Clouds

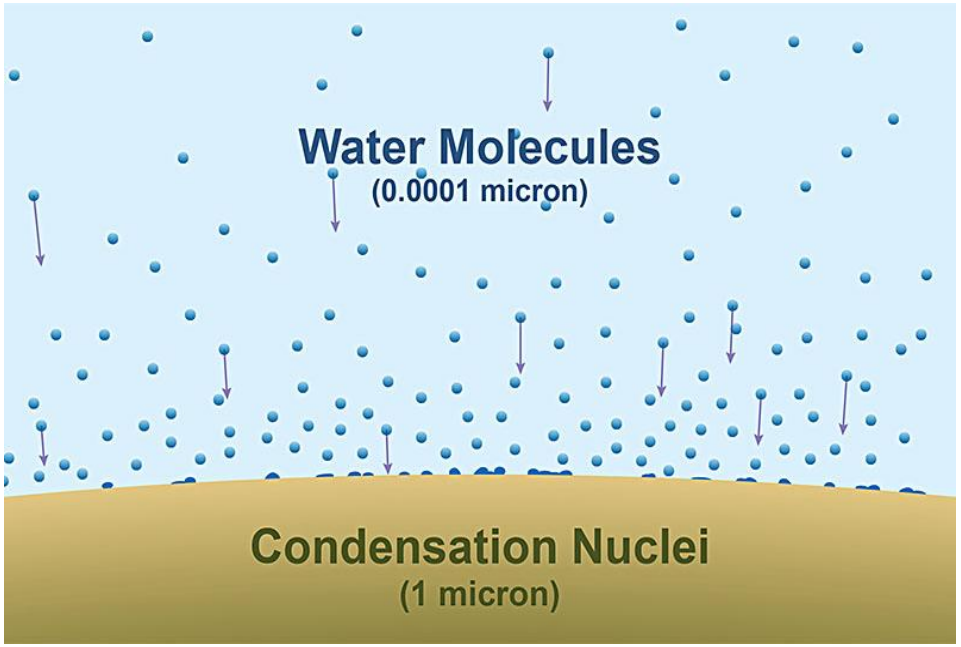
A <u>cloud</u> is a visible mass of billions of tiny water droplets or ice crystals suspended in the atmosphere.

- **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.**

- **<u>Ingredients required</u> 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 <u>requires a surface of some sort to condense on</u> - 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 ~1-2 µm but can be as large as 100 µm.**

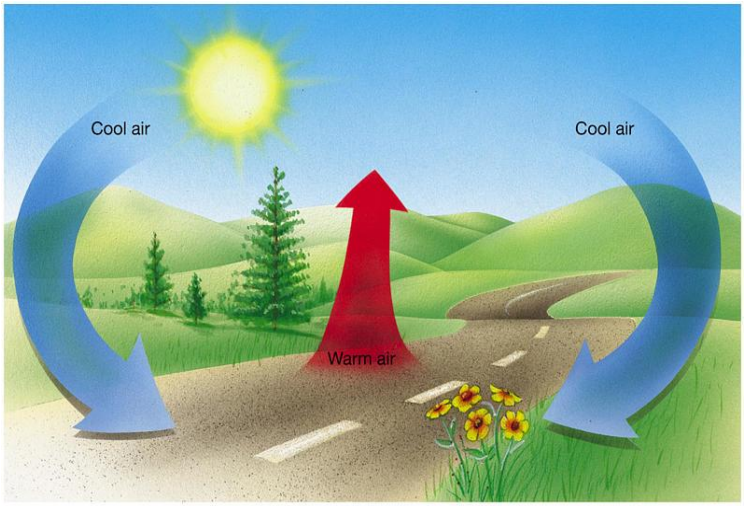
Without these particles, clouds would not form!

Cooling Conditions

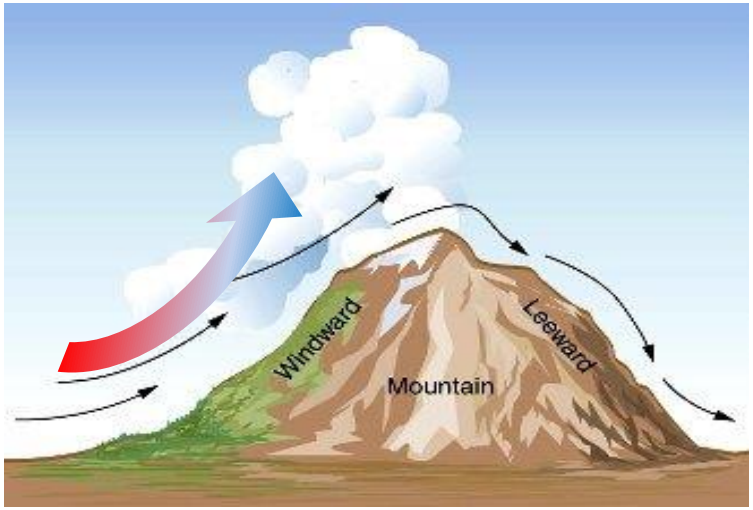
Generally, the air must rise in order for it to cool.

What can cause the air to rise?

Convectional 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.



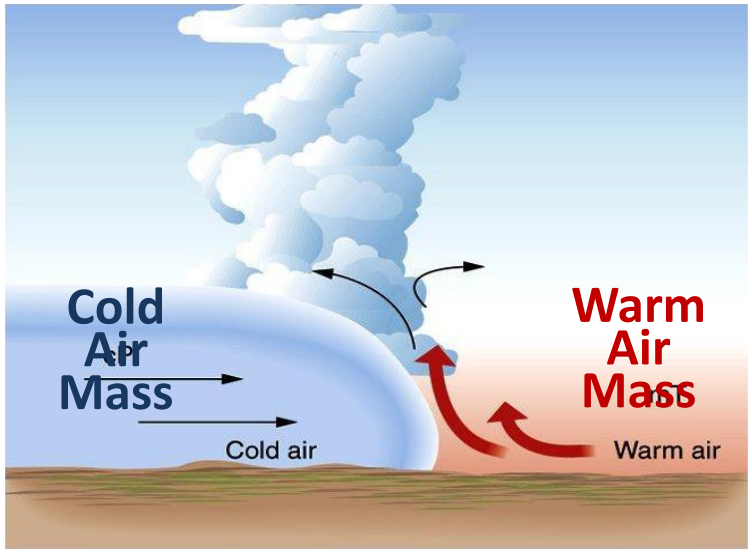
Orographic uplift occurs when air is forced to rise because of the physical presence of elevated land such as mountains.



Cooling Conditions

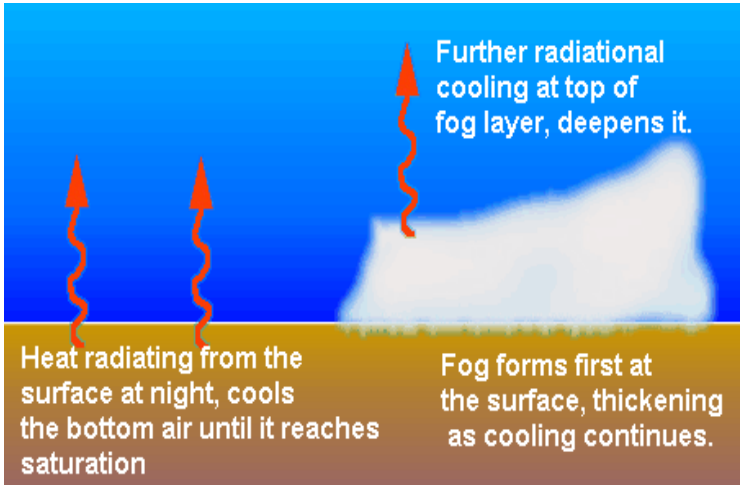
rising air

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



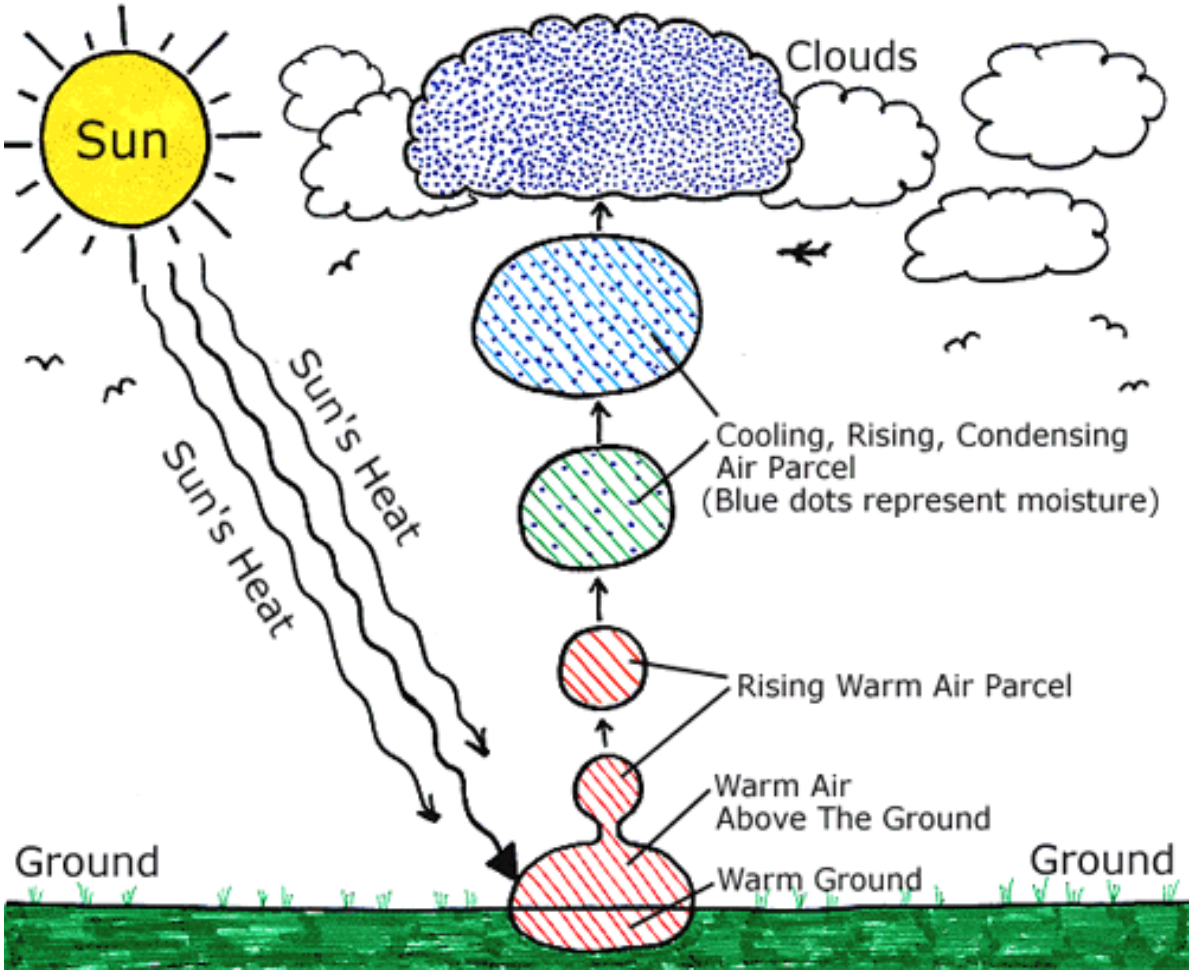
rapid surface cooling

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

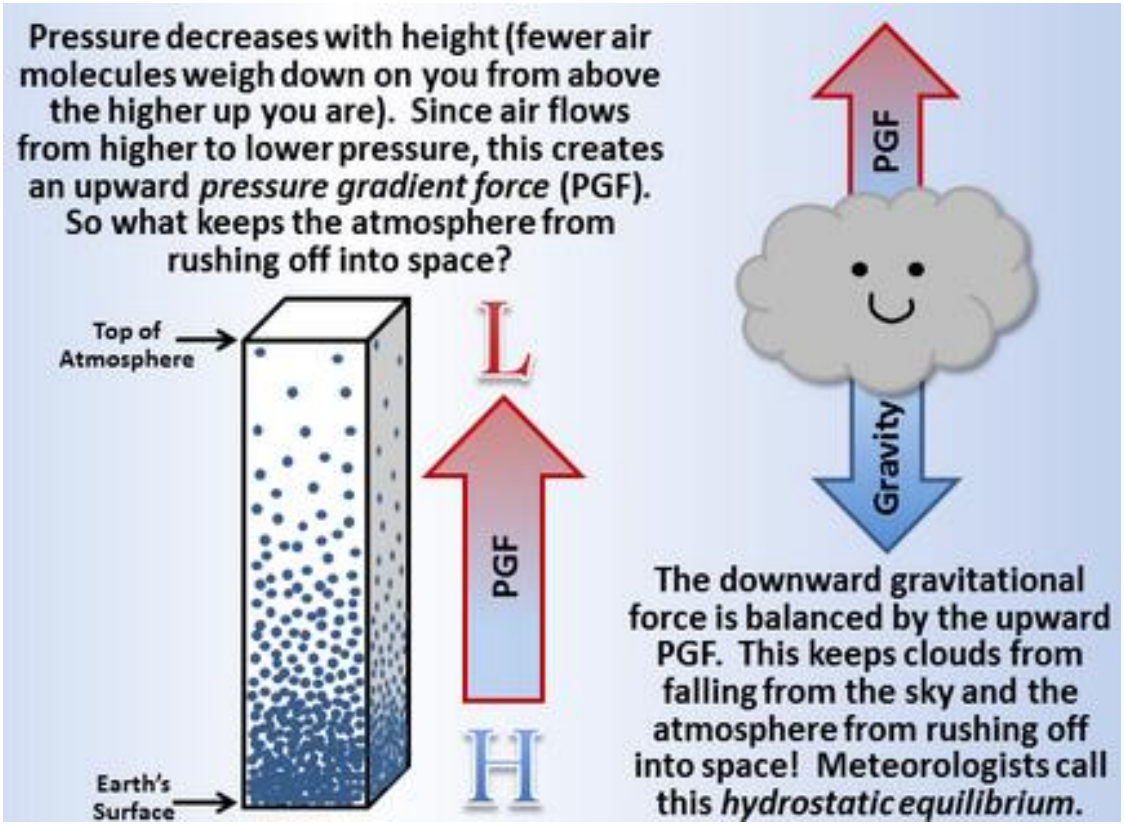
As the air rises, it encounters less pressure.
The air parcels expand and cool.



- **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



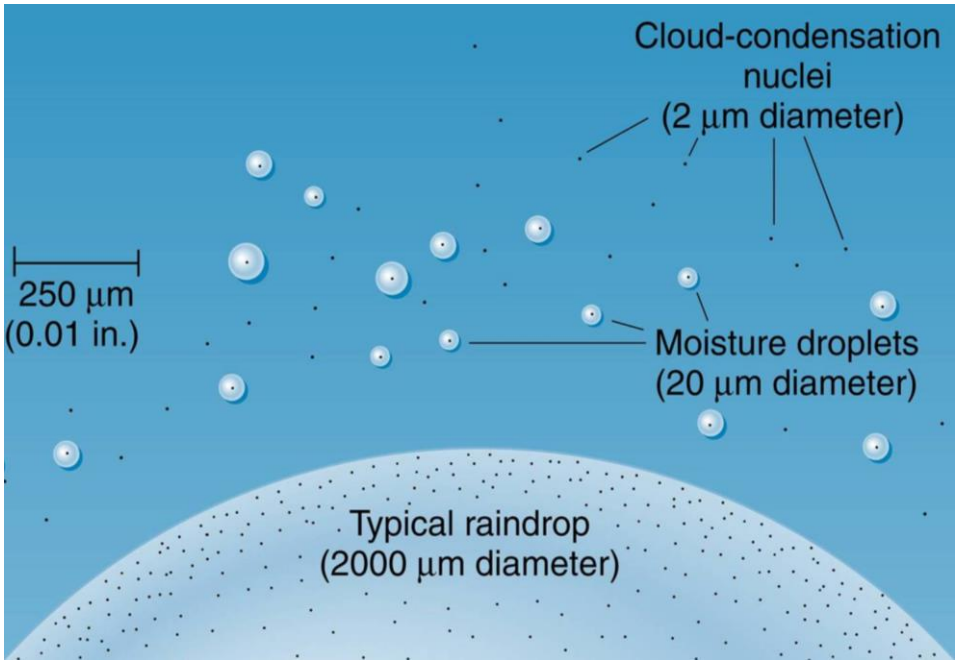
- **Clouds exist in the moving air: rising up due to *pressure difference* or pushed along by wind.**
- **Moving air creates an upward drag force.**

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

Precipitation

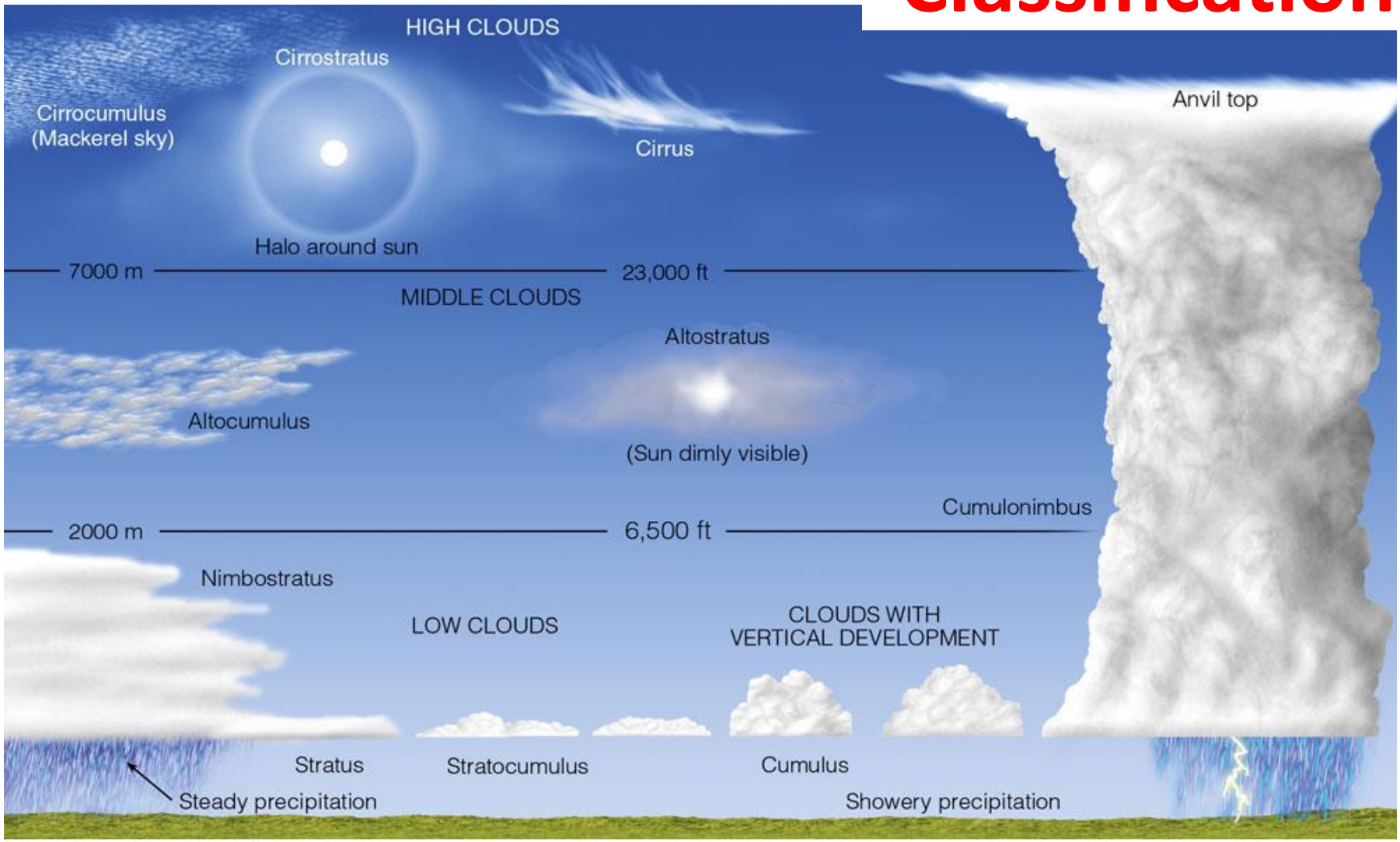
Droplets suspended in the air will interact with each other, either by colliding and bouncing off each other or by combining to form a larger droplet.

- **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 than fall to the ground as <u>precipitation</u>.**

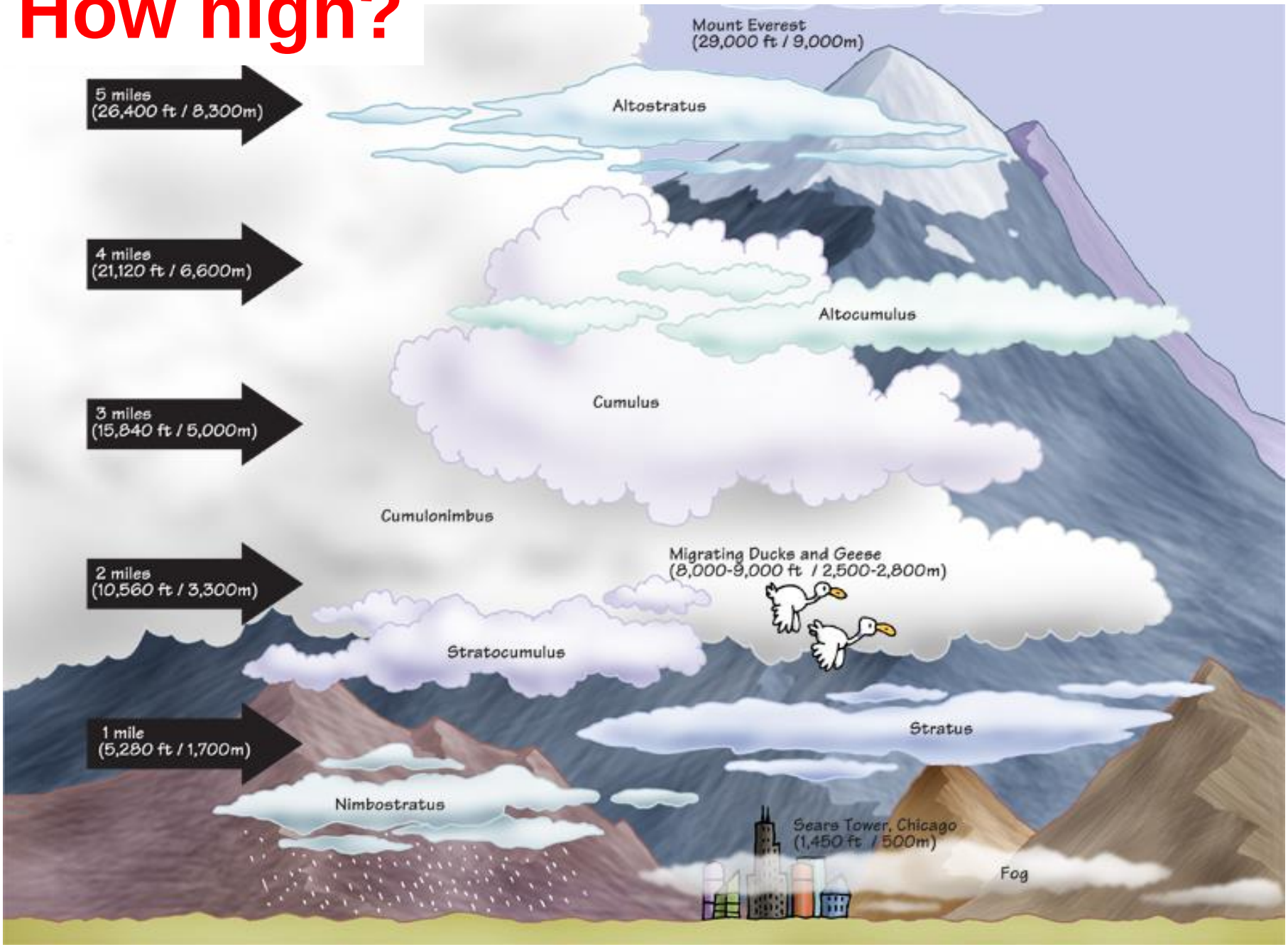
Classification



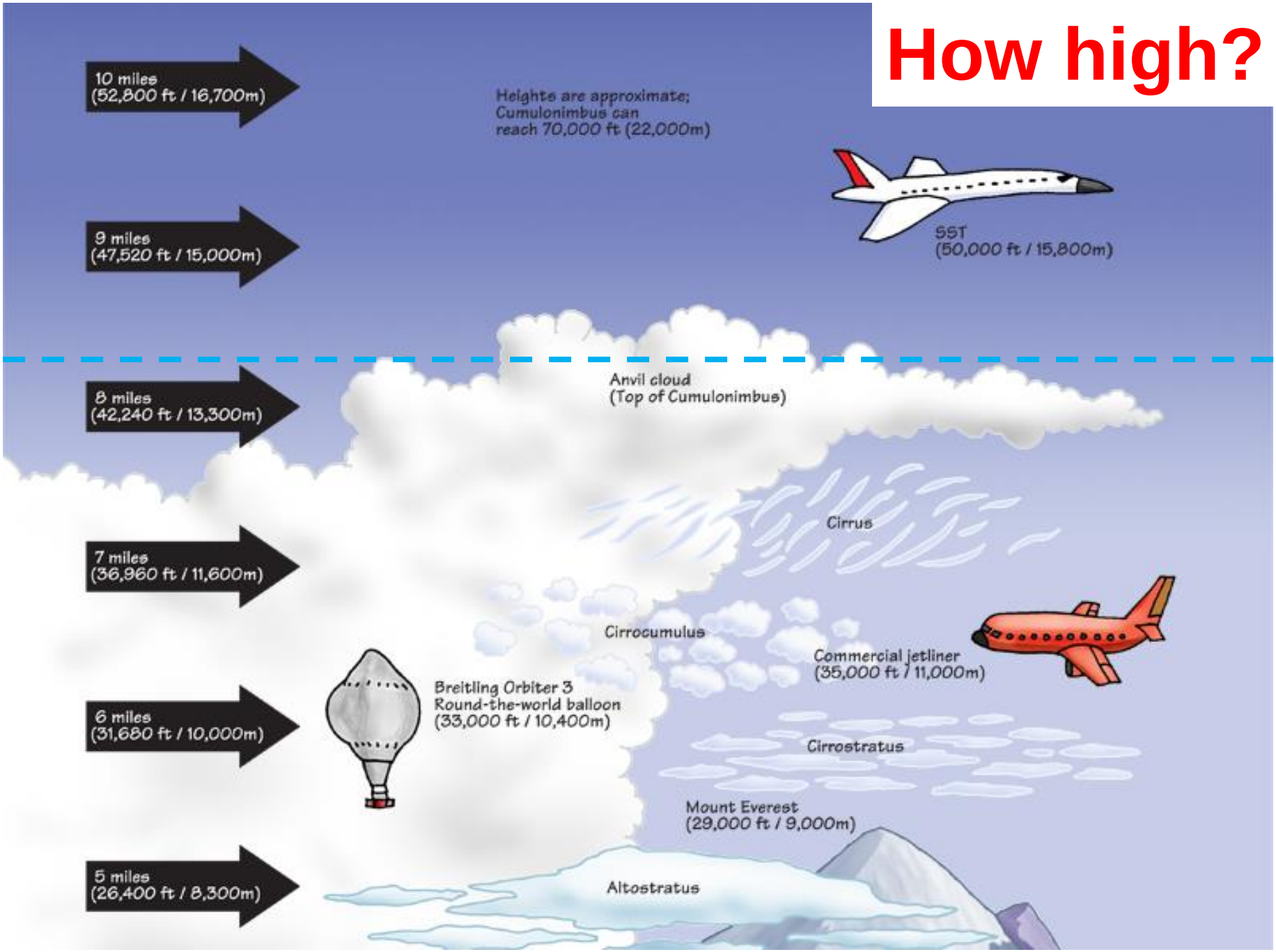
<u>Based on</u>: • **altitude of their bases/bottoms (*alto, cirro*)**

• **shape (*cumulus, stratus*)** • **presence of rain (*nimbus*)**

How high?


Mount Everest
(29,000 ft / 9,000m)
5 miles
(26,400 ft / 8,300m)
Altostratus
4 miles
(21,120 ft / 6,600m)
Altocumulus
3 miles
(15,840 ft / 5,000m)
Cumulus
Cumulonimbus
Migrating Ducks and Geese
(8,000-9,000 ft / 2,500-2,800m)
2 miles
(10,560 ft / 3,300m)
Stratocumulus
Stratus
1 mile
(5,280 ft / 1,700m)
Nimbostratus
Sears Tower, Chicago
(1,450 ft / 500m)
Fog

How high?


10 miles
(52,800 ft / 16,700m)
Heights are approximate;
Cumulonimbus can
reach 70,000 ft (22,000m)
9 miles
(47,520 ft / 15,000m)
SST
(50,000 ft / 15,800m)
8 miles
(42,240 ft / 13,300m)
Anvil cloud
(Top of Cumulonimbus)
Cirrus
7 miles
(36,960 ft / 11,600m)
Cirrocumulus
Commercial jetliner
(35,000 ft / 11,000m)
Breitling Orbiter 3
Round-the-world balloon
(33,000 ft / 10,400m)
6 miles
(31,680 ft / 10,000m)
Cirrostratus
Mount Everest
(29,000 ft / 9,000m)
5 miles
(26,400 ft / 8,300m)
Altostratus