

Clouds

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

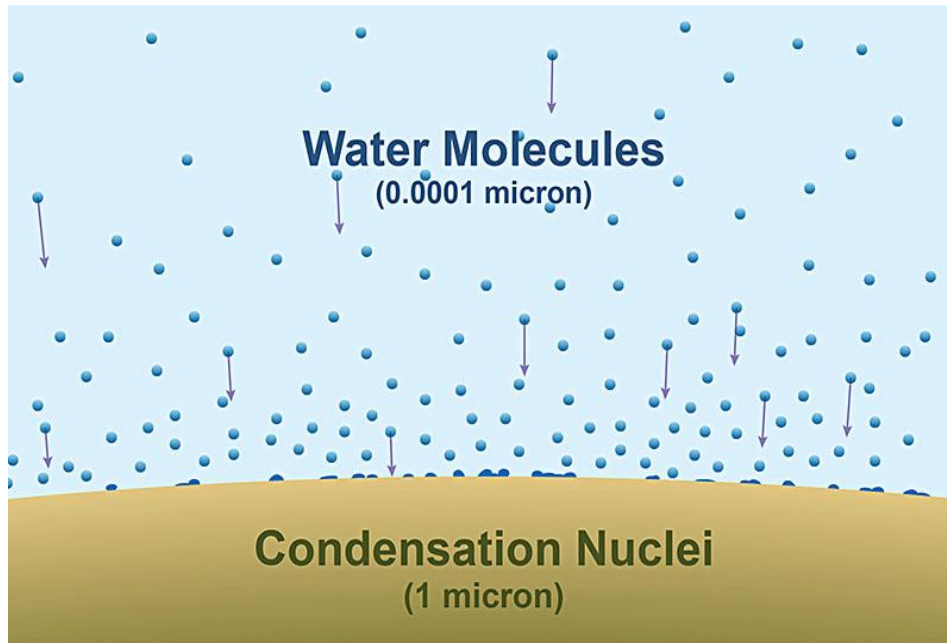
- In general, clouds develop in any air mass that becomes **saturated** (*relative humidity* becomes 100%).
- Saturation occurs due to either or both of two processes: **cooling of the air** and **adding water vapor**.



- 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 $\sim 1\text{-}2\ \mu\text{m}$ but can be as large as $100\ \mu\text{m}$.

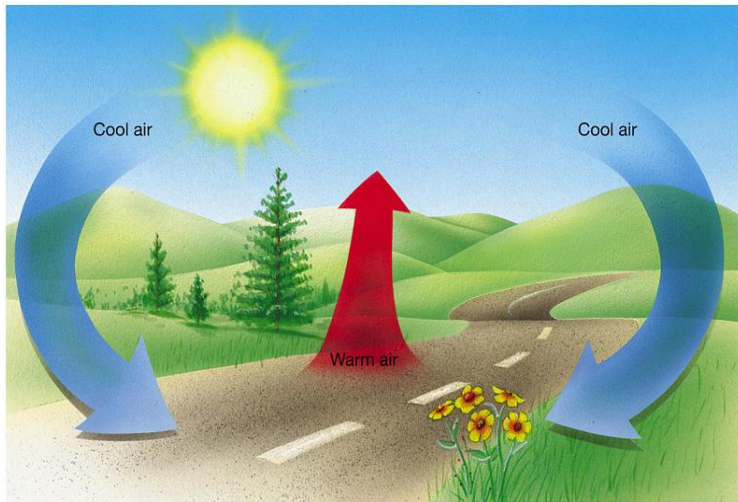
Without these particles, clouds would not form!

Cooling Conditions

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

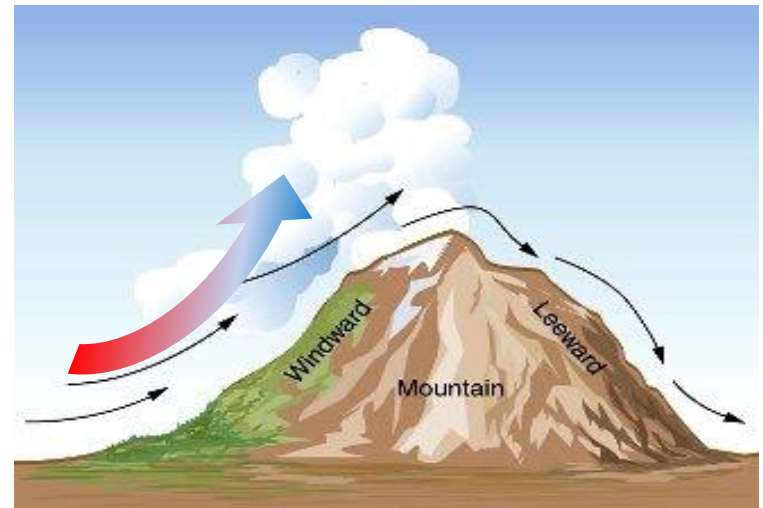
What can cause the air to rise?

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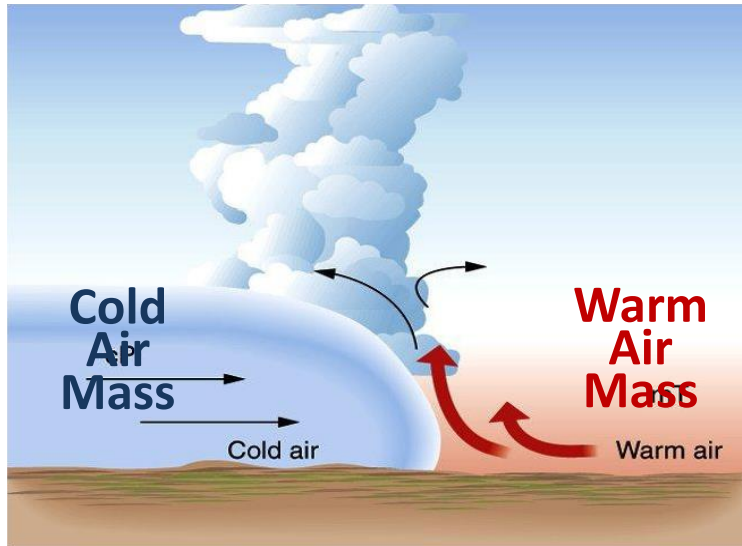
Orographic uplift occurs when air is forced to rise because of the physical presence of **elevated land** such as **mountains**.



Cooling Conditions

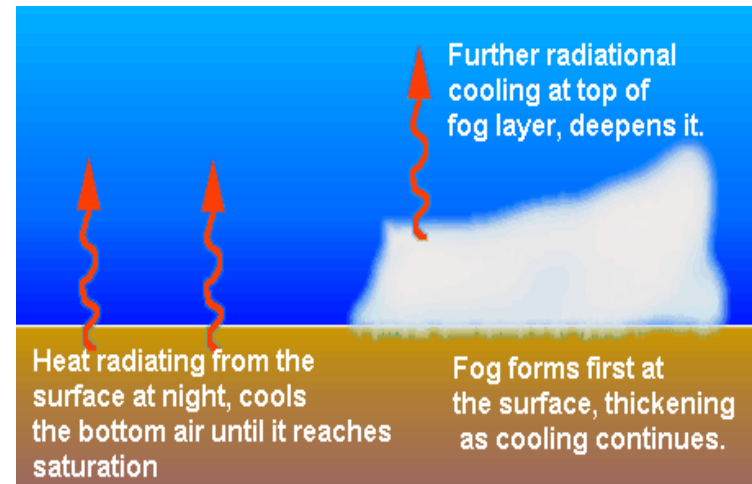
rising air

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



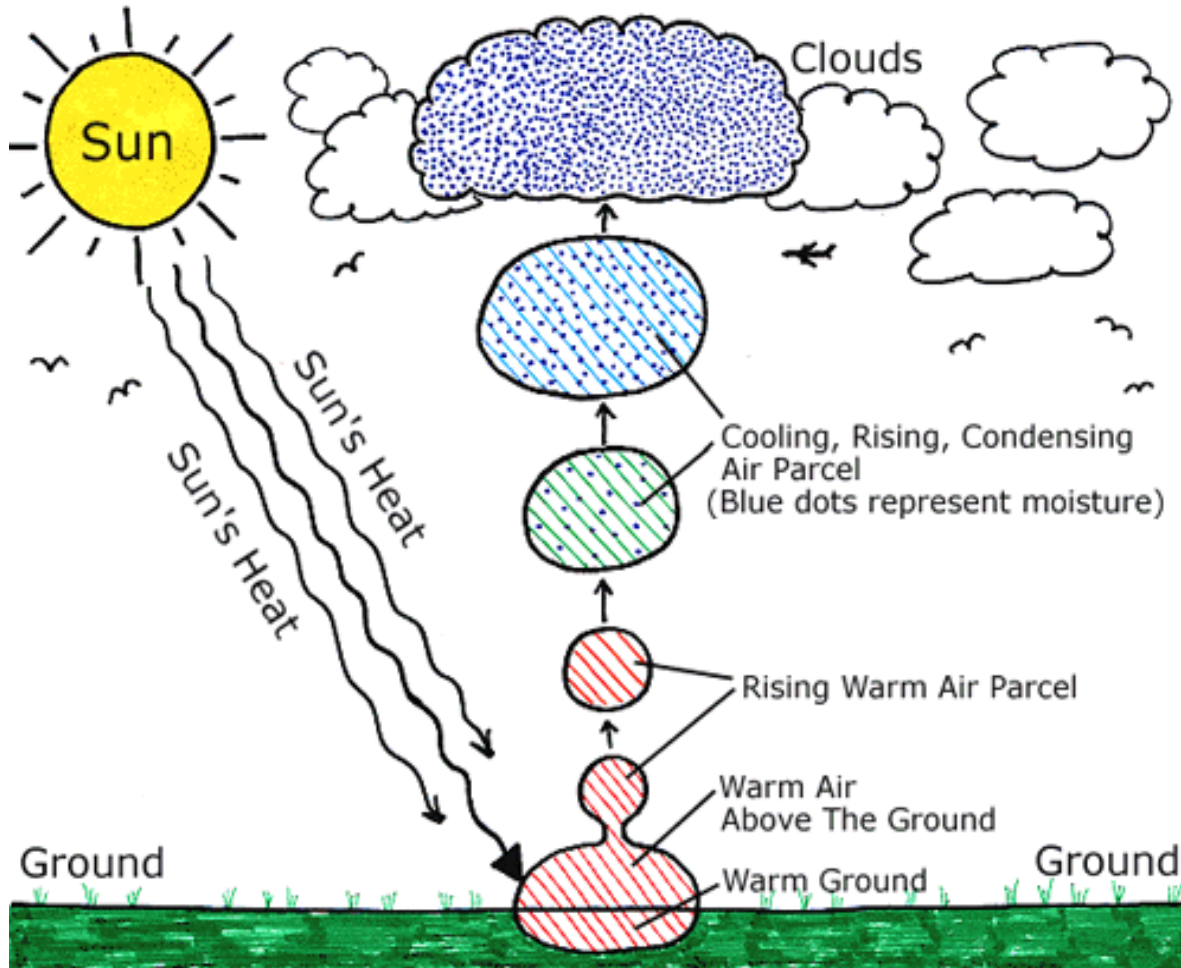
rapid surface cooling

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.



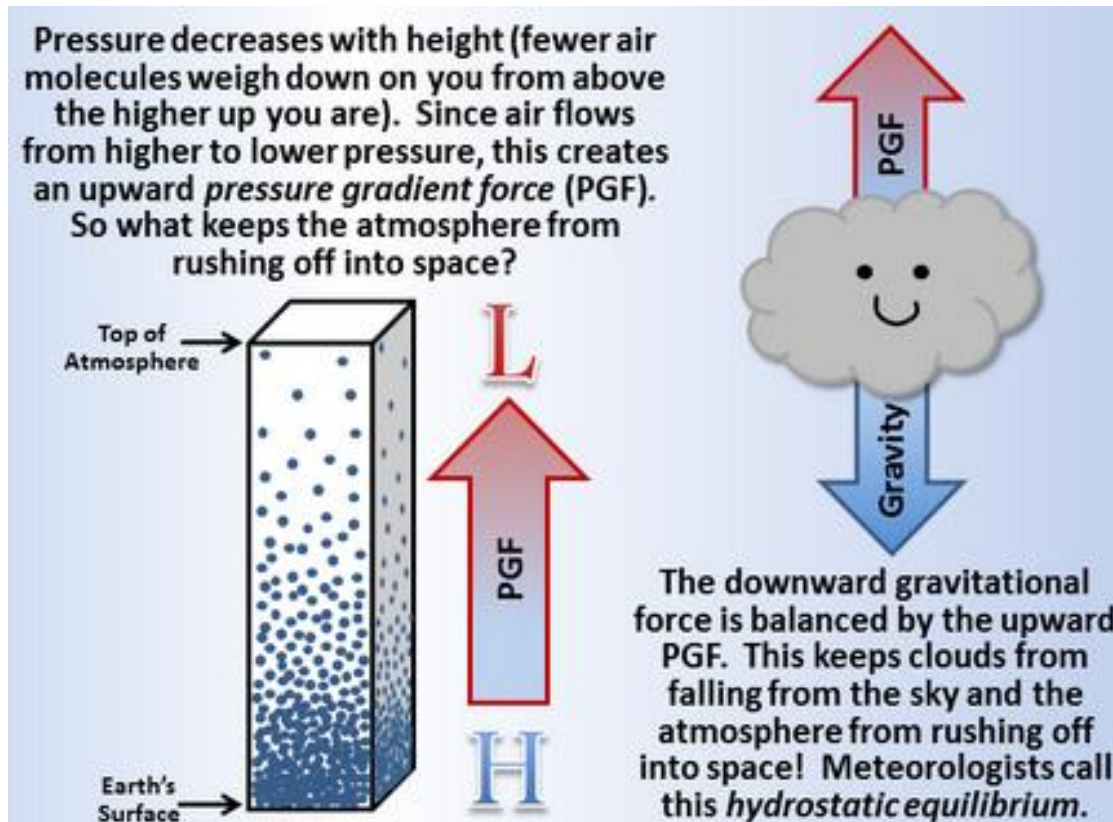
Basic Cloud Formation

As the air rises, it encounters **less pressure**.
The air parcels **expand and cool**.



- 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



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

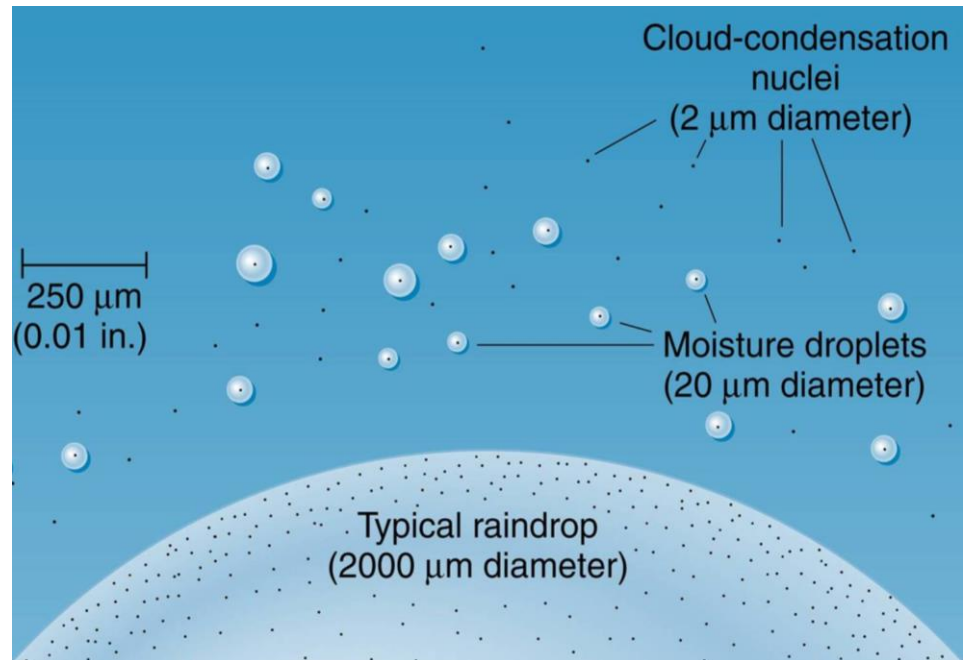


- A cloud will float as long as the **drag force** of the air **dominates over** the **gravitational force** for its constituent water droplets.

Precipitation

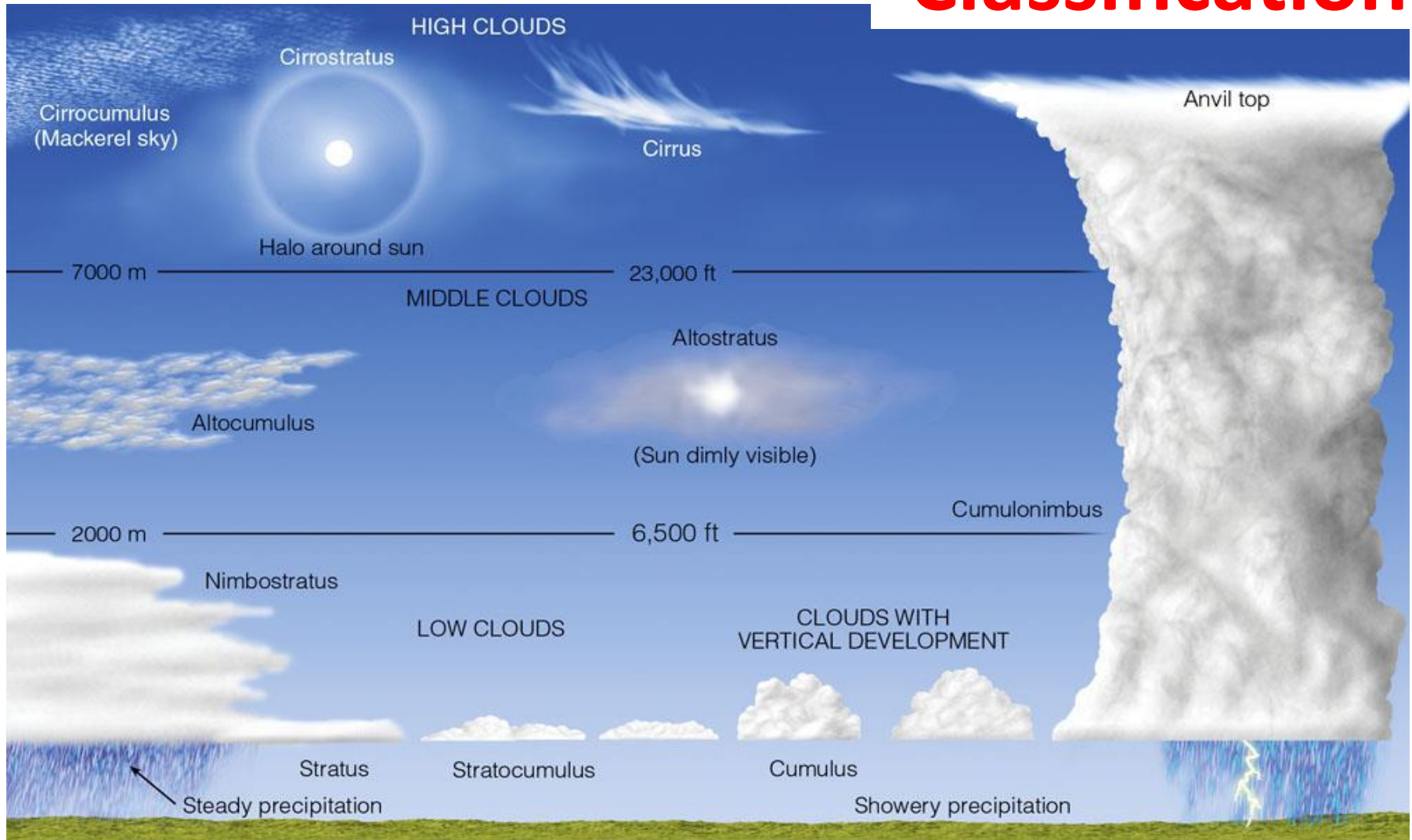
Droplets suspended in the air will **interact with each other**, either by **colliding and bouncing off** each other or by **combining to form a larger droplet**.

- 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** then fall to the ground as precipitation.

Classification



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Based on:

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