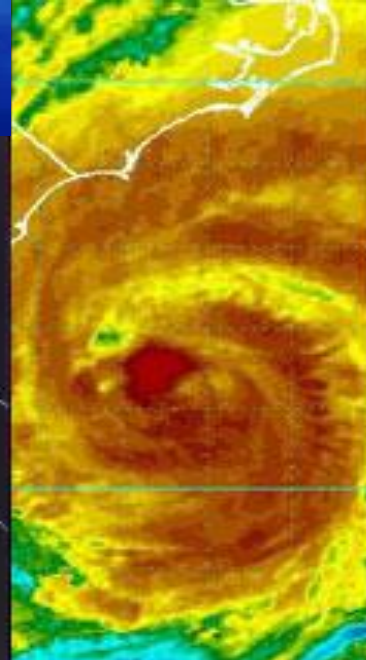


PART 3

Clouds



Clouds

A cloud is a visible mass of billions of tiny water droplets or ice crystals suspended in the atmosphere.

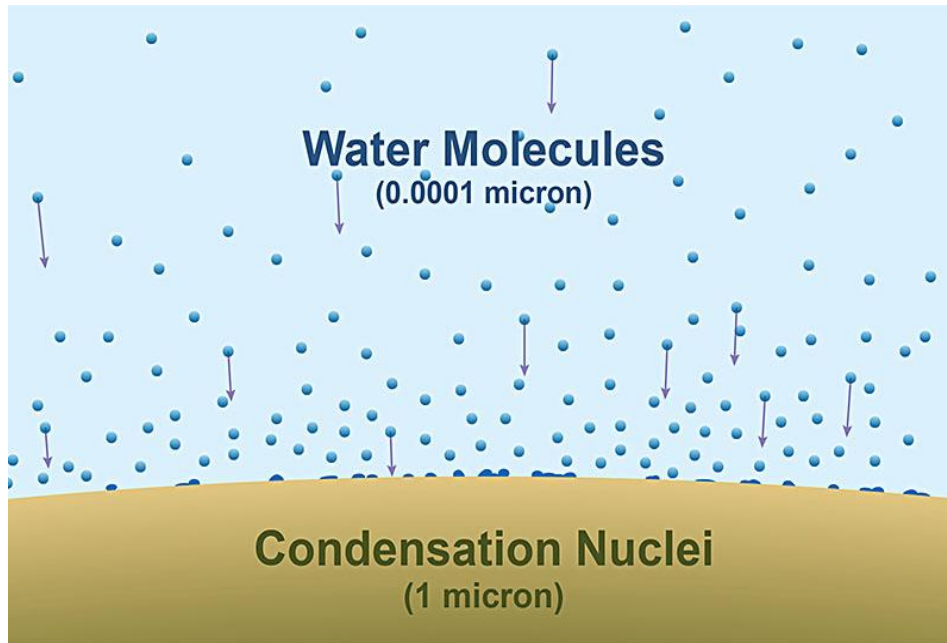
- In general, clouds develop in any air mass that becomes **saturated** (*relative humidity* becomes 100%).
- Saturation occurs due to either or both of two processes: **cooling of the air** and **adding water vapor**.



- Ingredients required for cloud formation:
 - water vapor (water in a *gaseous state*)
 - cooling conditions
 - a surface to condense/deposit on (*condensation nuclei*)

Condensation Nuclei

Similar to *dew* and *frost*, water vapor requires a surface of some sort to condense on - we call these airborne particles **cloud condensation nuclei**.



- **Terrestrial Sources**
 - Dust/sand/dirt particles
 - Smoke - volcanic, fires, and pollution
 - Pollens and spores
- **Oceanic Sources**
 - Sea Salts

- **Typical size ~1-100 μ m.**

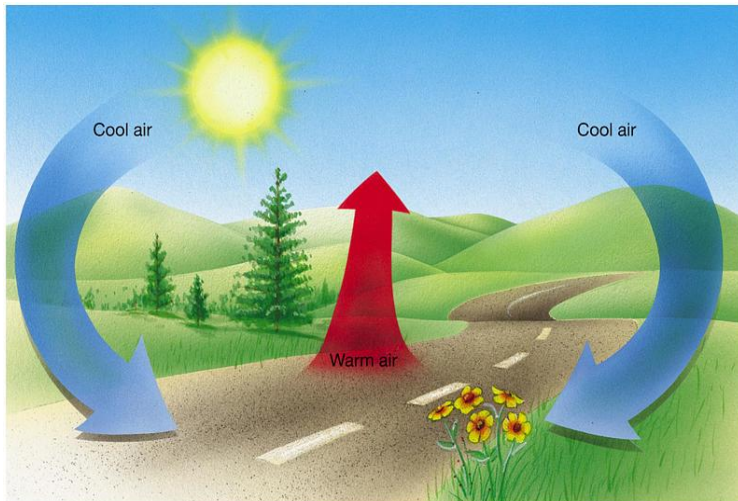
Without these particles clouds would not form!

Cooling Conditions

Generally, the air must rise in order for it to cool.

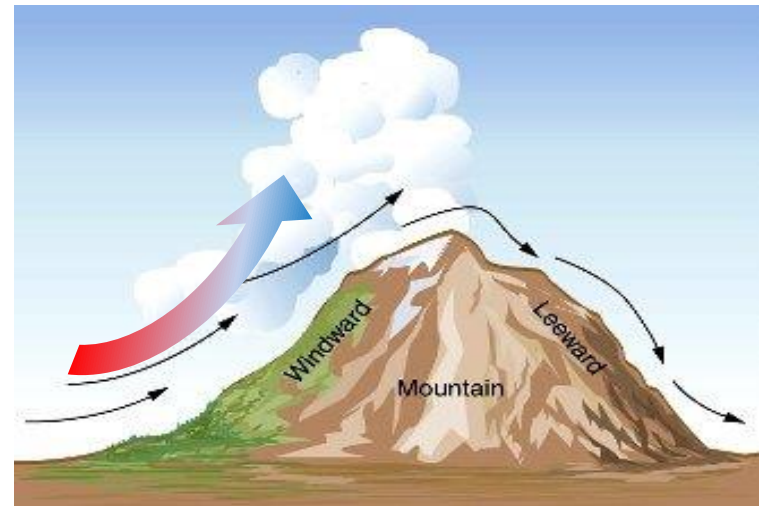
What can cause the air to rise?

Convictional lifting is associated with heating of the air at the ground surface. This process is active in the interior of continents and near the equator.



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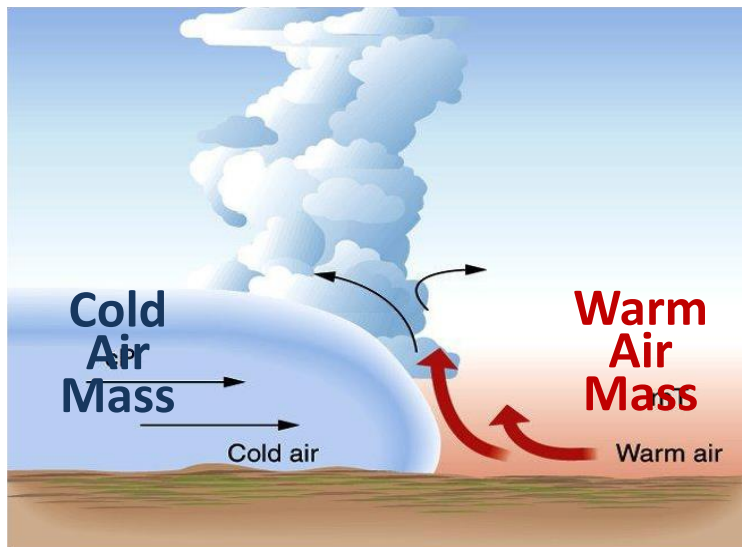
Orographic uplift occurs when air is forced to rise because of the physical presence of elevated land such as mountains.



Cooling Conditions

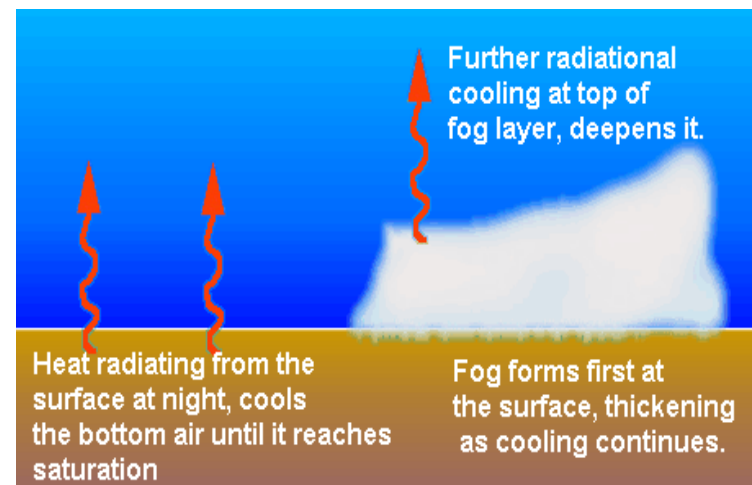
rising air

Frontal lifting (convergence) takes place when two masses of air come together. This mechanism of cloud formation is common at mid-latitudes.



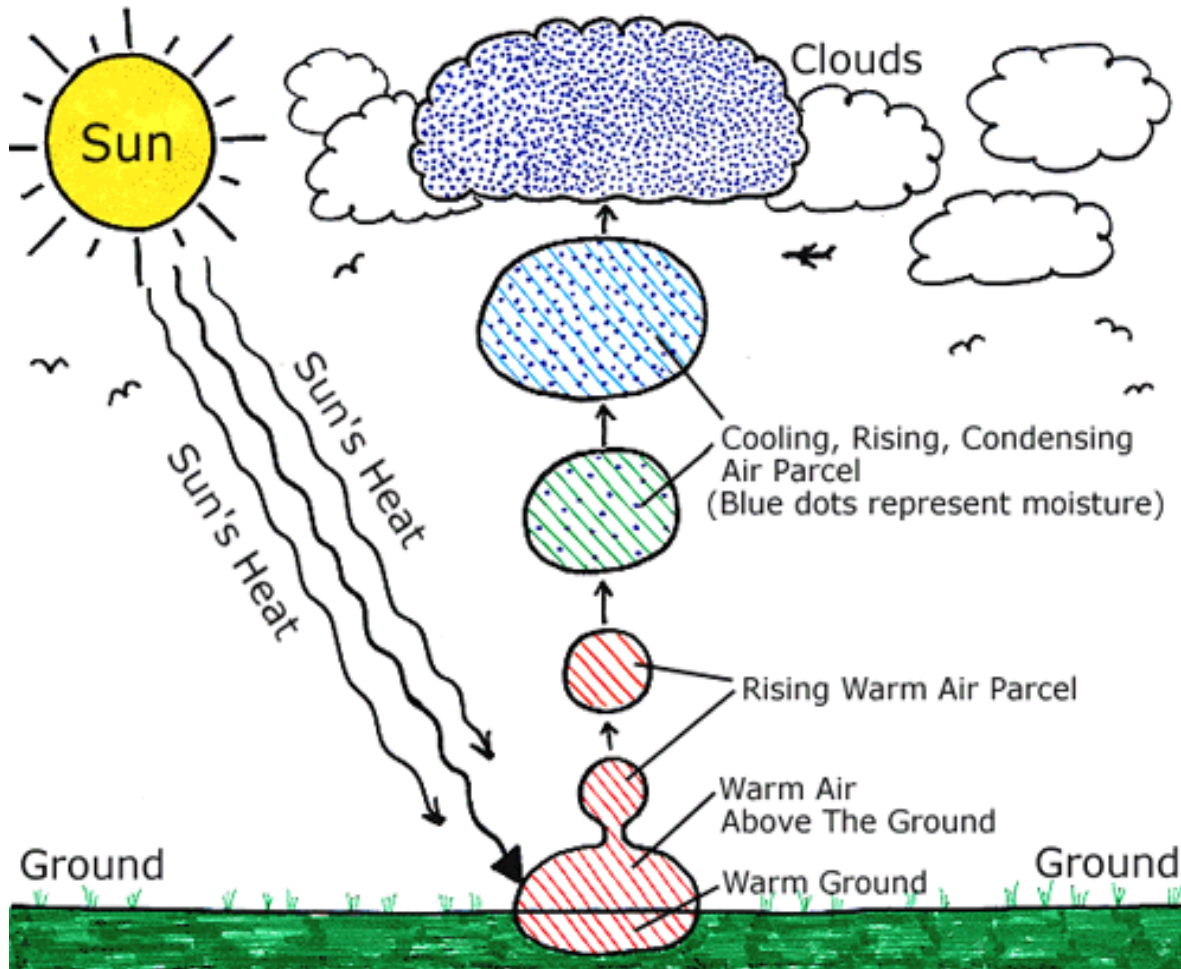
rapid surface cooling

Radiative cooling occurs when the Sun is no longer supplying the ground and overlying air with energy (that is, **night time**). The clouds that result from this type of cooling take the form of surface fog.



Basic Cloud Formation

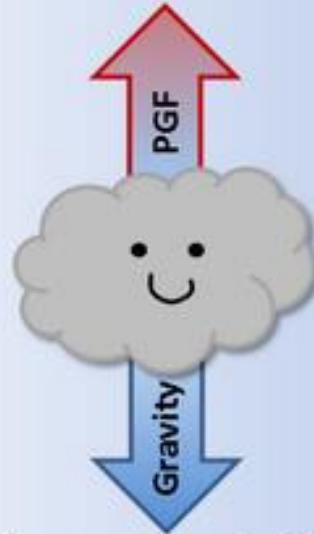
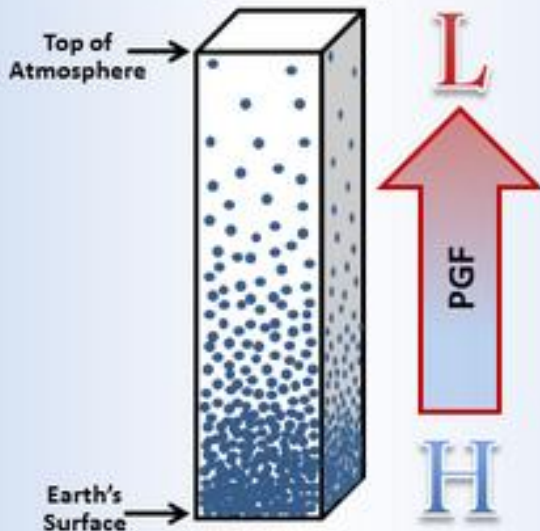
As the air rises, it encounters **less pressure**.
The air parcels **expand and cool** (called *adiabatic cooling*).



- When the air is **cooled to the dew point**, condensation occurs and clouds begin to form.
 - At **higher altitudes**, the dew point is the **frost point**, so water vapor deposition occurs resulting in **ice clouds** formation.

Floating Conditions

Pressure decreases with height (fewer air molecules weigh down on you from above the higher up you are). Since air flows from higher to lower pressure, this creates an upward *pressure gradient force* (PGF). So what keeps the atmosphere from rushing off into space?



The downward gravitational force is balanced by the upward PGF. This keeps clouds from falling from the sky and the atmosphere from rushing off into space! Meteorologists call this *hydrostatic equilibrium*.

- Clouds exist in the moving air: rising up due to *pressure gradient* or pushed along by wind.
- Moving air creates a drag force.

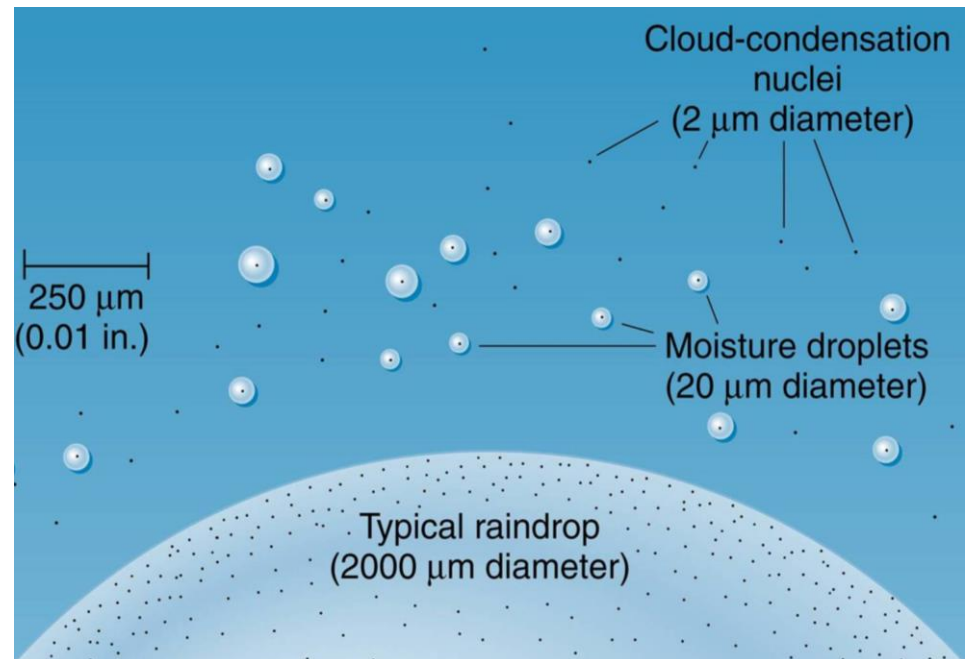


- A **cloud will float** as long as the **drag force** of the air **dominates over** the **gravitational force** for its constituent water droplets.

Precipitation

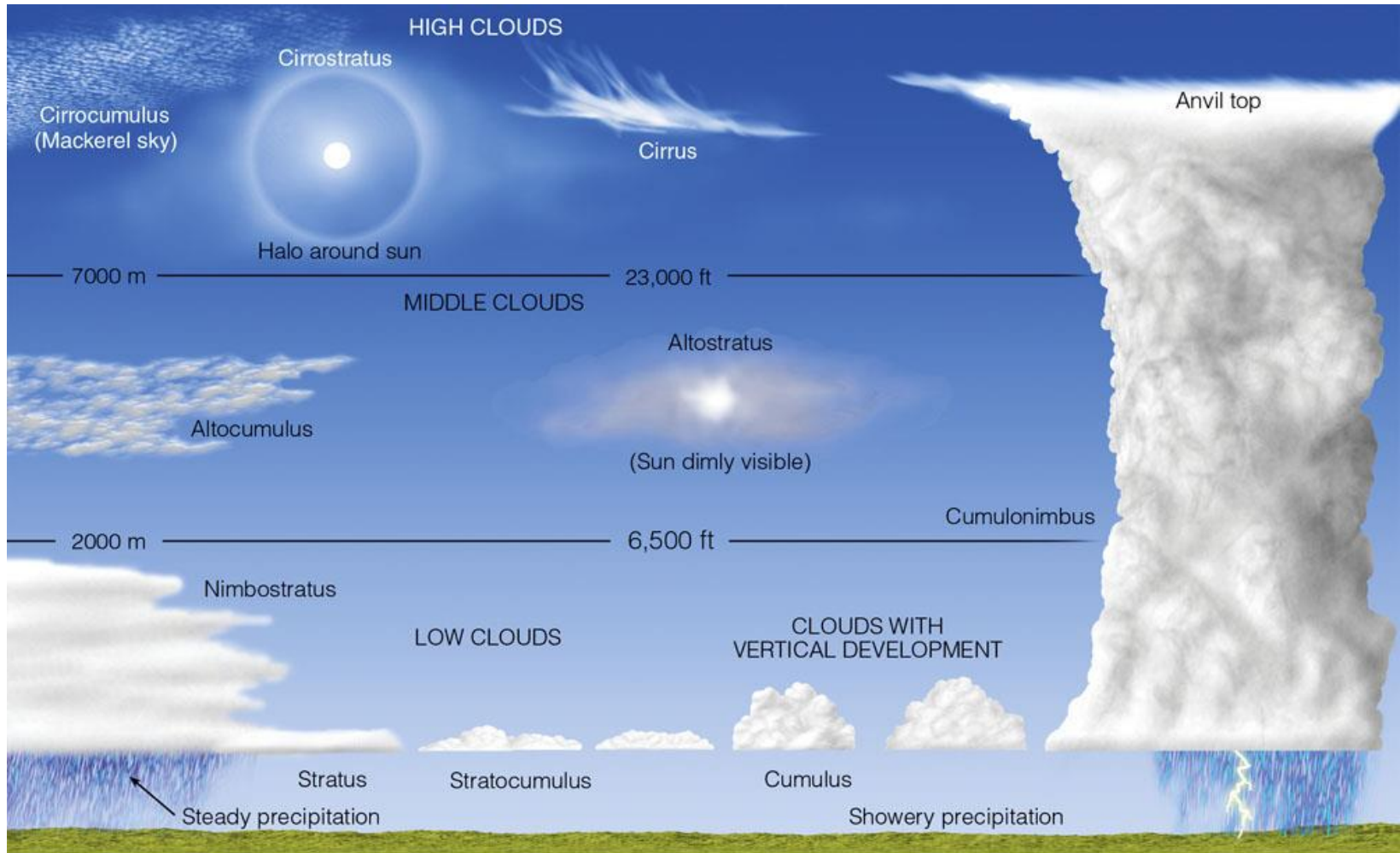
Droplets suspended in the air will **interact with each other**, either by **colliding and bouncing off** each other or by **combining to form a larger droplet**.

- Eventually, they become large enough so that the acceleration due to gravity is much larger than the acceleration due to drag.



- These **relatively large droplets** than fall to the ground as precipitation.

Clouds Classification



Based on:

- altitude of their bases/bottoms (*alto, strato*)
- shape (*cumulus, cirrus*)
- presence of rain (*nimbus*)

Thunderstorm

A thunderstorm (aka an *electrical storm*, a *lightning storm*, or a *thundershower*) is a type of storm characterized by the presence of **lightning** and its acoustic effect, **thunder**.

Thunderstorms result from the rapid upward movement of warm, moist air.

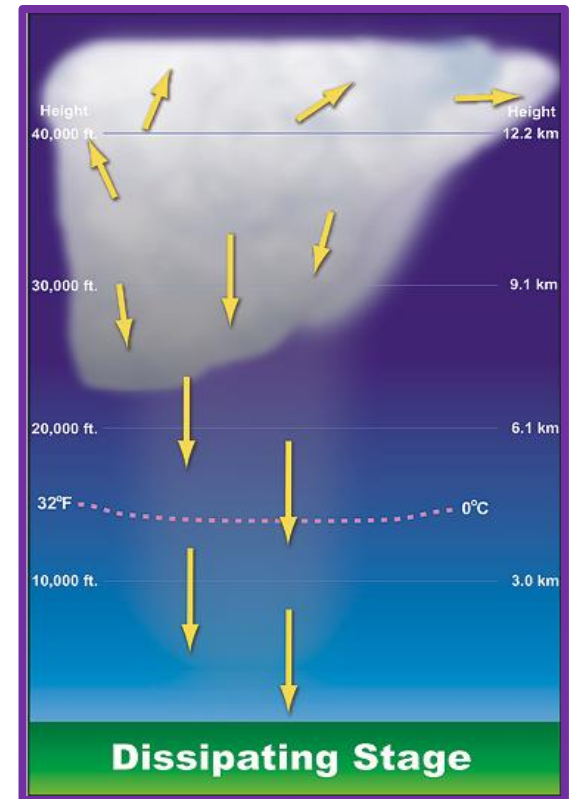
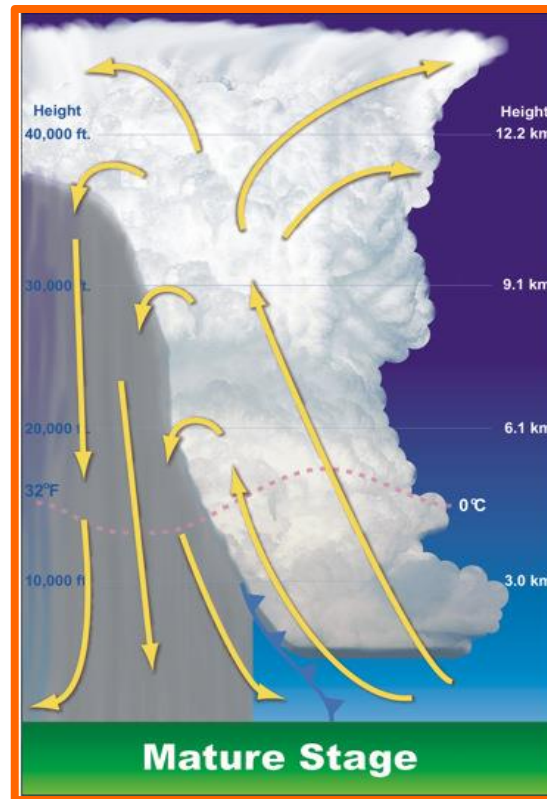
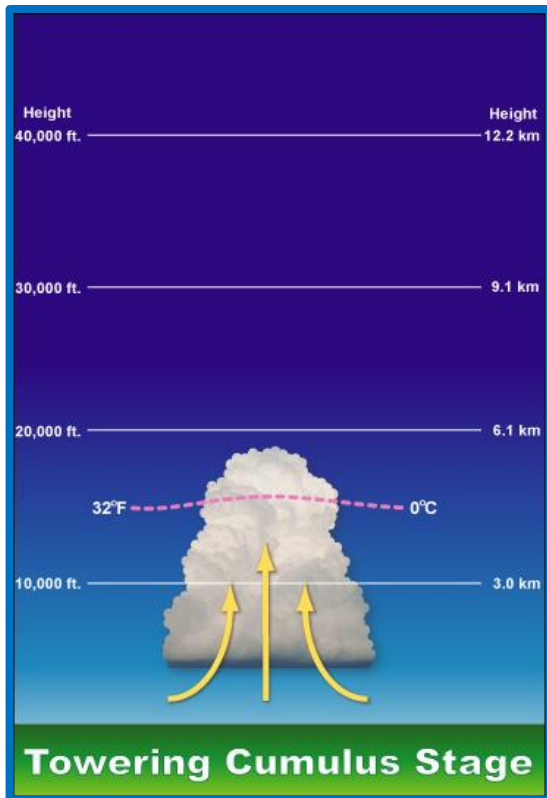


- In the Northern hemisphere, especially in North America, thunderstorms occur most often **between the months of March and September**.
- In a typical thunderstorm, approximately **500,000,000 kg** (~1.1 billion lb) of **water vapor** are **lifted** into the Earth's atmosphere.
- Thunderstorms have also been observed on **Jupiter** and **Venus**.

Thunderstorm Lifecycle

All thunderstorms go through the following three stages:

- **developing** stage aka **cumulus** stage
- **mature** stage
- **dissipation** stage



Depending on the atmospheric conditions, the **full cycle** takes an average of **30-60 minutes** to go through.