fog resulting from the radiation cooling of the ground and the adjacent air.

Advection Fog: Fog resulting when warm moist air is blown over a cold surface

Upslope Fog: Fog resulting from orographic uplift and adiabatic cooling

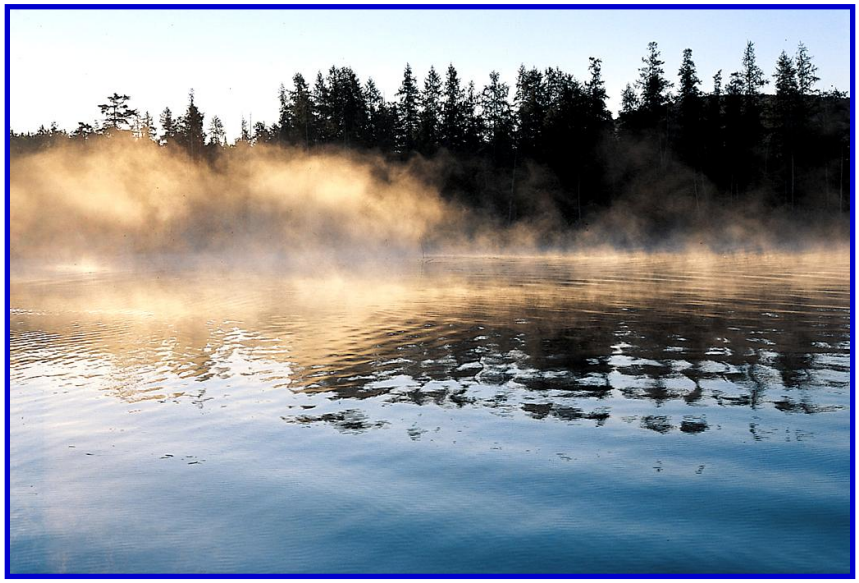
Fogs formed by Evaporation:

Steam Fog: Fog resulting when cold air moves over a warm lake

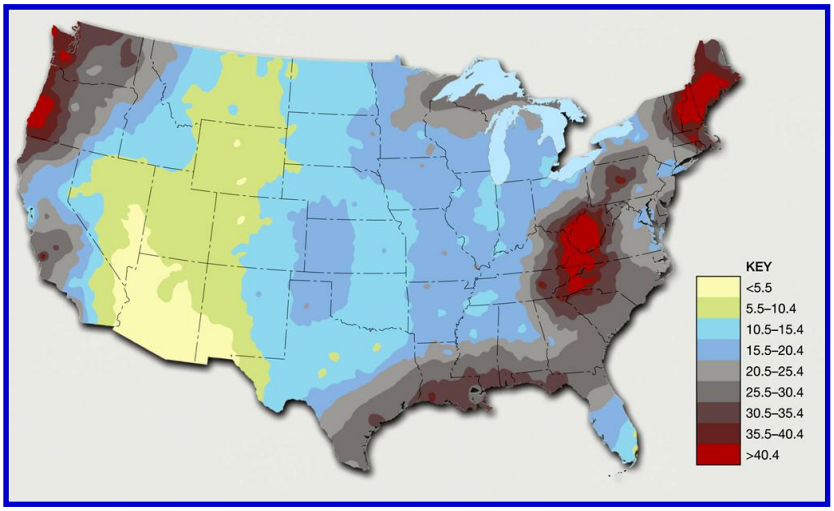
Frontal Fog: Fog resulting from rain evaporating in cold air, and condensing as fog

Fog

Fog



Fog



Dew and Frost

Dew: Condensation on surfaces that are below the dew point temperature of the surrounding air

Frost: Deposition (gas to solid) of water vapor onto surfaces that are below freezing.
Frost is NOT frozen Dew!

Precipitation Formation

Condensation does NOT produce rain!
Condensation produces CLOUDS!
Precipitation forms within clouds in two ways…

In Warm Clouds: Collison / Coalescence

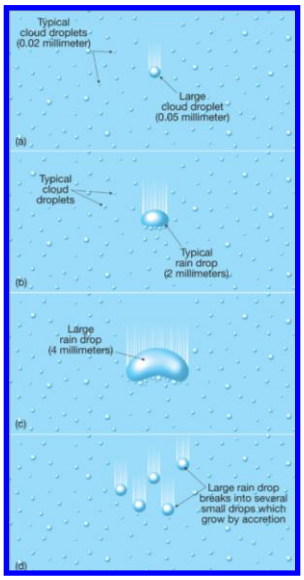
In Cold Clouds: The Bergeron Process

Collision / Coalescence

~ warm cloud process~

Collision/Coalescence:

- Cloud droplets are in motion within the cloud
- These droplets randomly collide with other droplets
- They coalesce (join together) and form a larger droplet
- This process continues until a rain drop forms (big enough to fall)

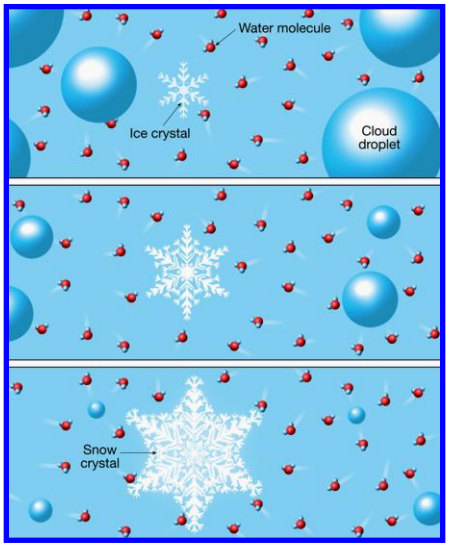


The Bergeron Process

~ cold cloud process~

The Bergeron Process:

- The cloud (at least the tops) are below freezing
- Cloud droplets *do not* freeze at 0°C… (it is closer to -40°C!)
- This property of water is called supercooled water
- Supercooled water will freeze on contact with an object (freezing rain/glaze)

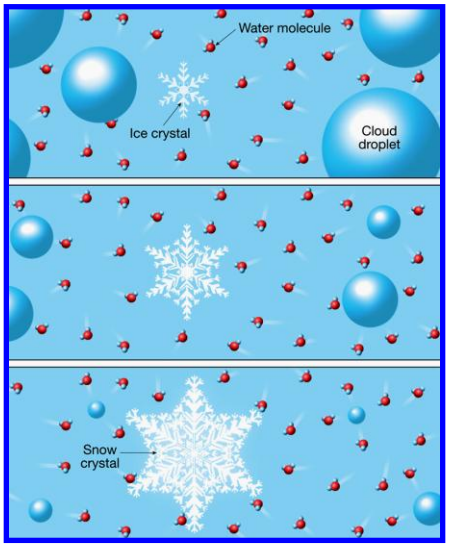


The Bergeron Process

~ cold cloud process~

The Bergeron Process:

- Freezing Nuclei are needed to form precipitation in the cloud (Note: These are NOT the same as Condensation Nuclei)
- The supercooled cloud droplets will evaporate into the air…
- …and then deposit (gas → solid) onto the freezing nuclei
- This forms snow crystals



Forms of Precipitation

Rain: **Drops of water that fall from a cloud**

Snow: Ice crystals (snow flakes) or clusters of crystals that fall from a cloud

Sleet: Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze

Glaze: Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects

Hail: Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.
Largest US hailstone = 7"+ diameter = volleyball-sized

Rime: Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Forms of Precipitation

Rain: Drops of water that fall from a cloud

Snow: **Ice crystals (snow flakes) or clusters of crystals that fall from a cloud**

Sleet: Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze

Glaze: Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects

Hail: Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.
Largest US hailstone = 7"+ diameter = volleyball-sized

Rime: Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Forms of Precipitation

Rain: Drops of water that fall from a cloud

Snow: Ice crystals (snow flakes) or clusters of crystals that fall from a cloud

Sleet: **Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze**

Glaze: Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects

Hail: Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.
Largest US hailstone = 7"+ diameter = volleyball-sized

Rime: Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Forms of Precipitation

Rain: Drops of water that fall from a cloud

Snow: Ice crystals (snow flakes) or clusters of crystals that fall from a cloud

Sleet: Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze

Glaze: **Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects**

Hail: Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.
Largest US hailstone = 7"+ diameter = volleyball-sized

Rime: Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Forms of Precipitation

Rain: Drops of water that fall from a cloud

Snow: Ice crystals (snow flakes) or clusters of crystals that fall from a cloud

Sleet: Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze

Glaze: Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects

Hail: **Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.**
Largest US hailstone = 7"+ = volleyball-sized

Rime: Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces

Hail

Rain:

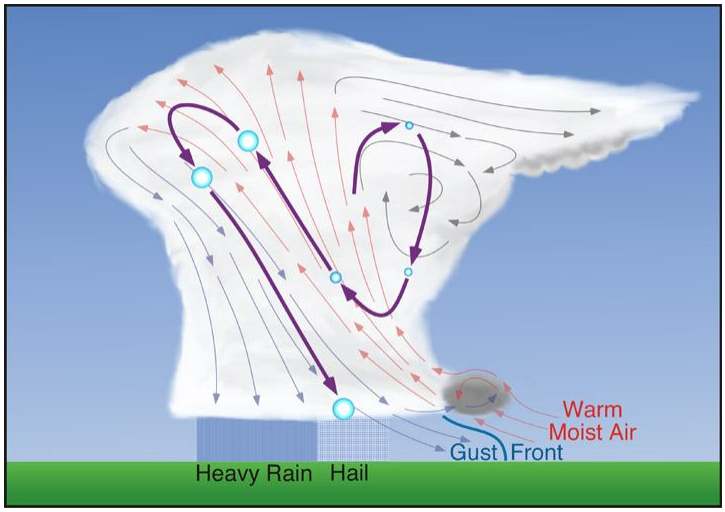
Snow:

Sleet:

Glaze:

Hail:

Rime:



Forms of Precipitation

Rain:

Snow:

Sleet:

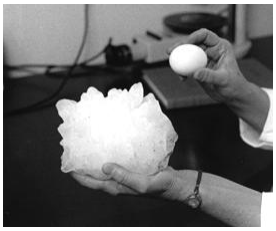
Glaze:

Hail:

Rime:

Largest US Hailstone – In South Dakota

Weight: 1.9 pounds
Diameter: 8.1 inches
Circumference: 18.8 inches



Forms of Precipitation

Rain: Drops of water that fall from a cloud

Snow: Ice crystals (snow flakes) or clusters of crystals that fall from a cloud

Sleet: Frozen raindrops. Occurs when liquid rain falls through a cold lower layer and the drops freeze

Glaze: Occurs when liquid rain falls onto objects that are below freezing (or the air near the ground is below freezing), causing a coating of ice to form on the objects

Hail: Frozen ball of ice formed in the updrafts of a powerful cloud. Multiple trips up and down through the cloud produce semi-concentric layers of ice.
Largest US hailstone = 7"+ diameter = volleyball-sized

Rime: **Deposition (gas → solid) forms from supercooled fog or cloud droplets onto below freezing surfaces**

Forms of Precipitation

Rain:

Snow:

Sleet:

Glaze:

Hail:

Rime:

Weather Modification

Intentional methods of modifying the Weather

Cloud Seeding: Intentional injection of condensation nuclei (or freezing nuclei) into a cloud to induce precipitation (usually for a beneficial outcome, i.e. ease drought conditions)

Fog and Cloud Dispersal: Attempts to induce precipitation in order to remove the droplets from the air (often as an aid to visibility)

Hail Suppression: Attempts to limit or stop the formation of hail within large cloud banks

Frost Prevention: Involve either heating the air near the ground, or insulating the objects needing protection (often fruit crops) Spraying water can prevent fruit freezing.

ONLY PROVEN METHOD!