Clouds: What are They?

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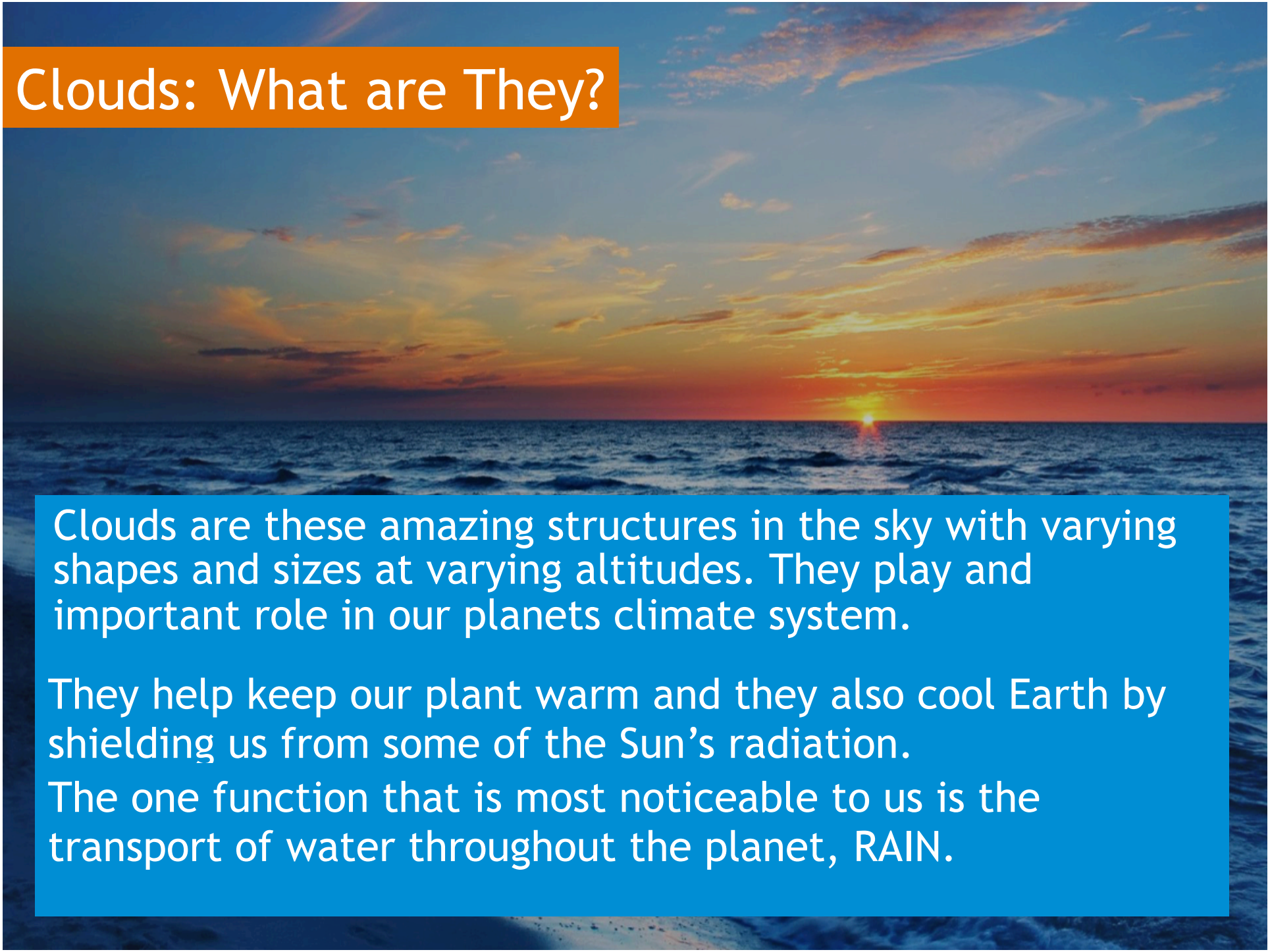
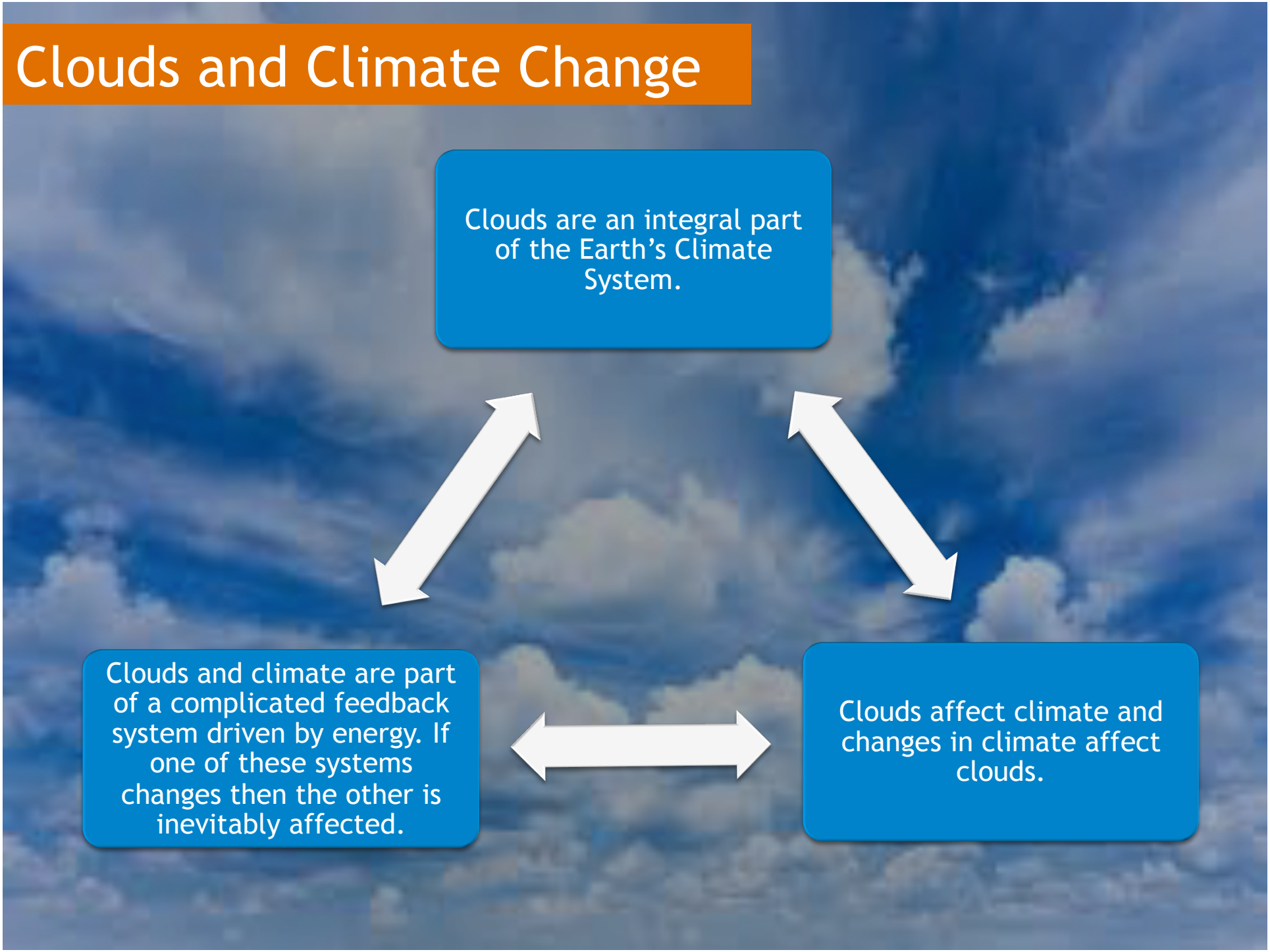


Clouds are these amazing structures in the sky with varying shapes and sizes at varying altitudes. They play and important role in our planets climate system.

They help keep our plant warm and they also cool Earth by shielding us from some of the Sun's radiation.

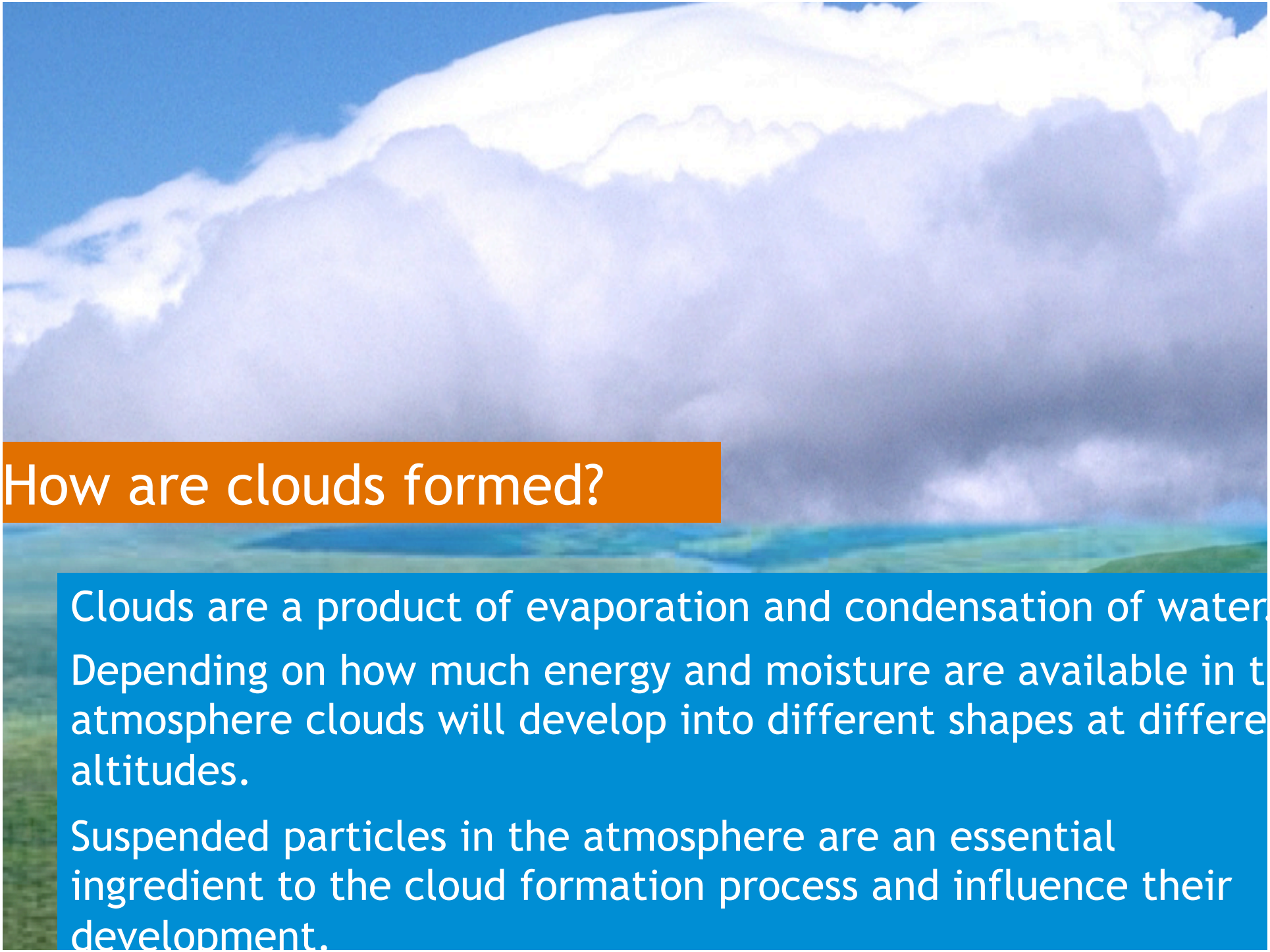
The one function that is most noticeable to us is the transport of water throughout the planet, RAIN.

Clouds and Climate Change



What are clouds made of?

Clouds are made of hundreds of million tiny water droplets and or ice crystals suspended in the lower atmosphere.



How are clouds formed?

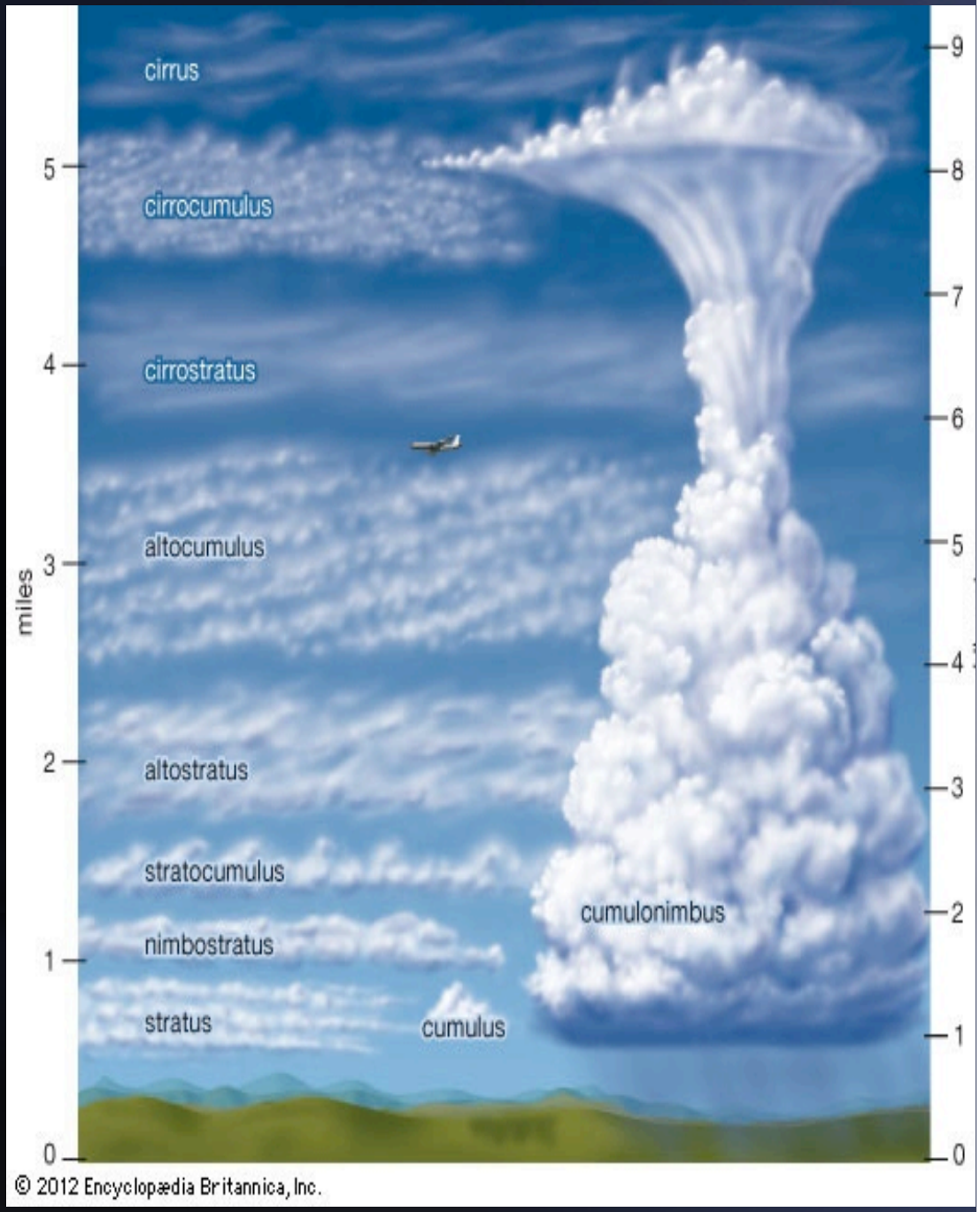
Clouds are a product of evaporation and condensation of water.

Depending on how much energy and moisture are available in t atmosphere clouds will develop into different shapes at differe altitudes.

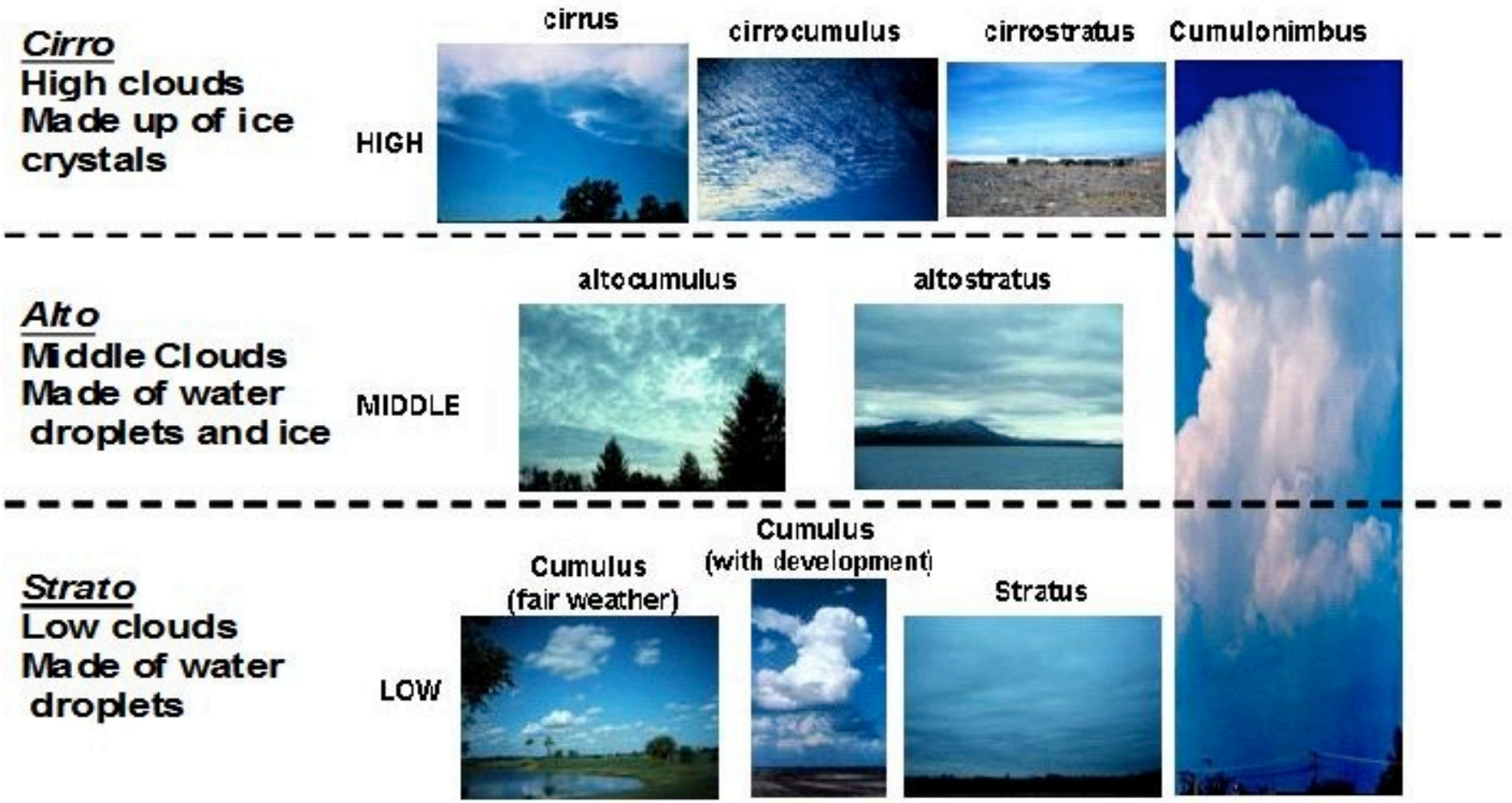
Suspended particles in the atmosphere are an essential ingredient to the cloud formation process and influence their development.

Clouds Form at Different Altitudes

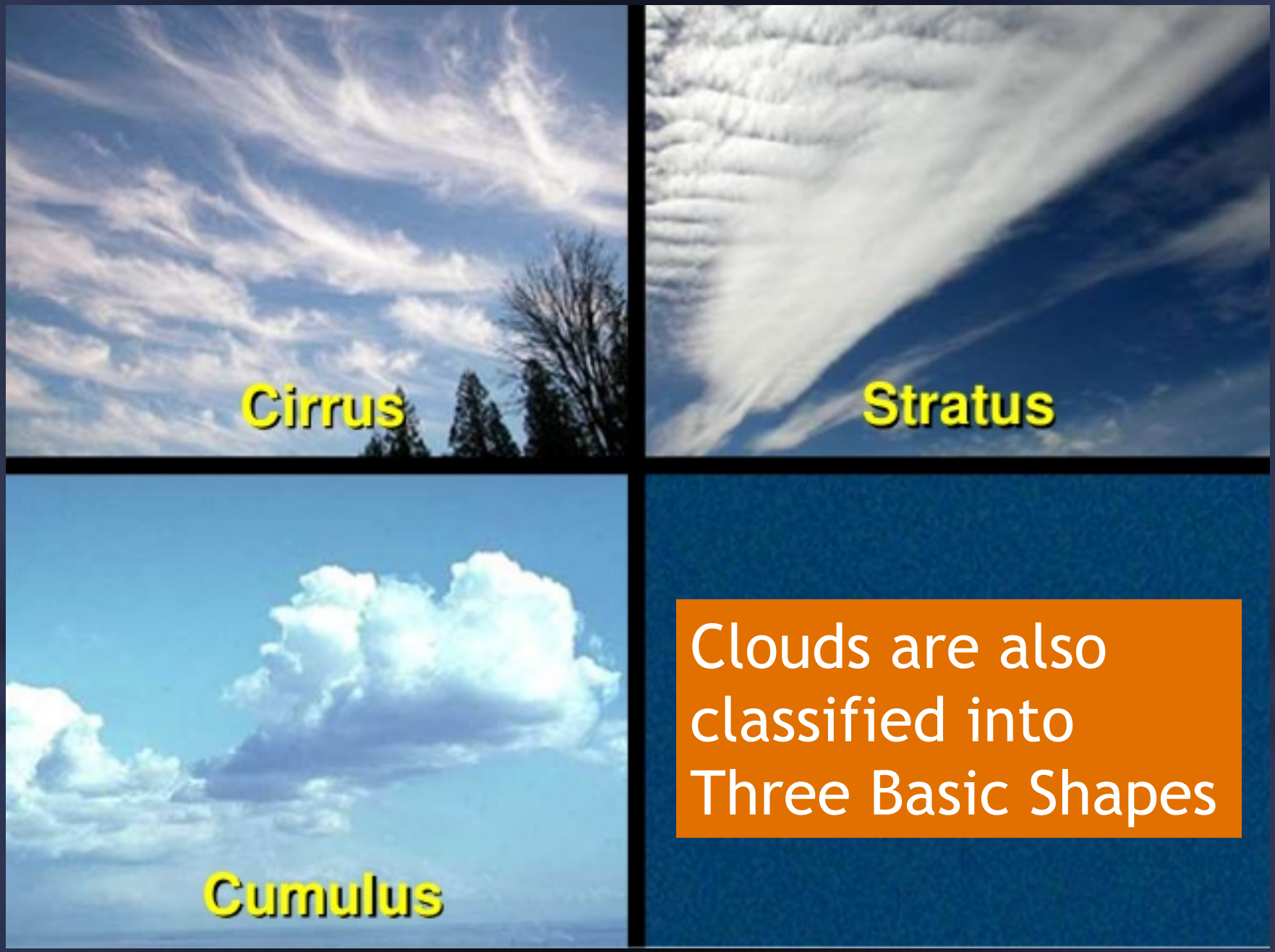
Millions of water droplets and or ice crystals organize depending on varying atmospheric conditions to form a different types of clouds in the vertical atmospheric column.



Classification of Clouds

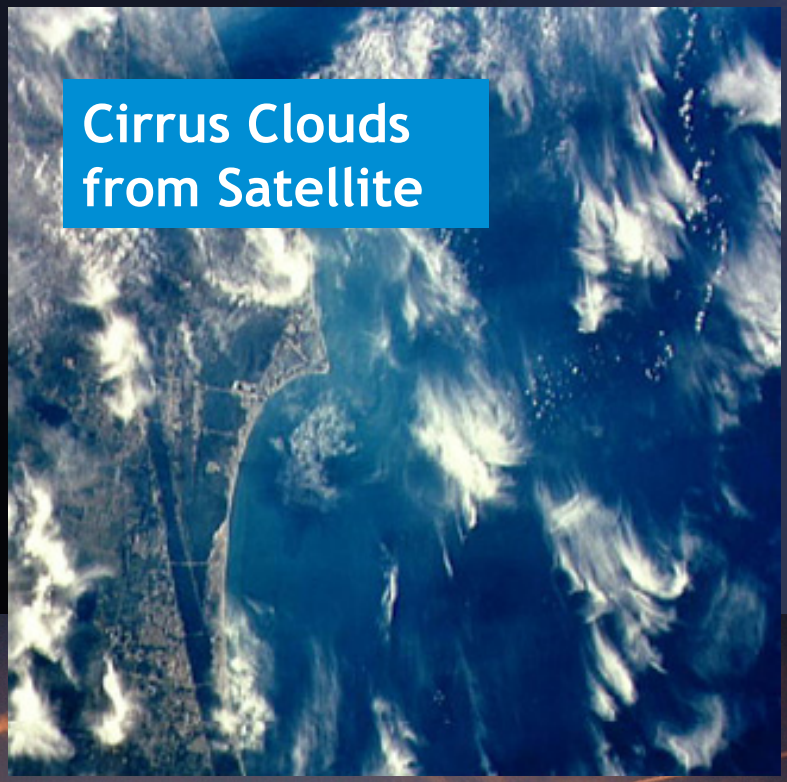


Cloud types are divided into three main groups according to the position they occupy in the atmospheric column. These groups are known as high, mid and low clouds.


Cirrus
Stratus
Cumulus
Clouds are also classified into Three Basic Shapes

Cirrus Clouds

Cirrus Clouds Clear Day



Cirrus Clouds from Satellite

Cirrus Clouds are mostly found above 20,000 feet. They are thin and have wispy strands.

Cirrus clouds are composed of ice crystals that form of supercooled freezing water droplets.

Cirrus Clouds at Sunset

Cumulus Clouds

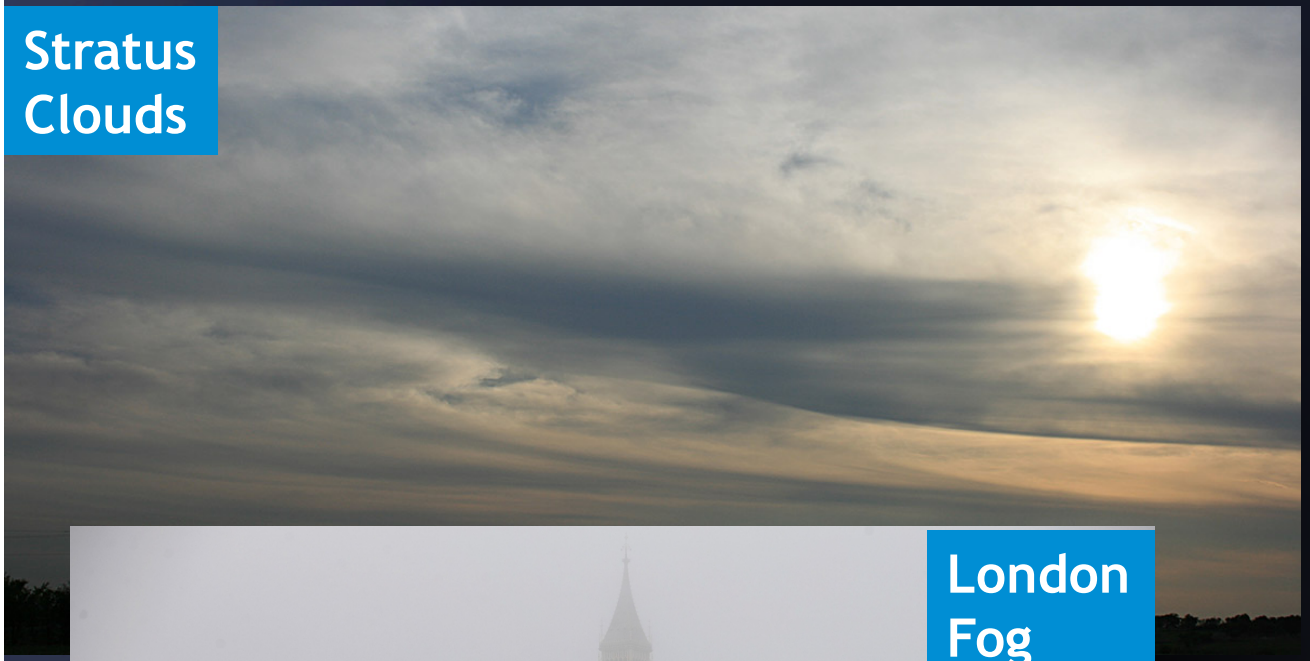
Cumulus Clouds are puffy and fluffy clouds that look like cotton. These clouds are piled up on one another, hence the word Cumulus. They are low level clouds found at 3,300 feet above the ground.

Cumulus clouds can transform into rain clouds as they get denser and thicker by accumulating more water. They change into a grey color indicating rain.

Cumulus Clouds

Cumulus Cloud in Transition

Stratus Clouds

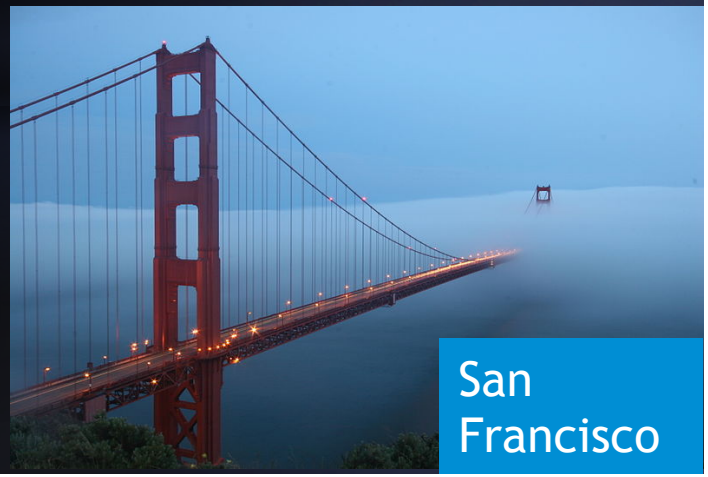


Stratus Clouds

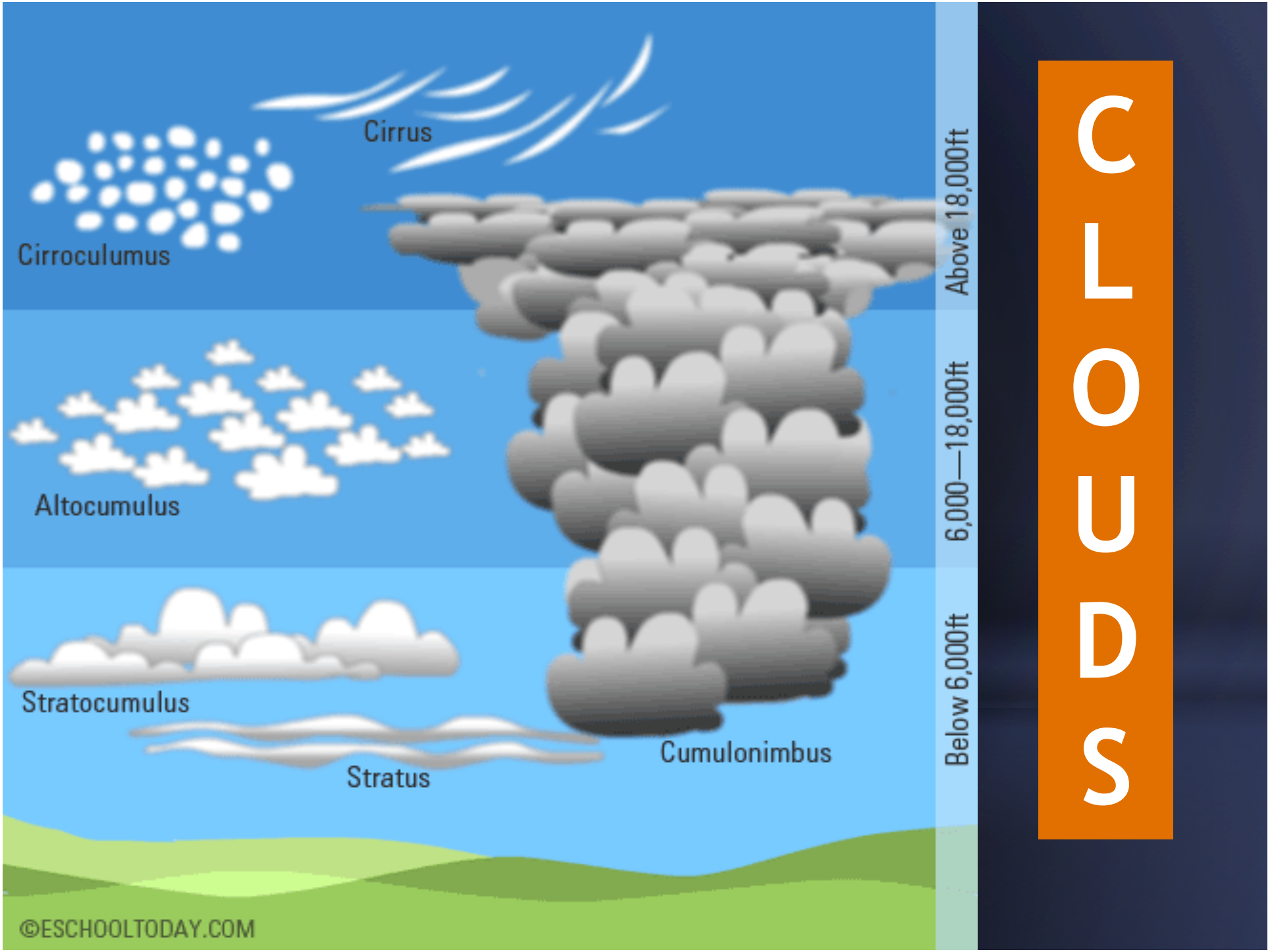
Stratus clouds are low lying clouds that produce a uniform grey veil throughout the sky. They may produce drizzle or snow. A well known stratus cloud is fog.

Stratus clouds form when air is cooled from below to it's dew point temperature.

London Fog



San Francisco


Cirrus
Cirroculumus
Altocumulus
Stratocumulus
Stratus
Cumulonimbus
Above 18,000ft
6,000—18,000ft
Below 6,000ft
CLOUDS
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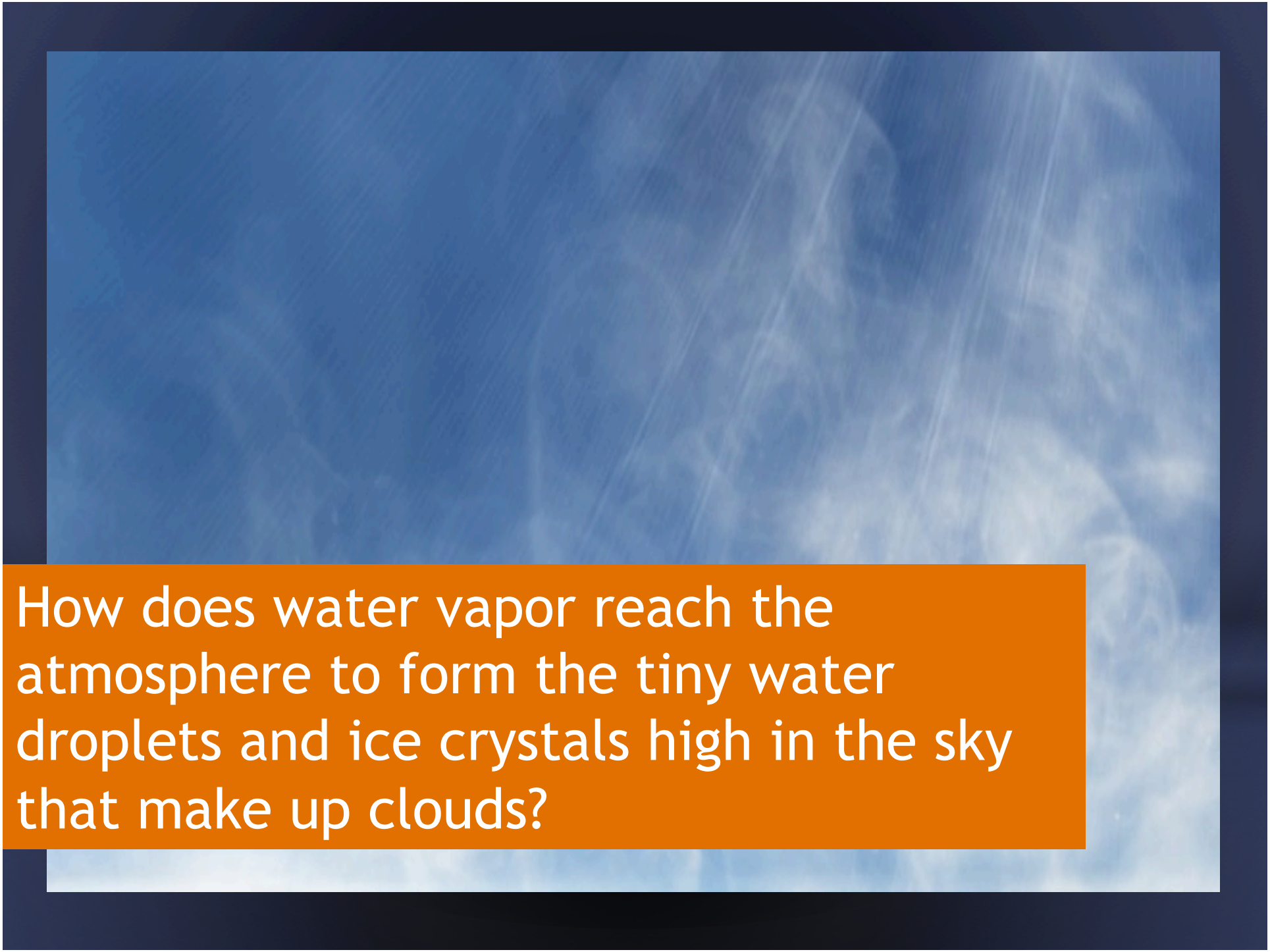
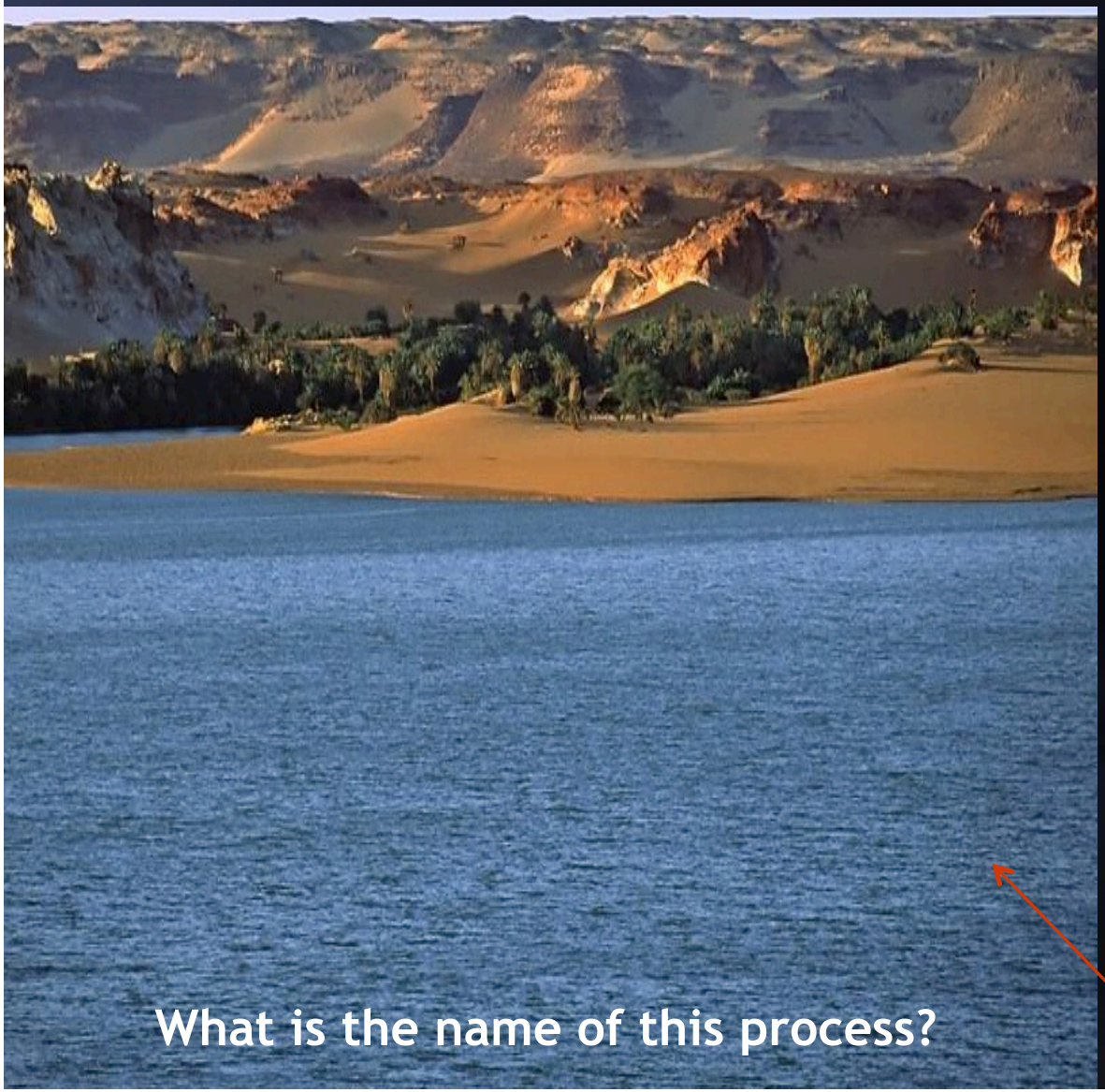

How does water vapor reach the atmosphere to form the tiny water droplets and ice crystals high in the sky that make up clouds?

Water Vapor Reaches the Atmosphere through a Series of Processes

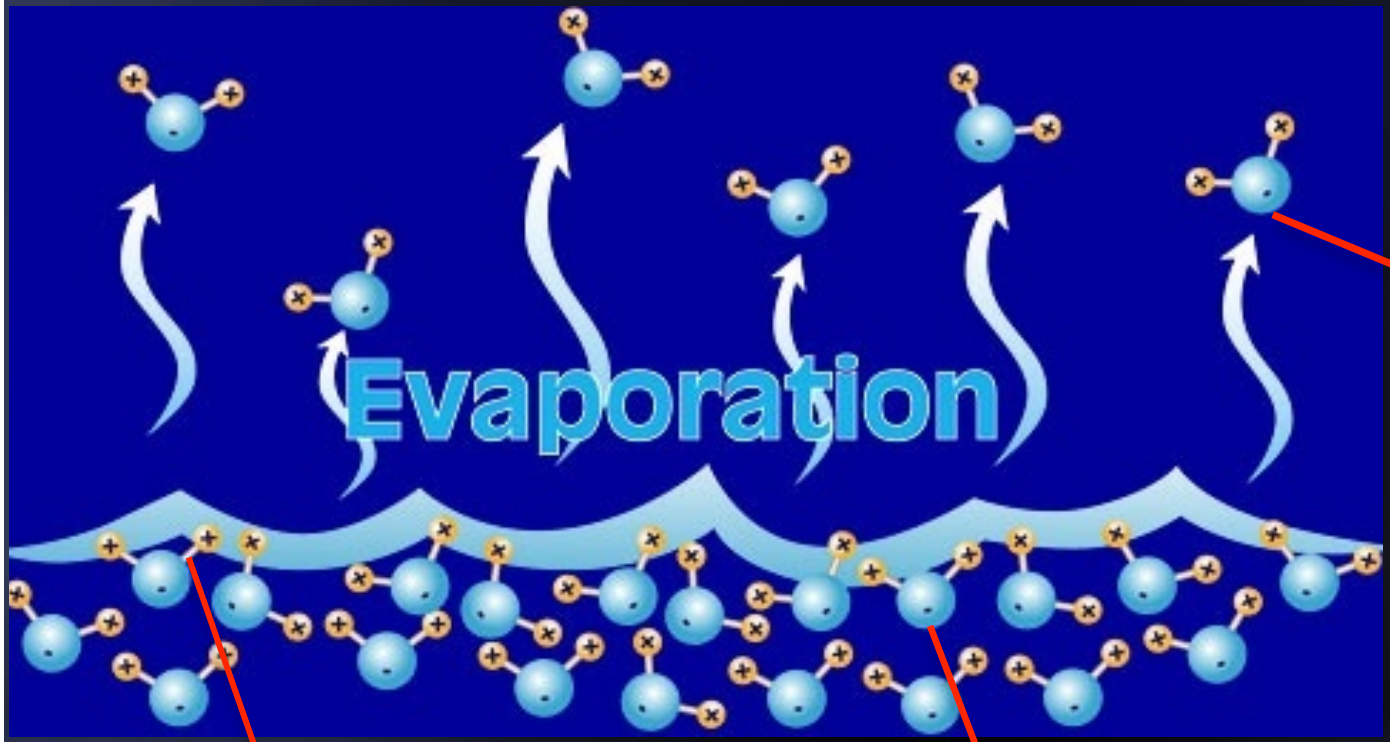


What is the name of this process?

- The Sun heats the surfaces of lakes, oceans, rivers and the ground. Water molecules increase in temperature and undergo a phase change by absorbing energy from the environment.
- This endothermic reaction causes liquid water to change into a gas called water vapor.
- This process is called ***<u>evaporation</u>***.

Image of Lake Chad in Africa

How does Water Vapor Reach the Atmosphere?



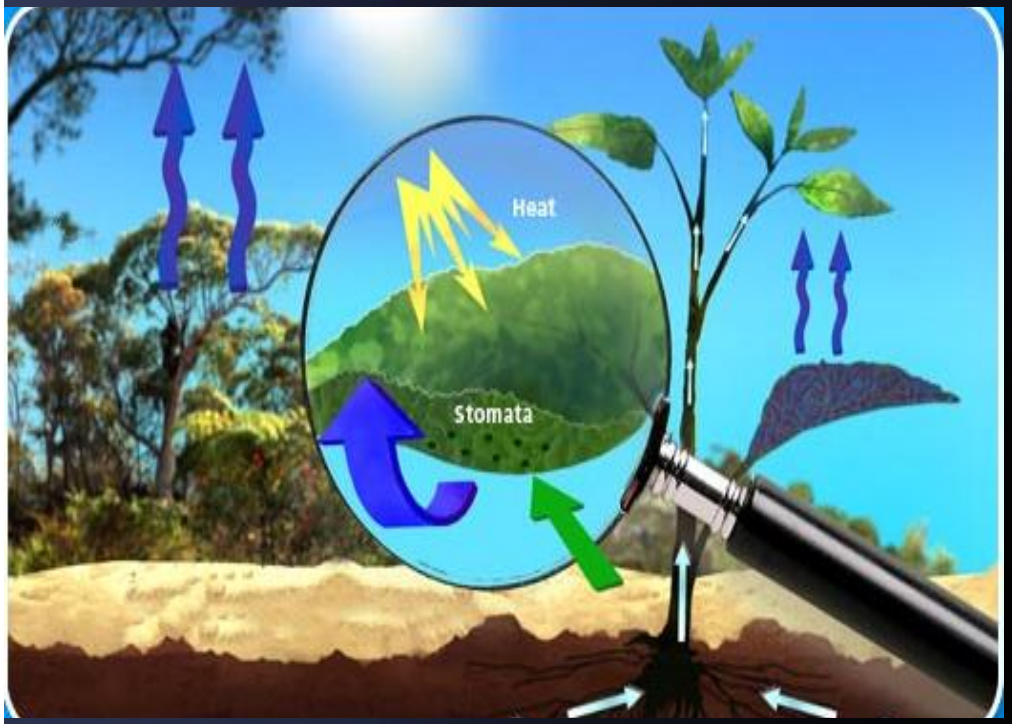
1 Heat from the sun is transferred on to the ocean's adding kinetic energy to the water molecules at the ocean surface.

2 The water at the ocean's surface undergoes a phase change, from liquid to a gas (water vapor) due to an increase in heat energy. Water retains its' molecular and chemical composition as a gas.

3 Less dense water vapor Gas rises up to the atmosphere.

Lakes, rivers, reservoirs, soil and other water sources produce water vapor as well.

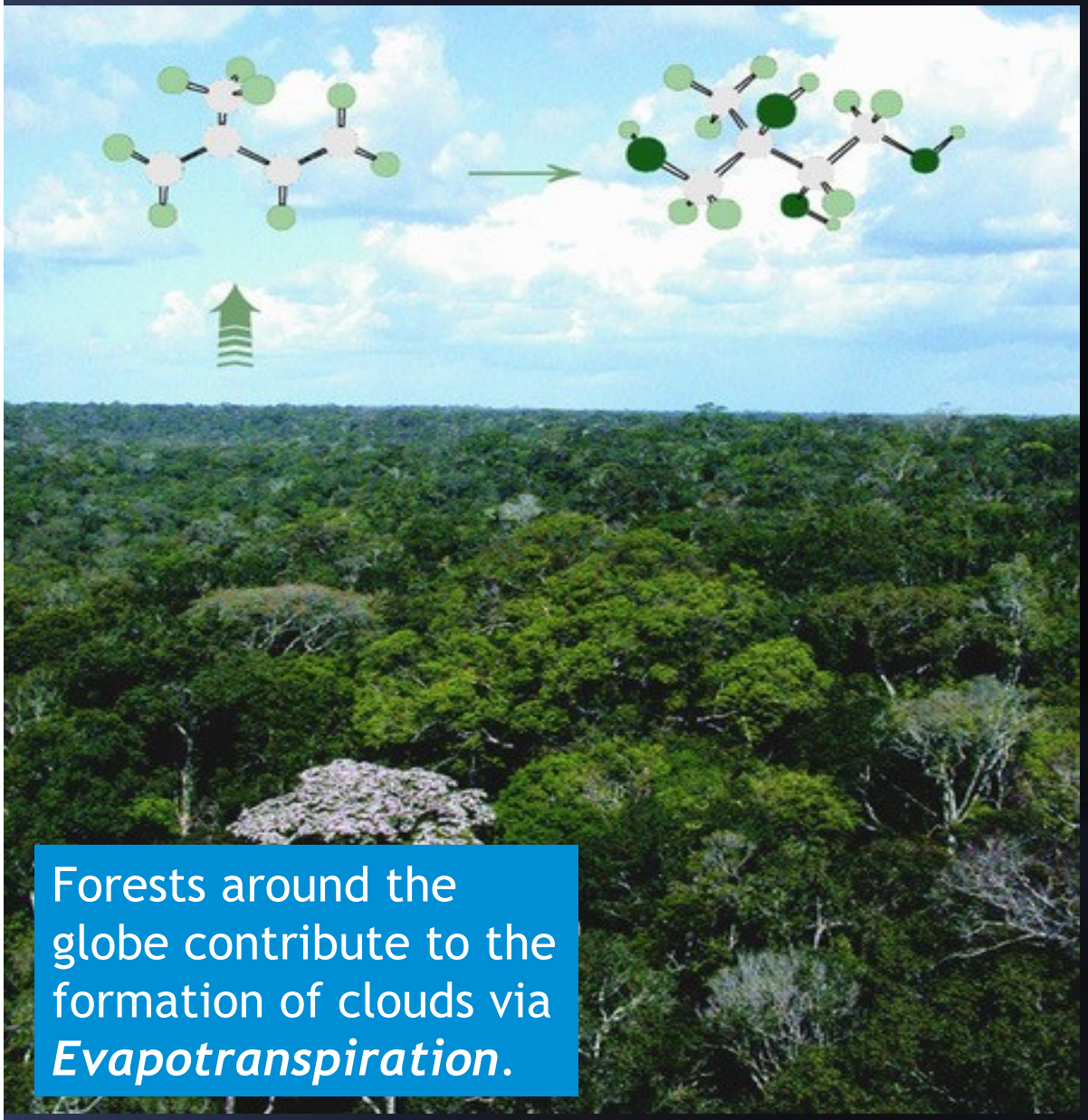
How does Water Reach the Atmosphere?



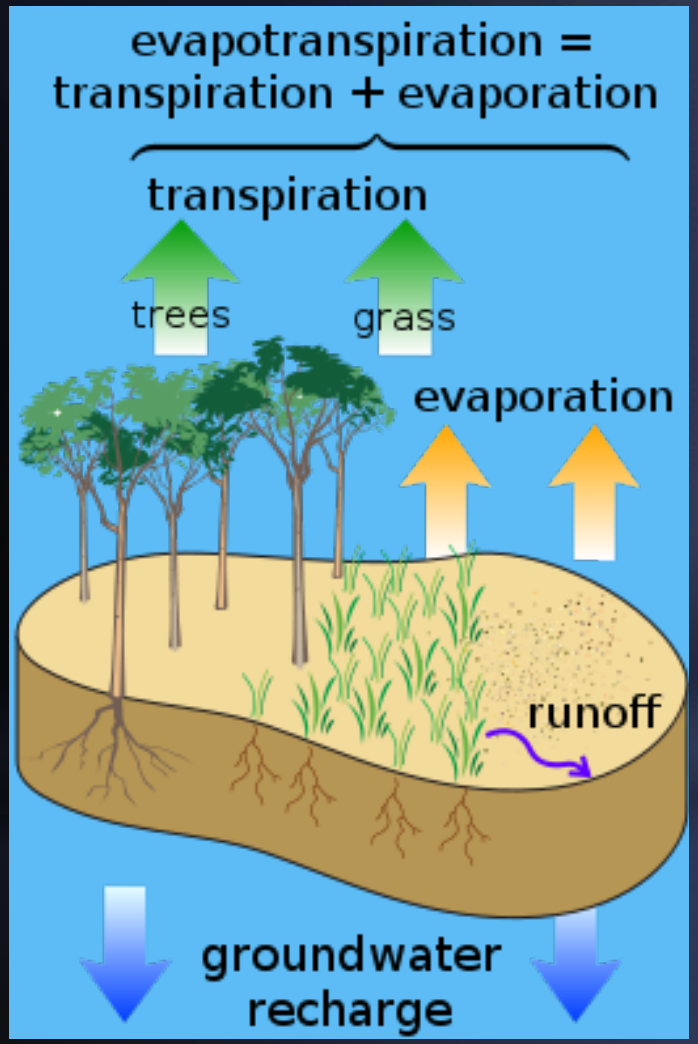
Trees and plants act like water pumps. Water is heated through the leaves and released as water vapor to the atmosphere.

Water is transported from the roots to the leaves via the stem to tiny pores called stomata. It is then released as water vapor contributing to cloud formation.

Forests are Large Water Vapor Pumps



Forests around the globe contribute to the formation of clouds via ***Evapotranspiration***.



Why and how Water Vapor rises?

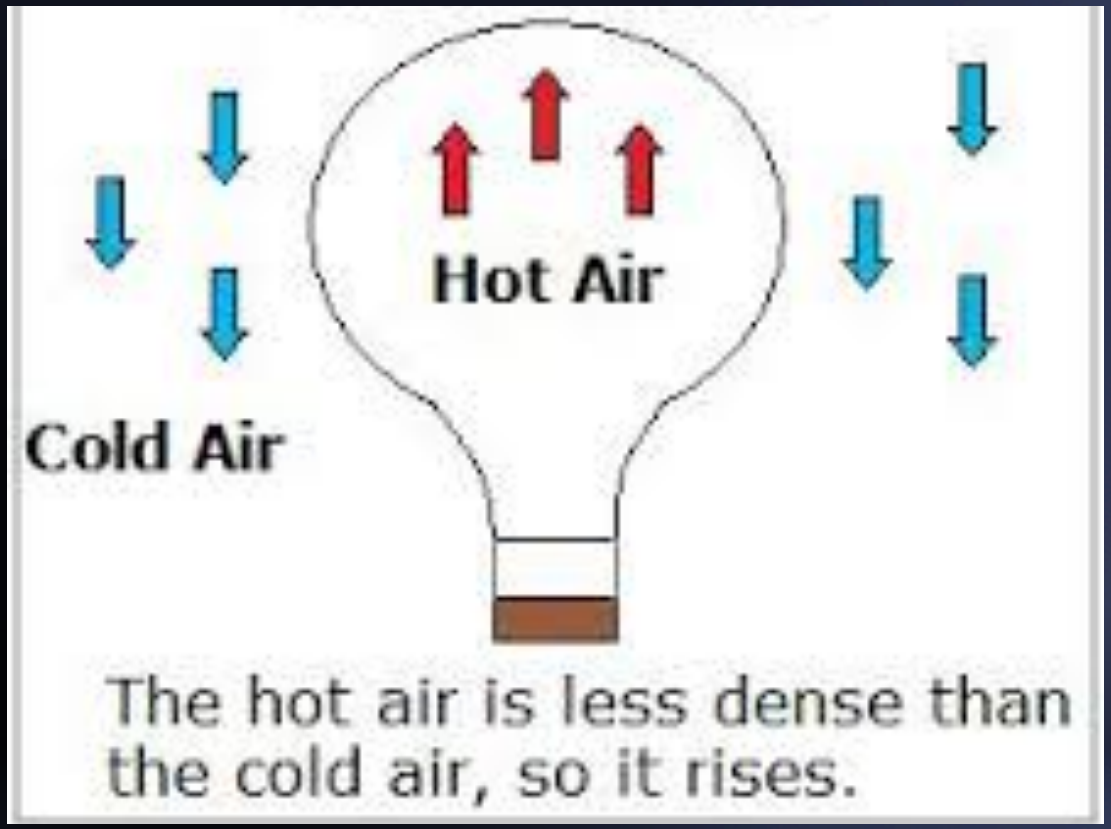
There are several ways that gases behave under certain conditions that help explain how water vapor moves up the atmospheric vertical column.

Temperature

Water Vapor is warmer than the air surrounding it. When gases are warmer they have more kinetic energy and expand becoming less dense like the air in a hot air balloon.

Density

Warmer gases are less dense than cooler gases. Water Vapor has a higher kinetic energy, therefore less dense. The change in density causes the water vapor to be much lighter.

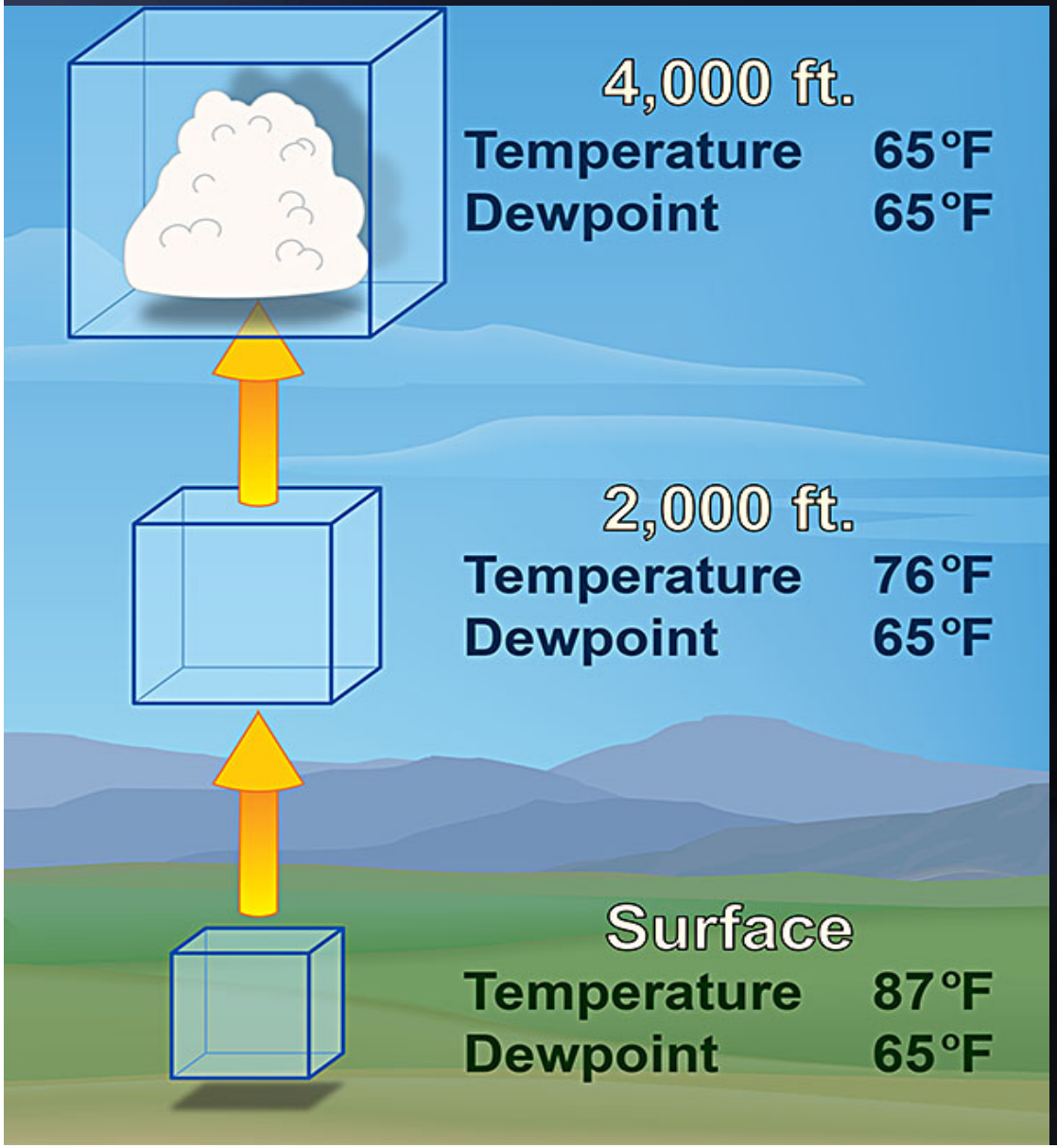


Pressure

Gas Expands as it travels higher in the atmosphere column due to lower pressure.

Let's use the hot air balloon analogy.

The Role of Temperature in the Cloud Forming Process

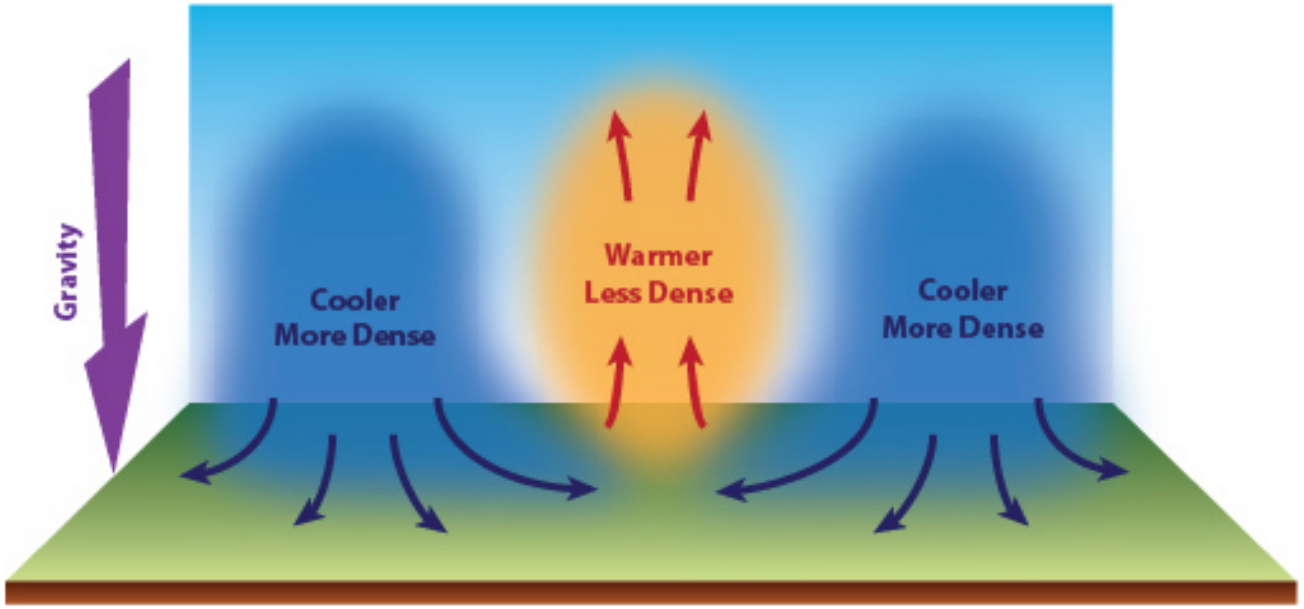


Temperature Conditions for a Cloud to Form

Air temperature needs to be below the saturation point.

Saturation is when the rate of evaporation is equal to the rate of condensation.

Why and How Water Vapor Rises?



Gravity

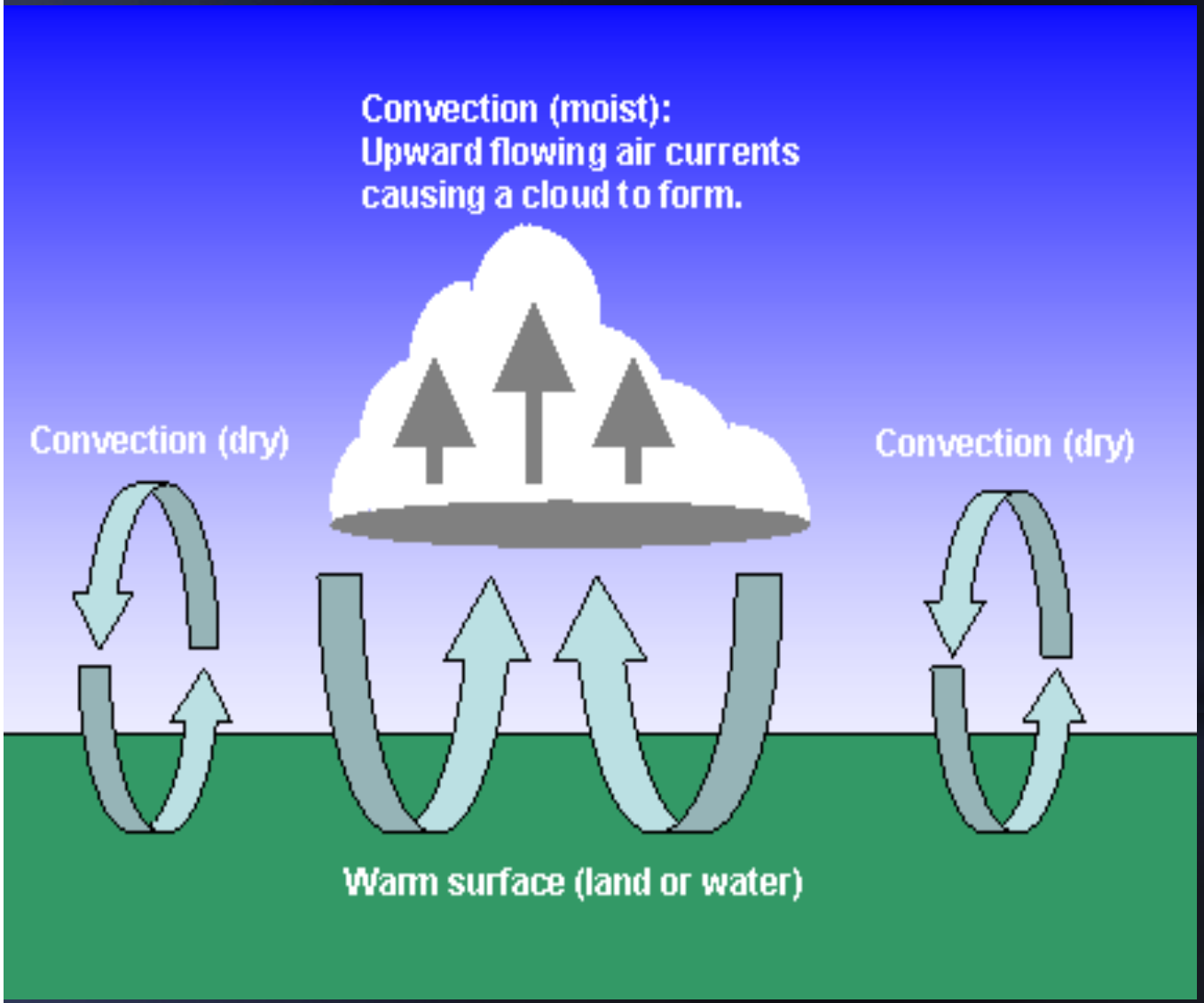
The force of gravity pulls the denser cooler air down due to it's larger air mass. Gravity exerts a greater force the cooler air because it's heavier. The cool air sinks under the warm air undercutting it and the force of this motion pushes the warmer air up forming updrafts triggering convective currents.

Warm air rises, but in order for it to reach higher altitudes a force needs to act upon it, obeying Newton's First Law of Motion.

What does this mean?

Newton's First Law of Motion states that an object at rest and an object in motion will stay at rest and in motion unless a force is excreted on it. The cooler denser air provides the needed force for the warm air to rise.

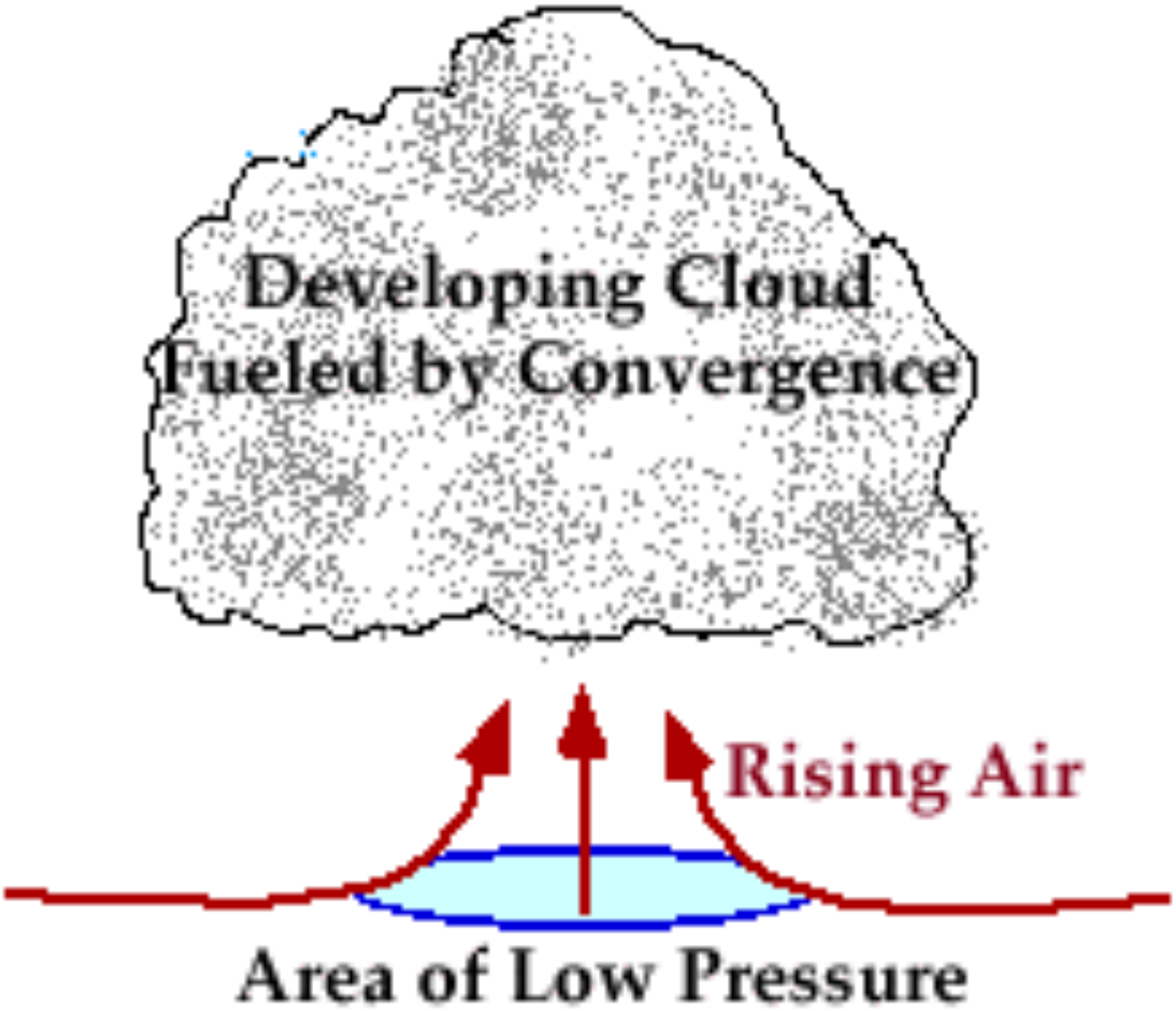
Why and How Water Vapor Rises?



The rise of warm air and the drop of cooler air causes circular air motion patters that can force water vapor to rise.

As the warm air rises it condenses and gives off heat to cool down, in other words it gives off energy. The heat it gives off helps fuel the convection further forcing more water vapor to rise.

How and Why Water Vapor Rises?



CONVERGENCE

When horizontal surface winds come together in an location and have no other option but to push up.

These convergent winds provide the energy for the air parcel of water vapor to rise.

Why and How Water Vapor Rises?

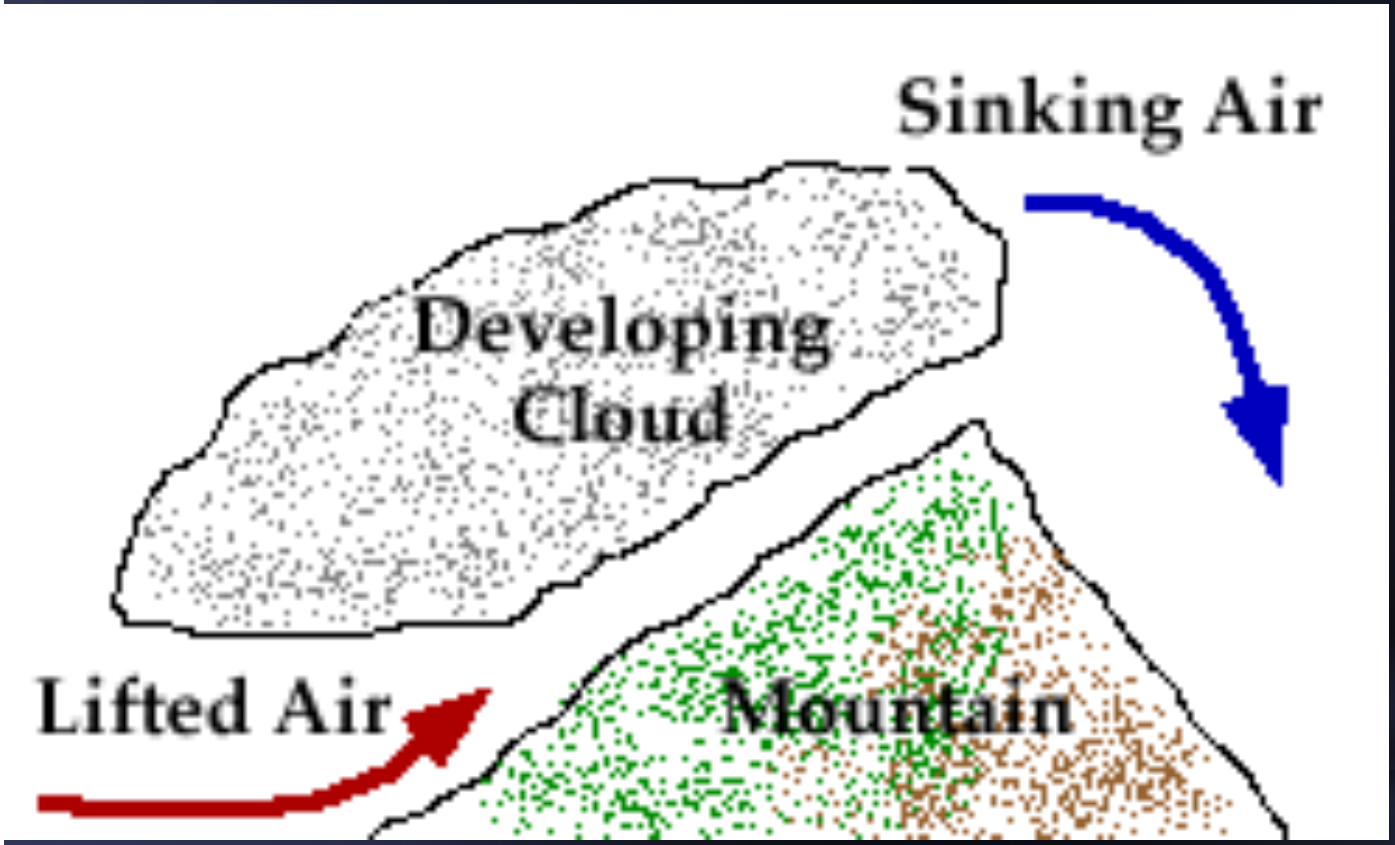
LIFTING BY WEATHER FRONTS

Air masses of different temperatures and moisture content encounter each other and create a boundary.

The warm air collides with the cold front which is denser than warm air.

The type of cloud that forms depends on if a cold front collides with the warm or the warm with the cold.

How and Why Water Vapor Rises?



Lifting Due to Topography

When an air parcel encounters a mountain or mountain range it is force to rise up the slope .

As it ascends it reaches its' dew point, it cools and condenses forming a cloud.

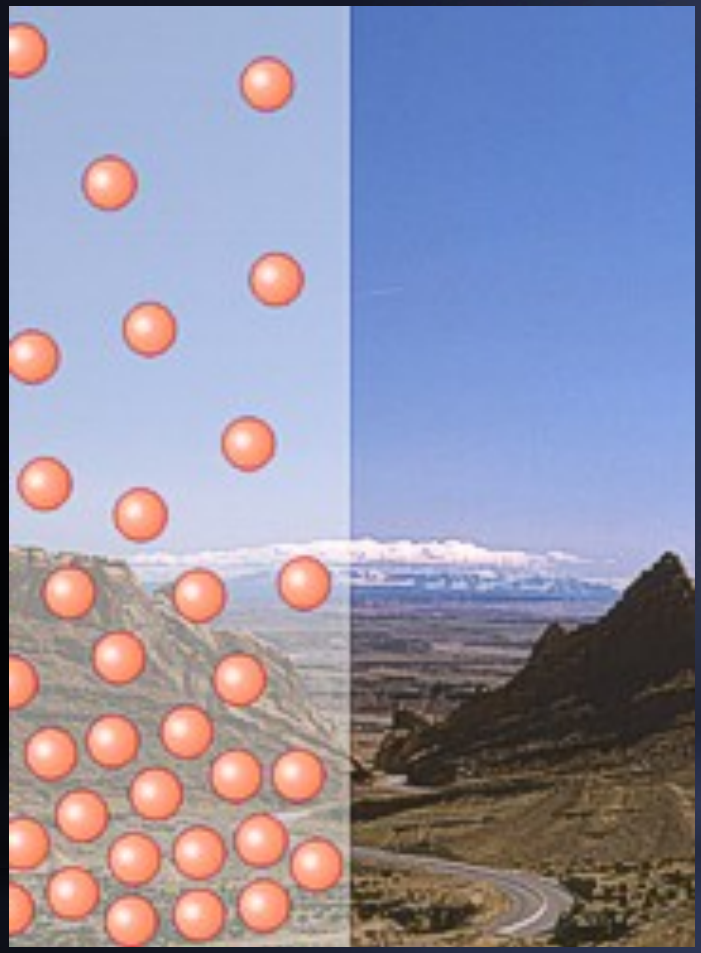
Why and How Water Vapor rises?

Atmospheric Pressure

Plays an important role in how water vapor moves up the vertical atmospheric column. It also affects how and were clouds form.

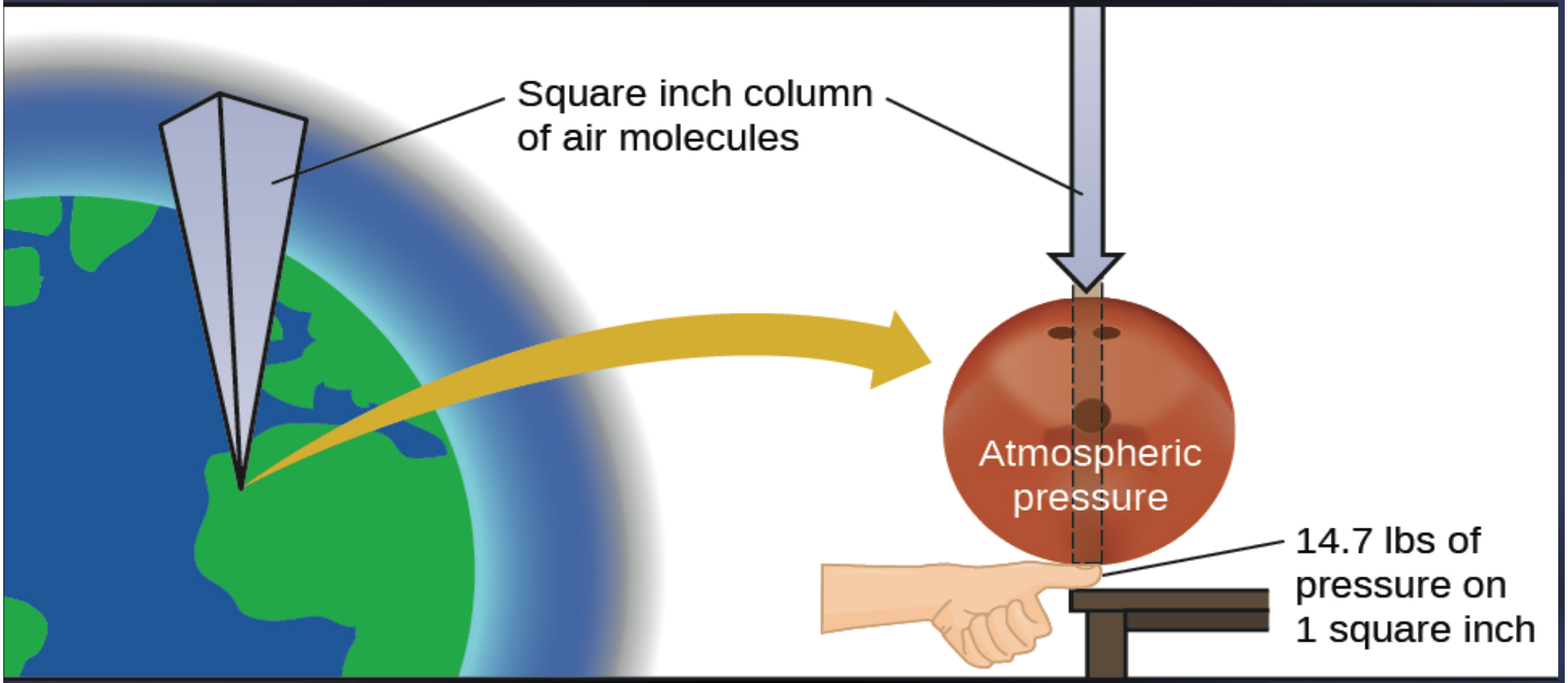
Water vapor transitions from high pressure to low pressure as it rises into the atmosphere.

Water vapor undergoes an expansion becoming less dense. The ideal gas laws help explain the relationship between air mass, pressure and temperature, which all affect cloud formation.



There is a higher density of air molecules closer to the ground. It changes with elevation becoming less dense.

What is Atmospheric Pressure?



Atmospheric Pressure

Is the force exerted by air molecules above the Earth's surface.

Measurement of Atmospheric Pressure

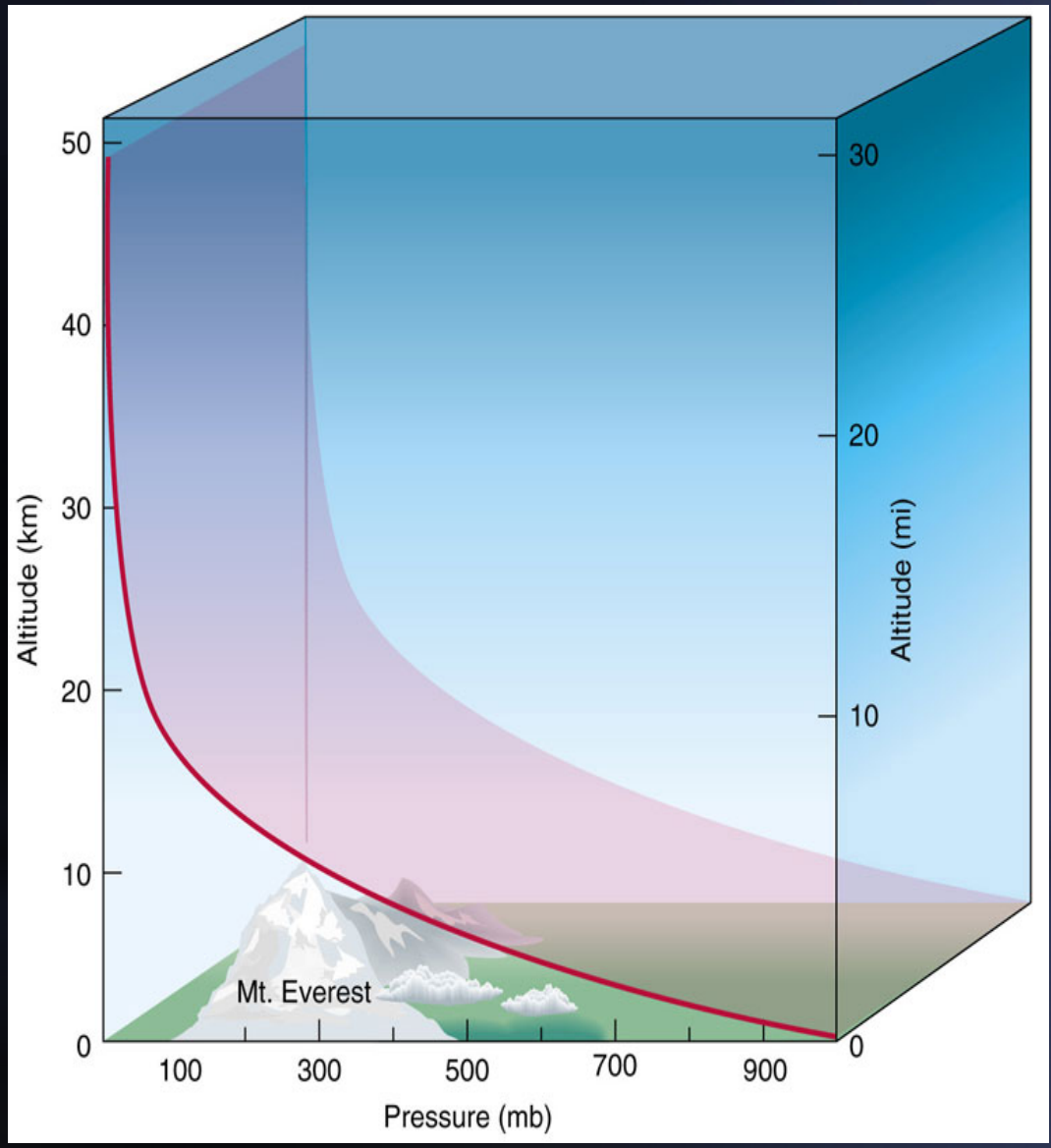
The atmospheric pressure at sea level is 14.7 lbs of pressure per square inch. We all experience it.

Atmospheric Pressure: Altitude vs. Pressure

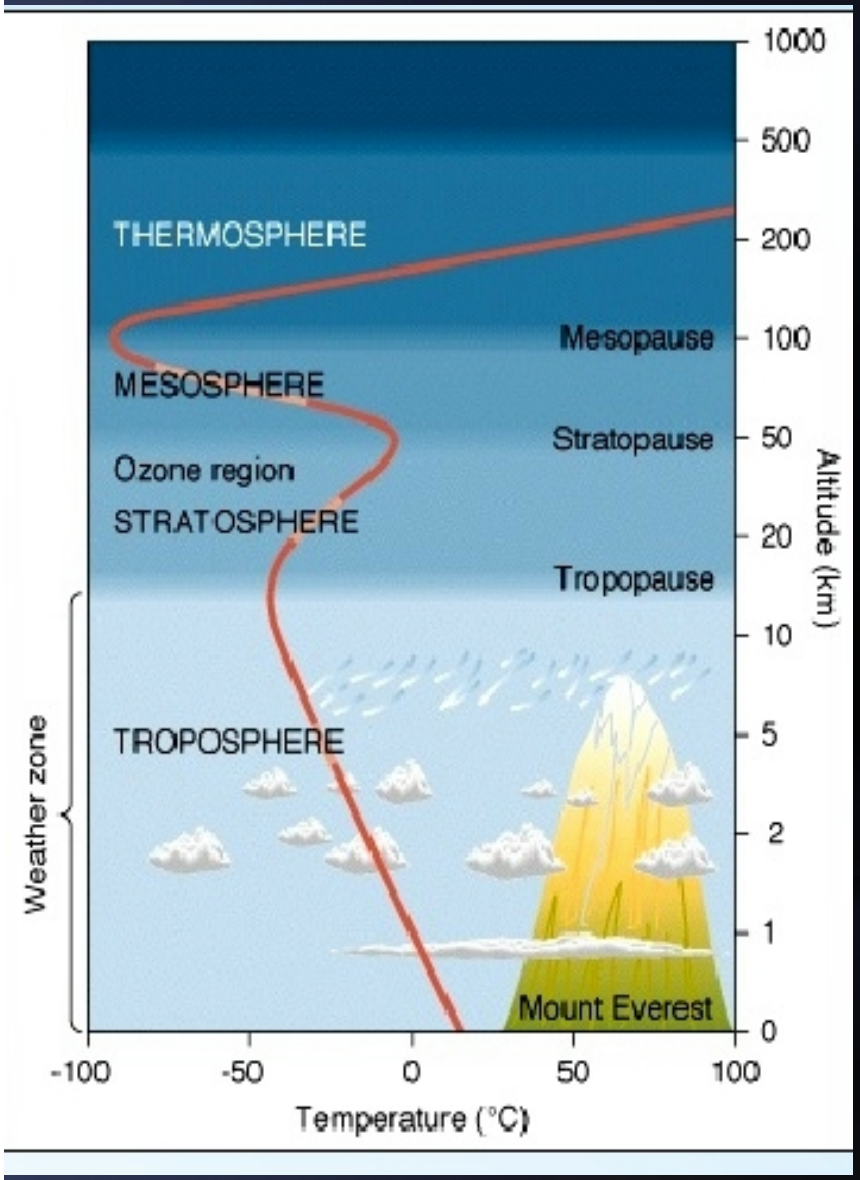
High Pressure to Low Pressure: From the Bottom UP

Atmospheric pressure decreases exponentially with altitude. This is called the ***pressure gradient***.

The total weight of air over Earth decreases with elevation because there are less air molecules per volume. It's less dense.



What is Needed for Water Vapor to form clouds?



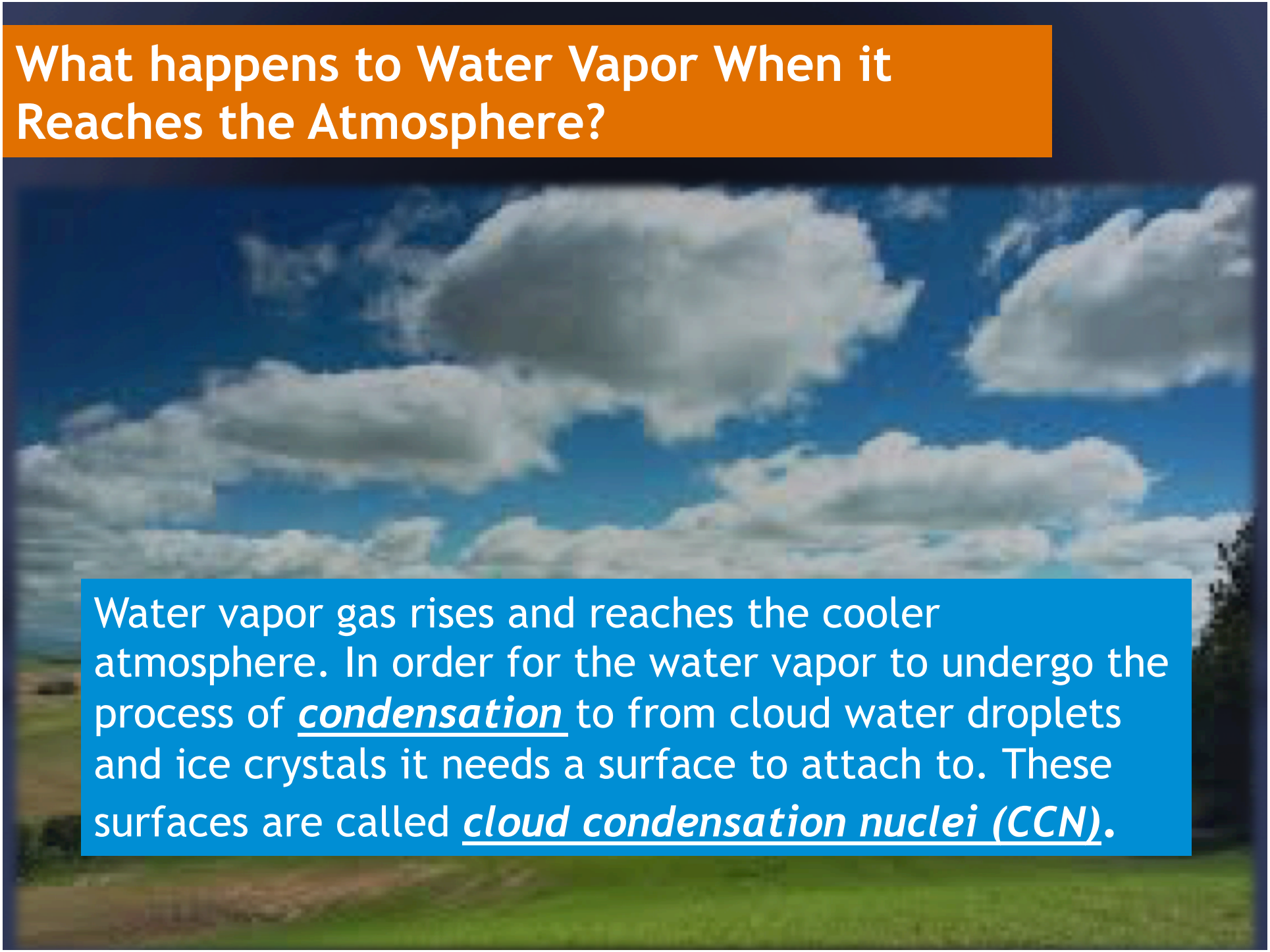
Cooler Temperatures

When water vapor rises into the upper layers of the troposphere it cools down considerably and becomes denser. The temperature ranges from 17C to -52C.

The troposphere starts at the Earth's surface and rises above approximately 14.5 km. This is where most weather occurs.

The cooler temperatures combined with the suspended dust particles are the prime ingredients that promote cloud formation.

What happens to Water Vapor When it Reaches the Atmosphere?



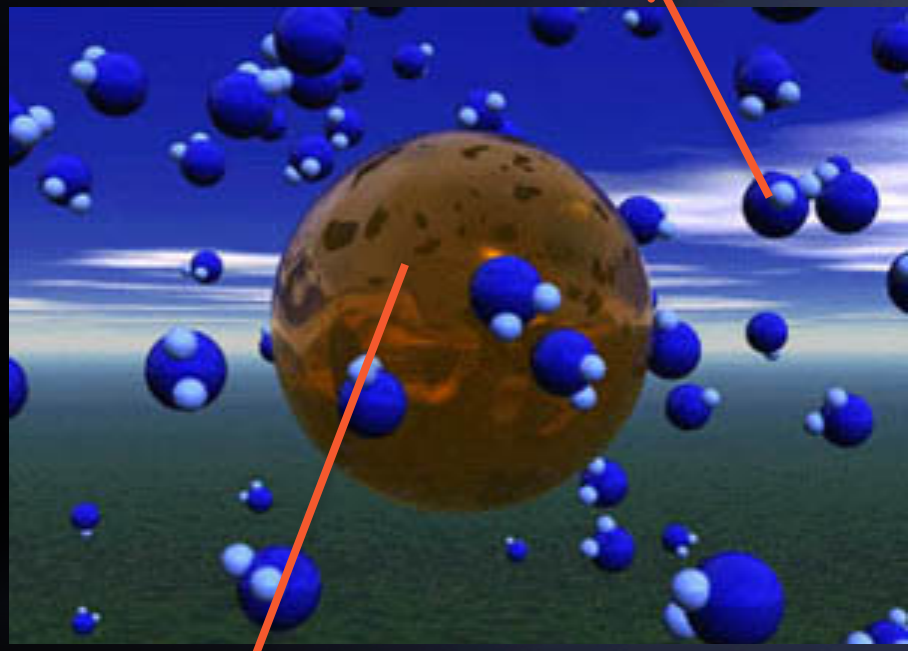
Water vapor gas rises and reaches the cooler atmosphere. In order for the water vapor to undergo the process of ***condensation*** to from cloud water droplets and ice crystals it needs a surface to attach to. These surfaces are called ***cloud condensation nuclei (CCN)***.

What are Cloud Condensation Nuclei?

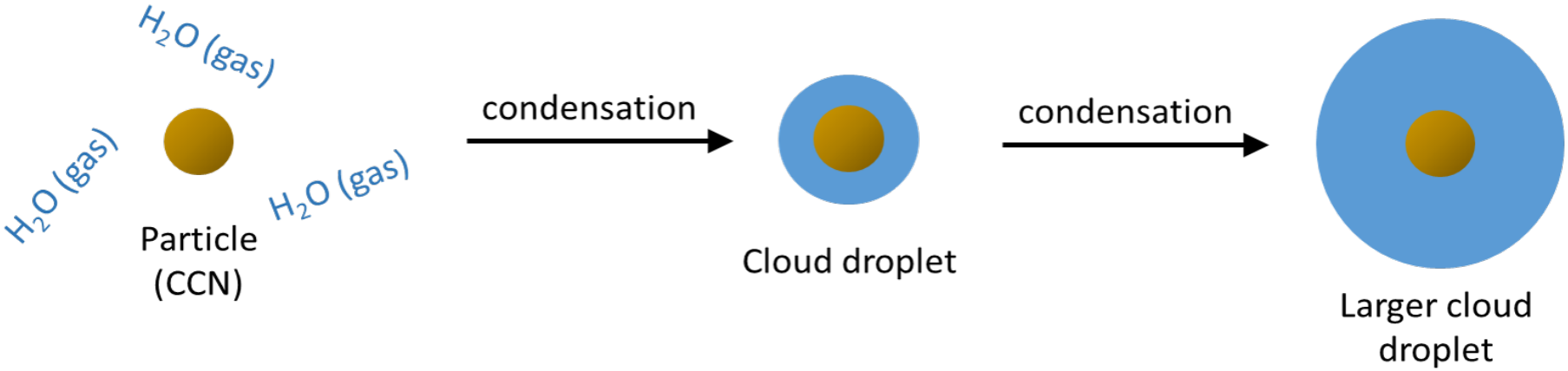
Cloud Condensation Nuclei is the term used for ***Aerosols*** that serve as a condensation surface for water vapor molecules to attach to.

Aerosols are tiny solid particles or liquid droplets suspended in the atmosphere.

Aerosols are essential to the seeding process of clouds.

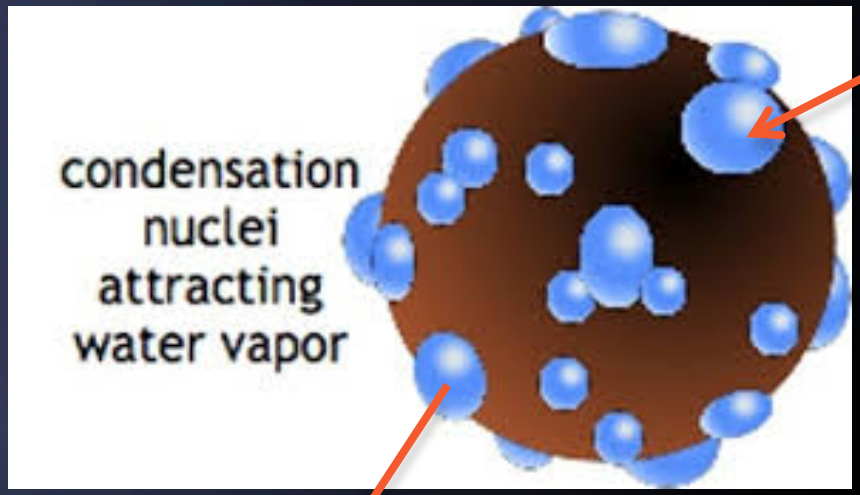


Condensation Nucleation Process



1. Water Vapor in the encounters aerosol particle suspended in the atmosphere.
2. Water vapor lands on the surface of the aerosol and condensates to form a cloud droplet.
3. Water vapor continues to collide with each other and coalesce to form larger cloud droplets.

What is the Cloud Condensation Nuclei?



Water Vapor continues to condensate on the surface of the Aerosol-CCN (Cloud Condensation Nuclei). Allowing the cloud droplet to get bigger.

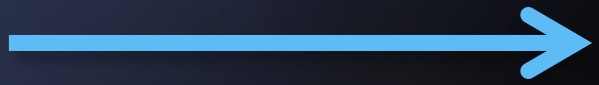
Water Vapor turns in to water droplets by condensing on the surface of an aerosol particle.

Aerosols particles come from different sources such as volcanic ash, sand, sea salt, among other natural sources. They are also produced by pollution due to human activity.

How does Condensation Occur?

Gas to Liquid

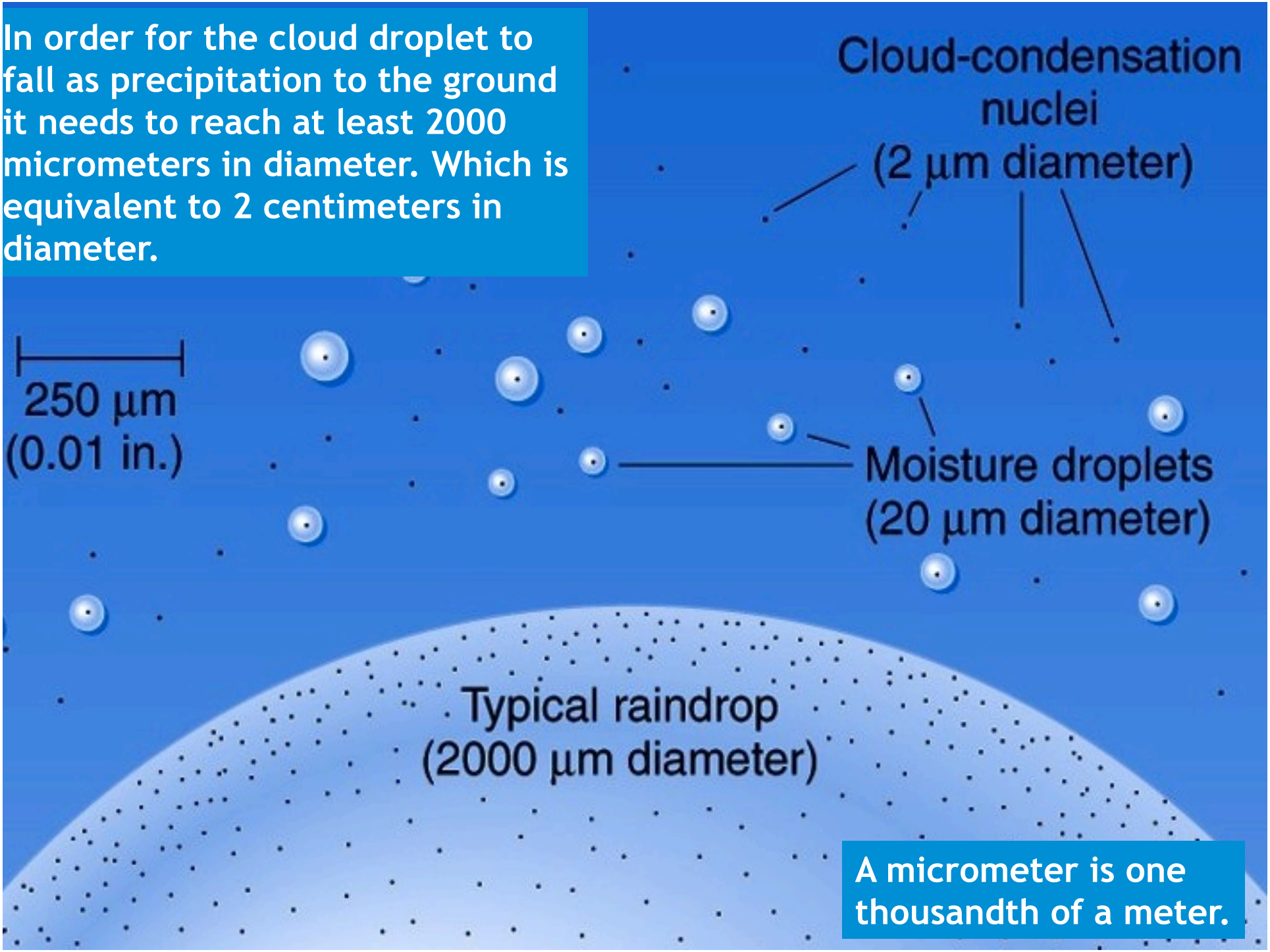
Take Away Energy



Heat is Released

When the water vapor comes in contact with a surface which are called cloud condensation nuclei, heat is released and it undergoes a phase change from gas to liquid. There is loss of energy due to a cooler environment.

In order for the cloud droplet to fall as precipitation to the ground it needs to reach at least 2000 micrometers in diameter. Which is equivalent to 2 centimeters in diameter.



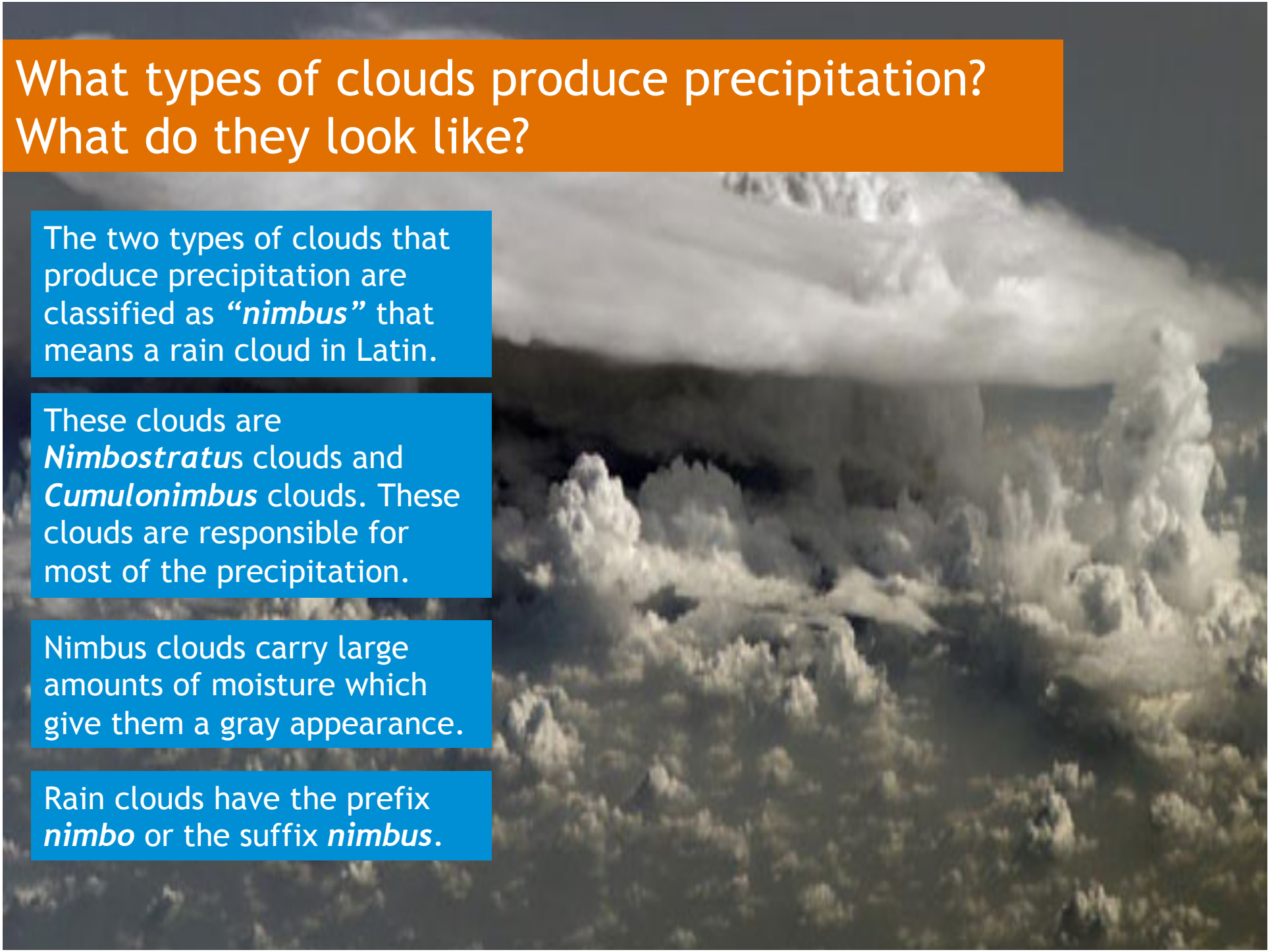
A micrometer is one thousandth of a meter.

One of Two Primary Cloud Functions

Produce Precipitation

Rain
Fog
Snow
Hail
Slet

What types of clouds produce precipitation? What do they look like?



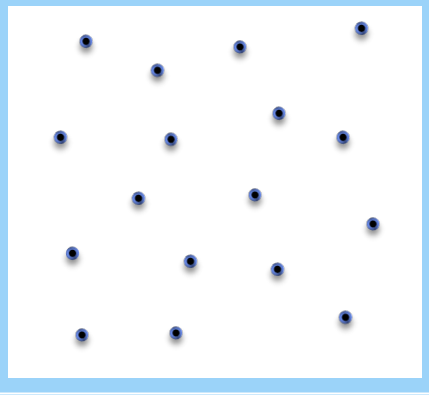
The two types of clouds that produce precipitation are classified as ***"nimbus"*** that means a rain cloud in Latin.

These clouds are ***Nimbostratus*** clouds and ***Cumulonimbus*** clouds. These clouds are responsible for most of the precipitation.

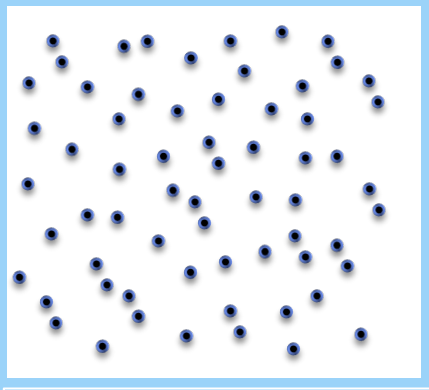
Nimbus clouds carry large amounts of moisture which give them a gray appearance.

Rain clouds have the prefix ***nimbo*** or the suffix ***nimbus***.

What Effect does the Density of Particles have on Cloud Formation?



Less Particles per cm^3

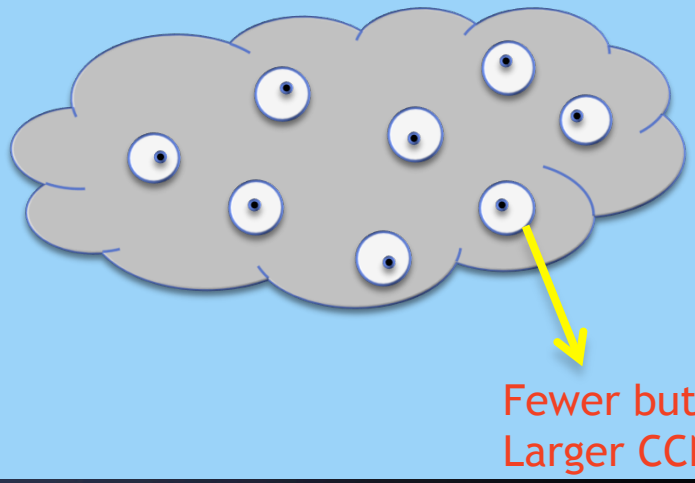


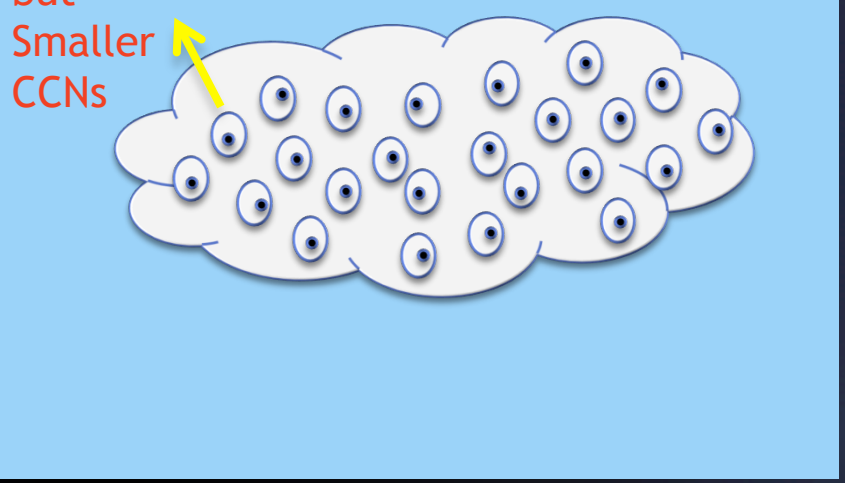
More particles per cm^3

Unpolluted air has 100s of aerosols per cm^3. Less particles per volume than polluted air.

Polluted air has 1000s of aerosols per cm^3. 10 times more particles per volume than clean air.

What Effect does Aerosol Pollution have on Clouds?





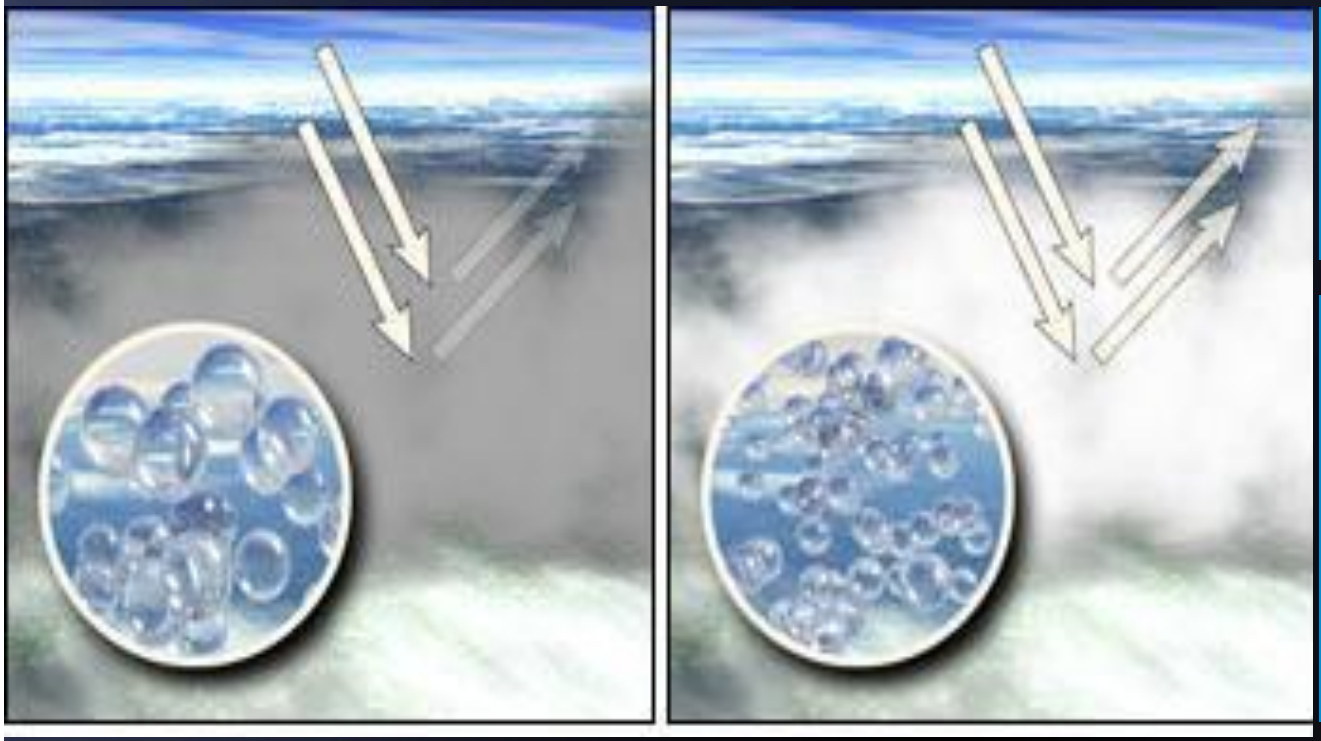
Unpolluted clouds have lower concentration of CCNs and ***larger water and ice droplets*** per cm^3.

When there are fewer aerosol particles more water vapor condenses and accumulates on the CCNs (Cloud Condensation Nuclei), rendering a larger droplet.

Polluted clouds have a higher concentration of CCN providing many nucleation points for lots of ***tiny water and ice droplets to form*** per cm^3.

More particles means that there is less accumulation of water or ice on the surface of the CNNs rendering the droplets smaller.

How does Aerosol Pollution Suppress Precipitation?



The unpolluted cloud on the left with the bigger droplets produces precipitation.

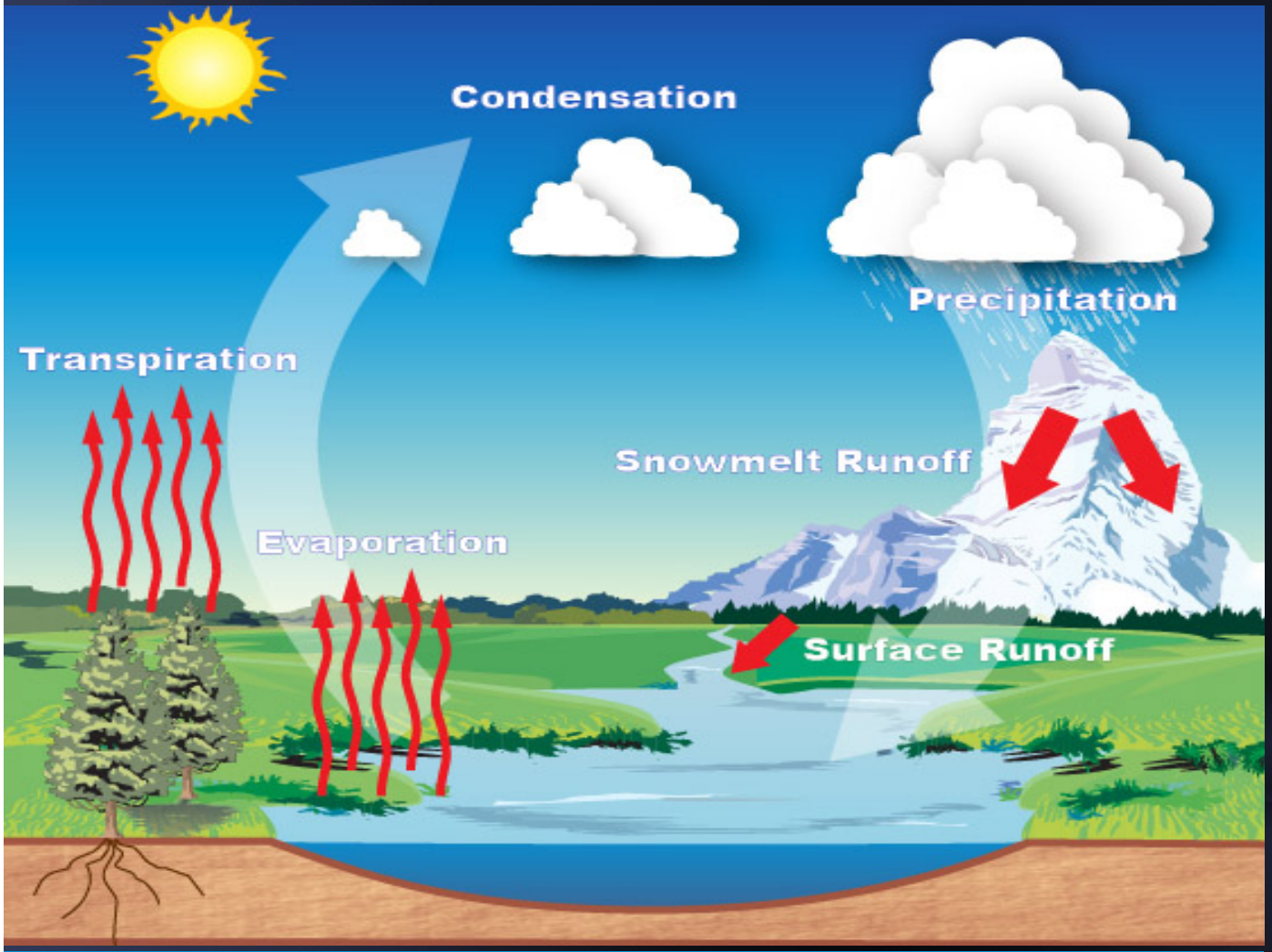
The polluted cloud on the right with tiny droplets suppresses precipitation. Prevent water droplets The drops are not heavy enough to fall to Earth.

Water droplets are bigger in pristine environments. They reach the 2000μm droplet radius. It can fall out of the cloud as precipitation defy gravity.

2000μm = 2 millimeters

Water droplets are to small to fall out of the cloud as precipitation. The higher concentration of aerosols per cm^3 affected the clouds ability to produce precipitation .

Water Cycle: The Hydrologic Cycle



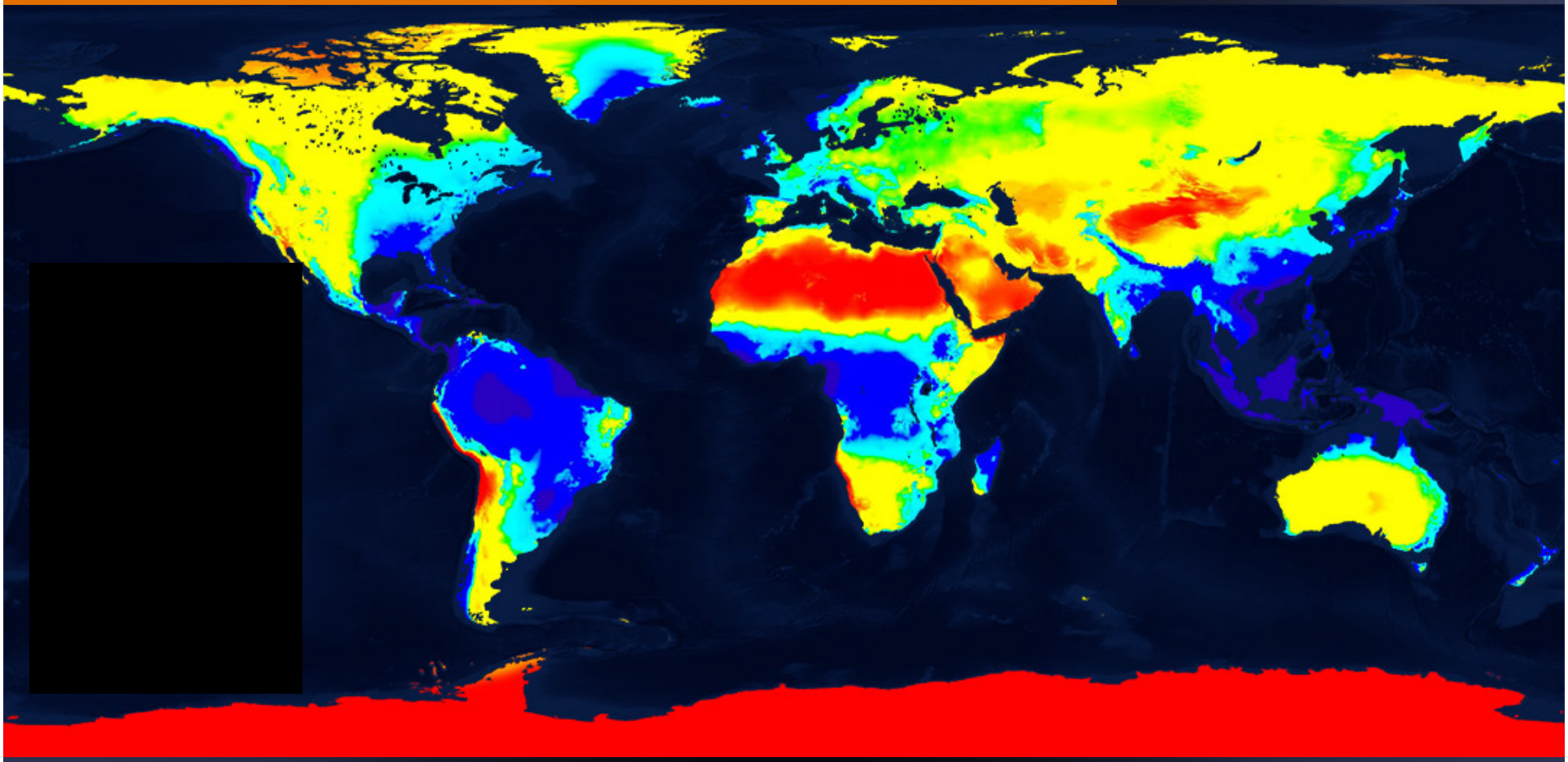
Which are some of the processes involved in the water cycle?

This is how water travels from Earth to the Atmosphere. It's transported via clouds to other locations across the globe.

These are the processes involved in the Water Cycle:

- Evaporation
- Evapotranspiration
- Cloud Nucleation
- Condensation
- Precipitation
- Runoff

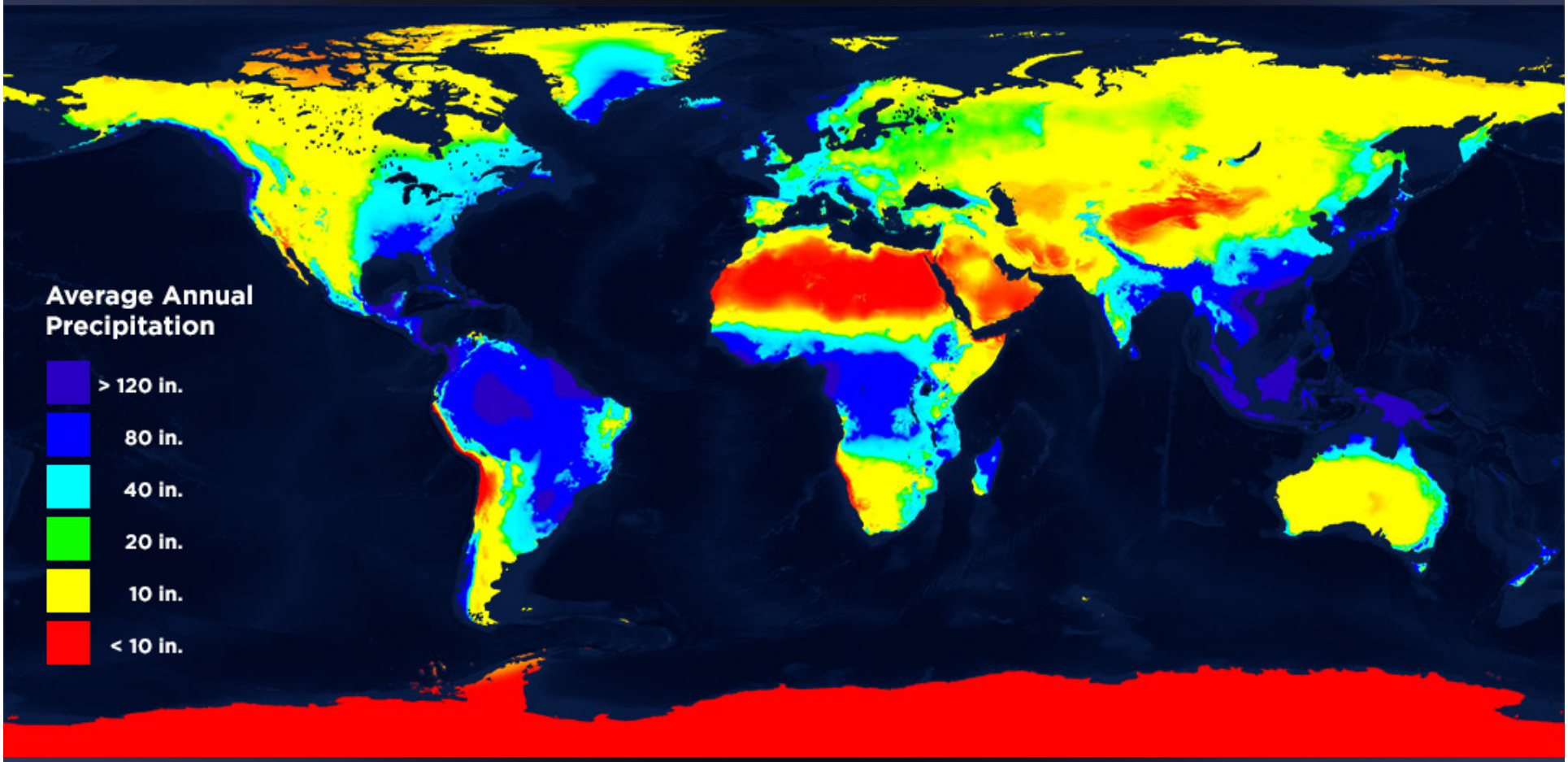
Where does Rain Fall and How Much?



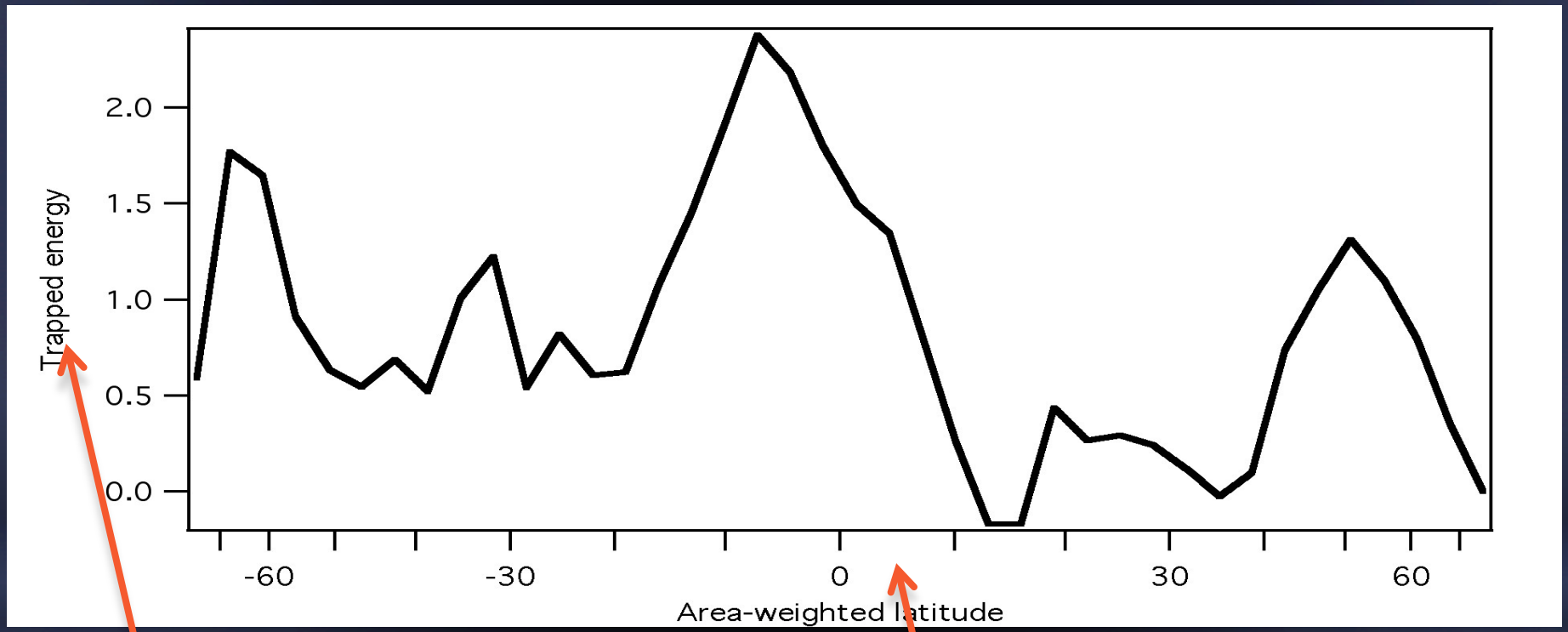
Create a legend for the color coded map. The colors on the map represent precipitation in inches.

Colors	Description (levels of precipitation by region)	Estimated Amount (annual precipitation)

Global Precipitation Map with Legend



Graph of Trapped Energy due to Water Vapor of Climate Variation from 2003 to 2008



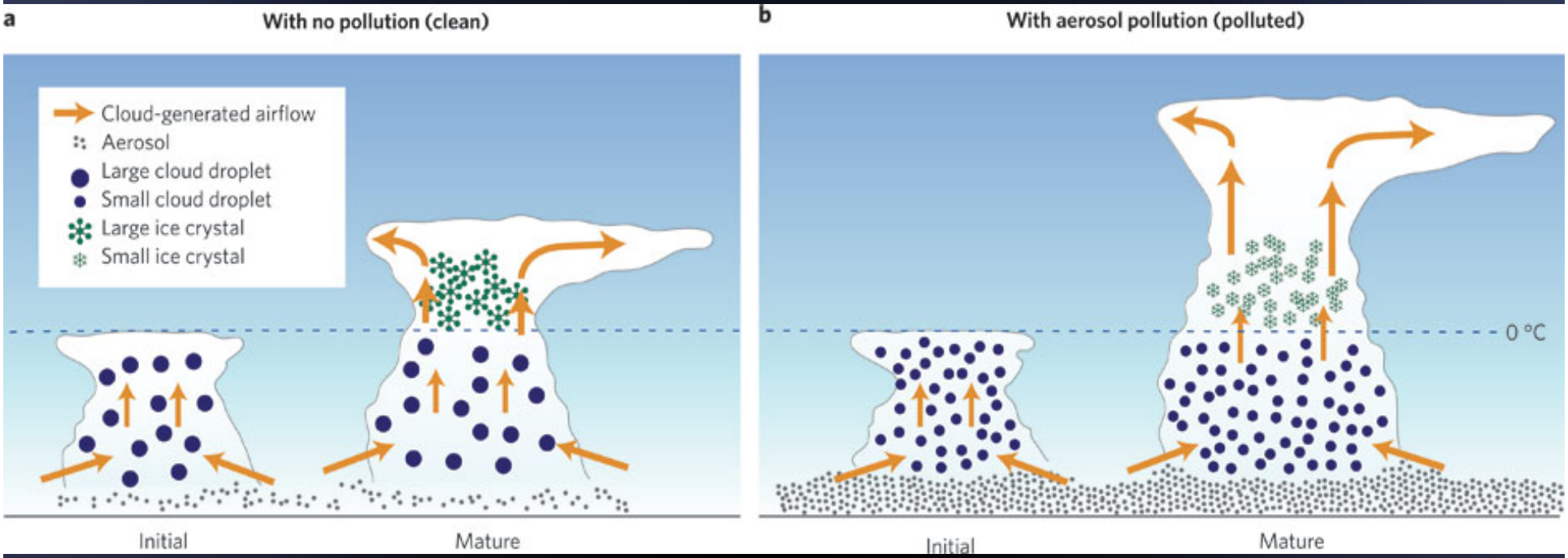
Trapped Energy by Water Vapor

Latitude Scale

Seasonal Transition of Water Vapor

Move cursor to play video

Cloud Formation from Initial CCN Stage to Maturity



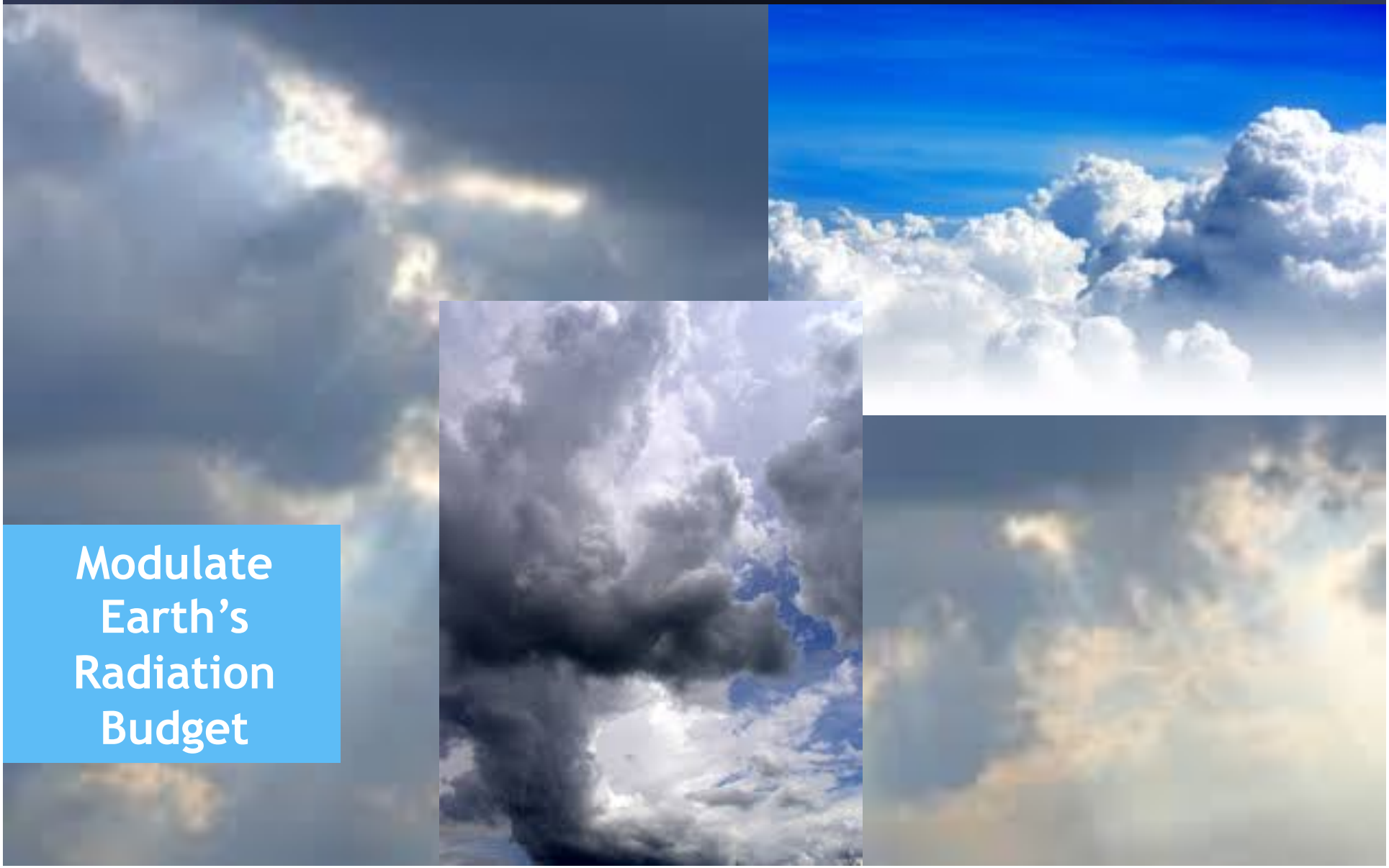
Cloud Generation with no Pollution

Cloud Generation with Pollution

NASA's Earth Water Cycle Animation Video

Move cursor to find play button

One of Two Cloud Primary Functions



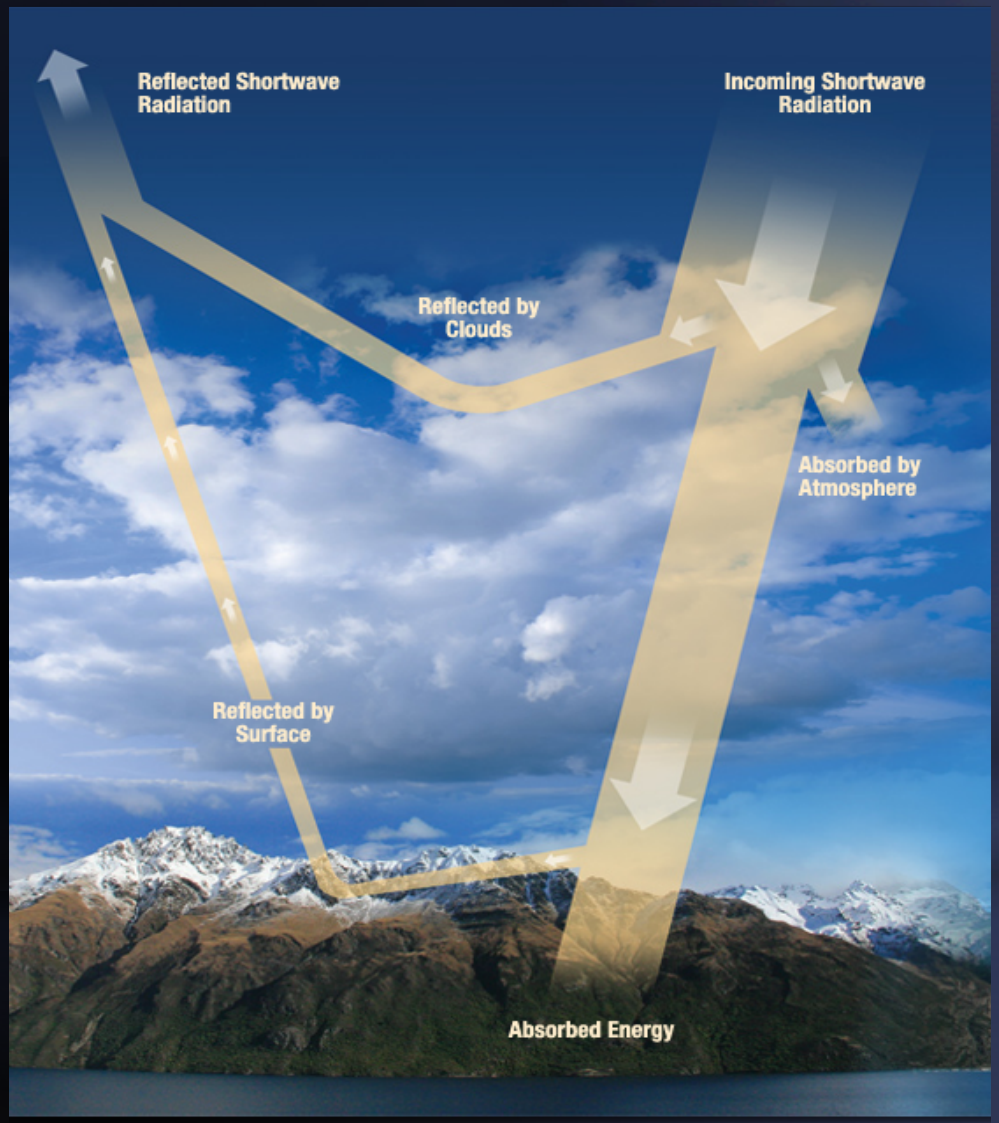
Modulate Earth's Radiation Budget

What is the Earth's Radiation Budget?

The Earth's Radiation Budget is the balance between the incoming energy from the Sun to Earth and the outgoing thermal and reflected energy from the Earth out into space.

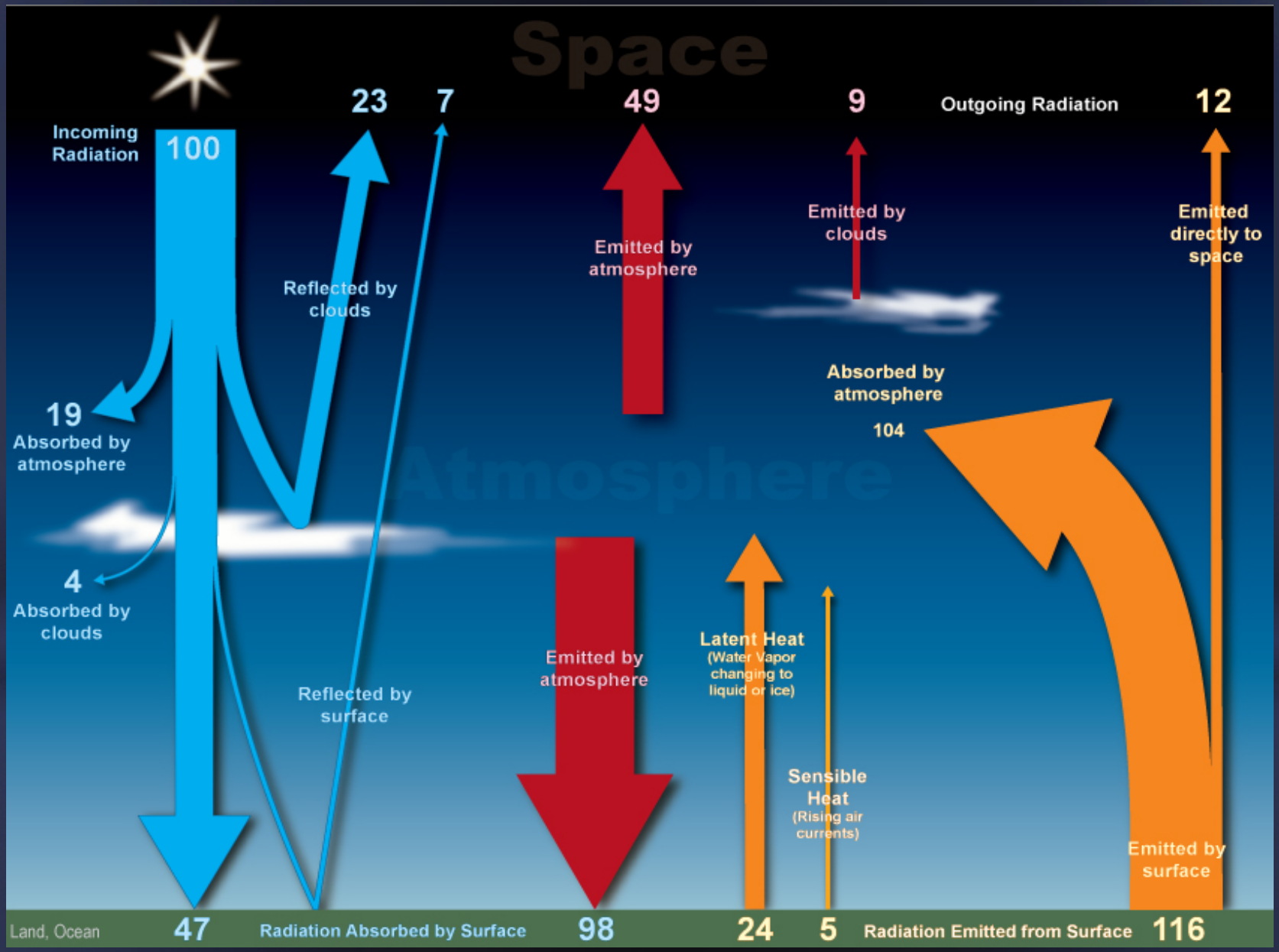
Clouds play a very important role in helping maintain a balance between the incoming and outgoing radiation. Clouds help maintain an equilibrium.

Without these mechanisms of balancing the amount of energy that comes in and goes out the Earth would over heat or get to cold to support life as we know it.



Incoming Radiation = Outgoing Radiation

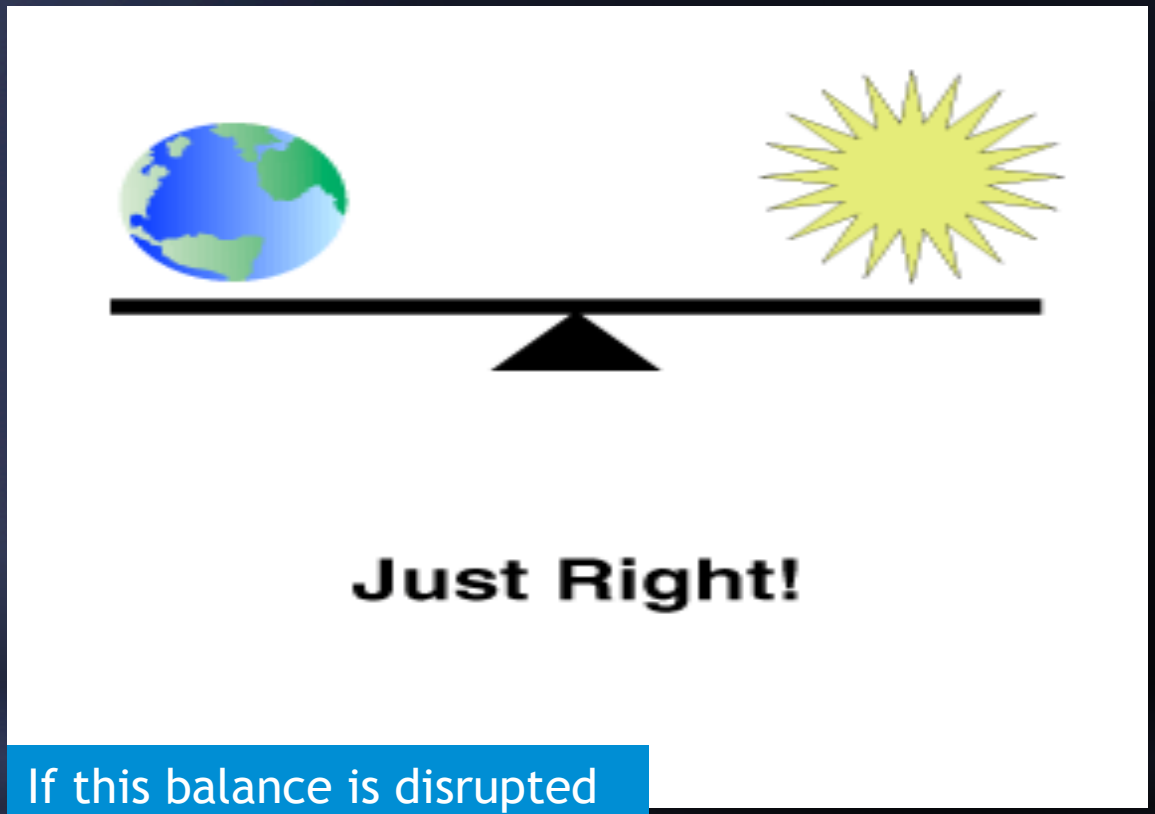
A Closer Look At The Earth's Radiation Budget



Earth's Radiation Budget Work Sheet

Arrows	Describe in general terms what do you think the arrows of the Earth's Radiation Budget Chart mean.
Color	
Direction_(Where is the Radiation Going?)	
Width	
Length	

A Closer Look At The Earth's Radiation Budget



QUESTION:

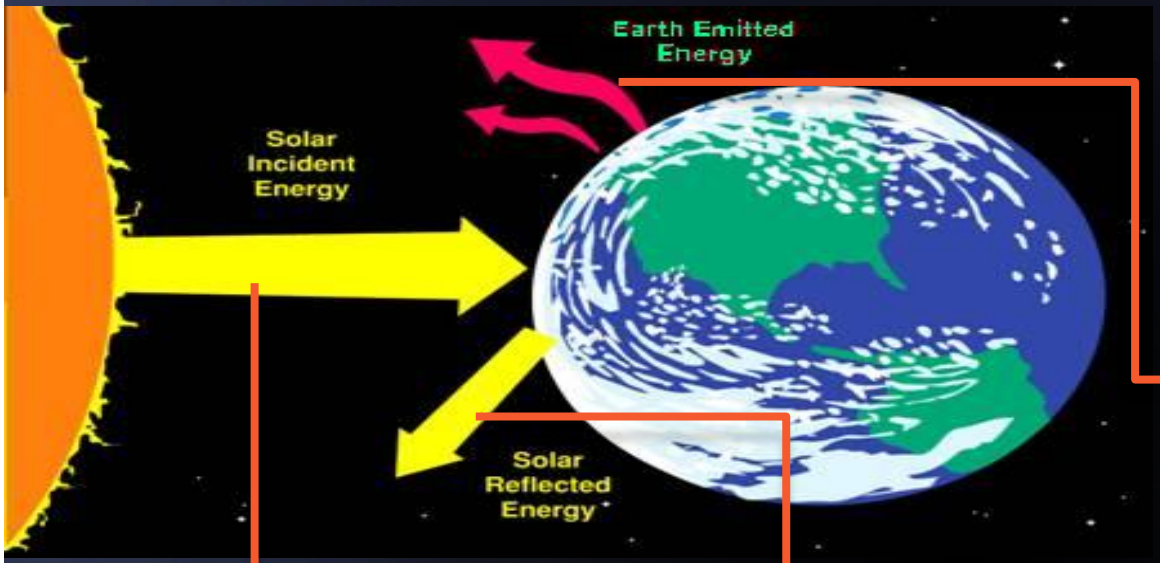
Why do you think the Earth needs to maintain an equilibrium between how much energy comes in and goes out?

What Earth Systems do you think would be most affected?

If this balance is disrupted then the Earth can heat up or cool to dangerous levels affecting earth climate systems, especially the atmosphere and oceans, therefore all living things.

A Closer Look At The Earth's Radiation Budget

Three Basic Parts of the Earth's Radiation Budget



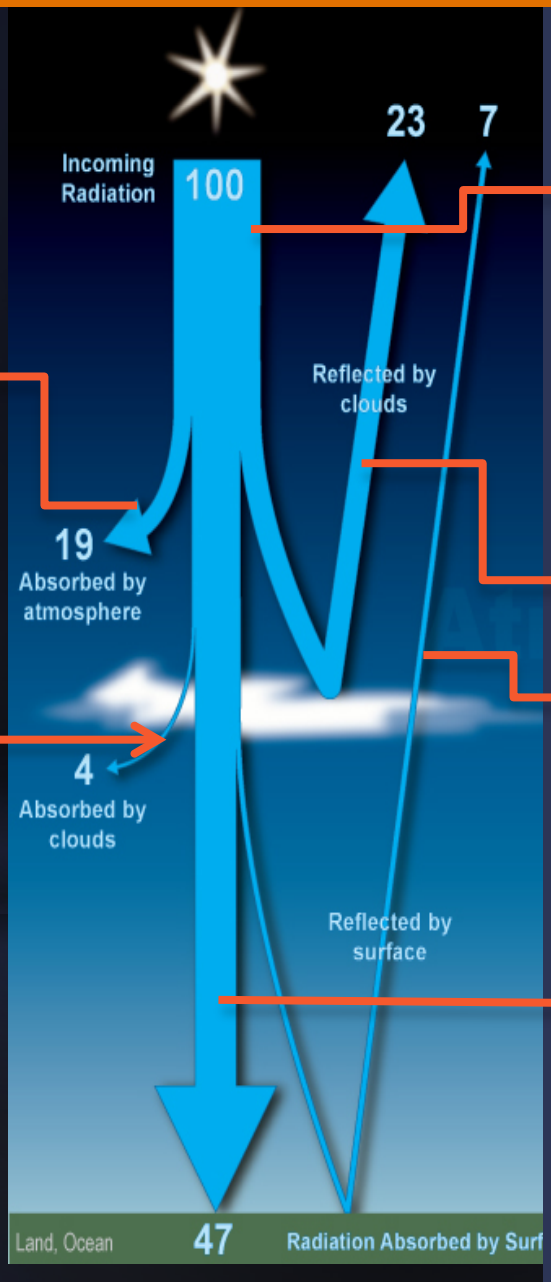
Earth Emitted Energy – Earth emits Infrared Radiation back to the atmosphere and space.

Incident Radiation – The amount of solar radiation received by a surface at a particular time.

Solar Reflected Energy – Is the solar Visible and UV Radiation that gets ***reflected*** back back to Space.

The Earth needs to maintain a balance between how much energy comes in and how much goes out.

A Closer Look at The Earth's Radiation Budget Chart



19% of the shortwave solar radiation is absorbed by the atmosphere.

4% of the shortwave radiation (Visible and UV) are absorbed by clouds.

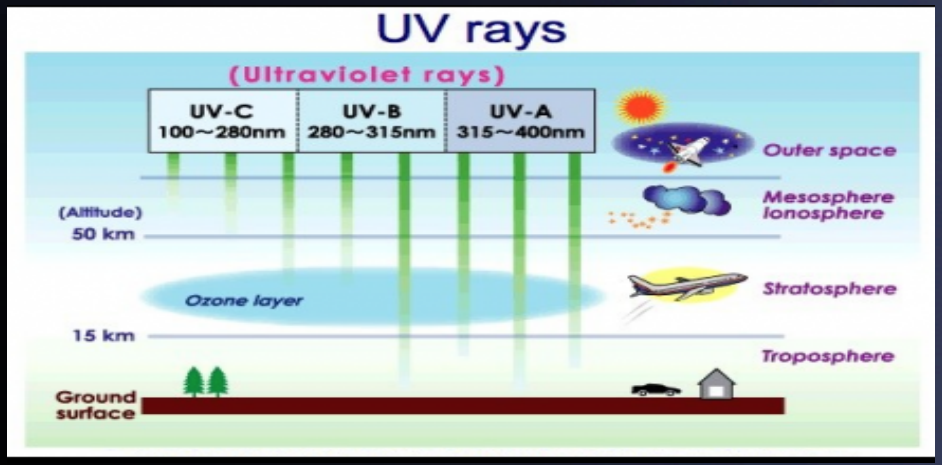
100% of the Solar Radiation penetrating the Earth's atmosphere are two types of shortwave radiation - Visible Light and UV (Ultra Violet Light).

30% of the shortwave radiation (Visible and UV) are ***reflected*** back to space by ***clouds*** and by various types of ***reflective Earth surface materials*** such as glaciers, snow, sand among others.

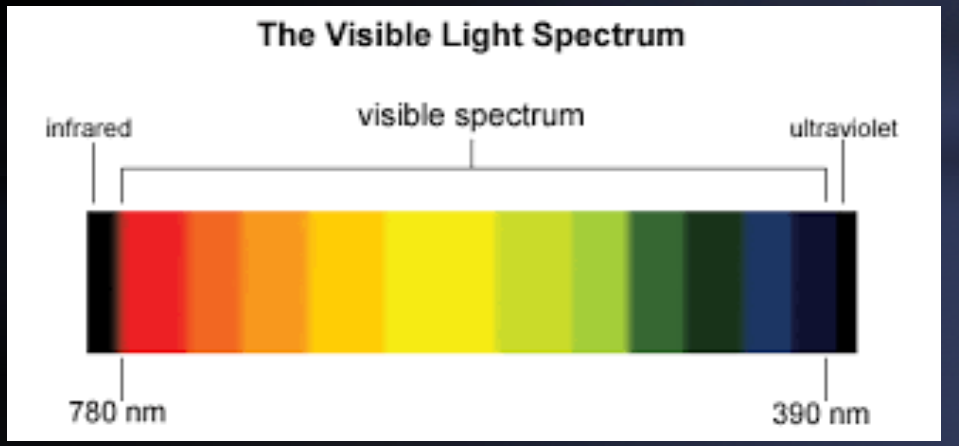
47% of the Solar Radiation that penetrates the atmosphere is ***absorbed*** by Earth's land and oceans.

Incident Incoming Shortwave Radiation

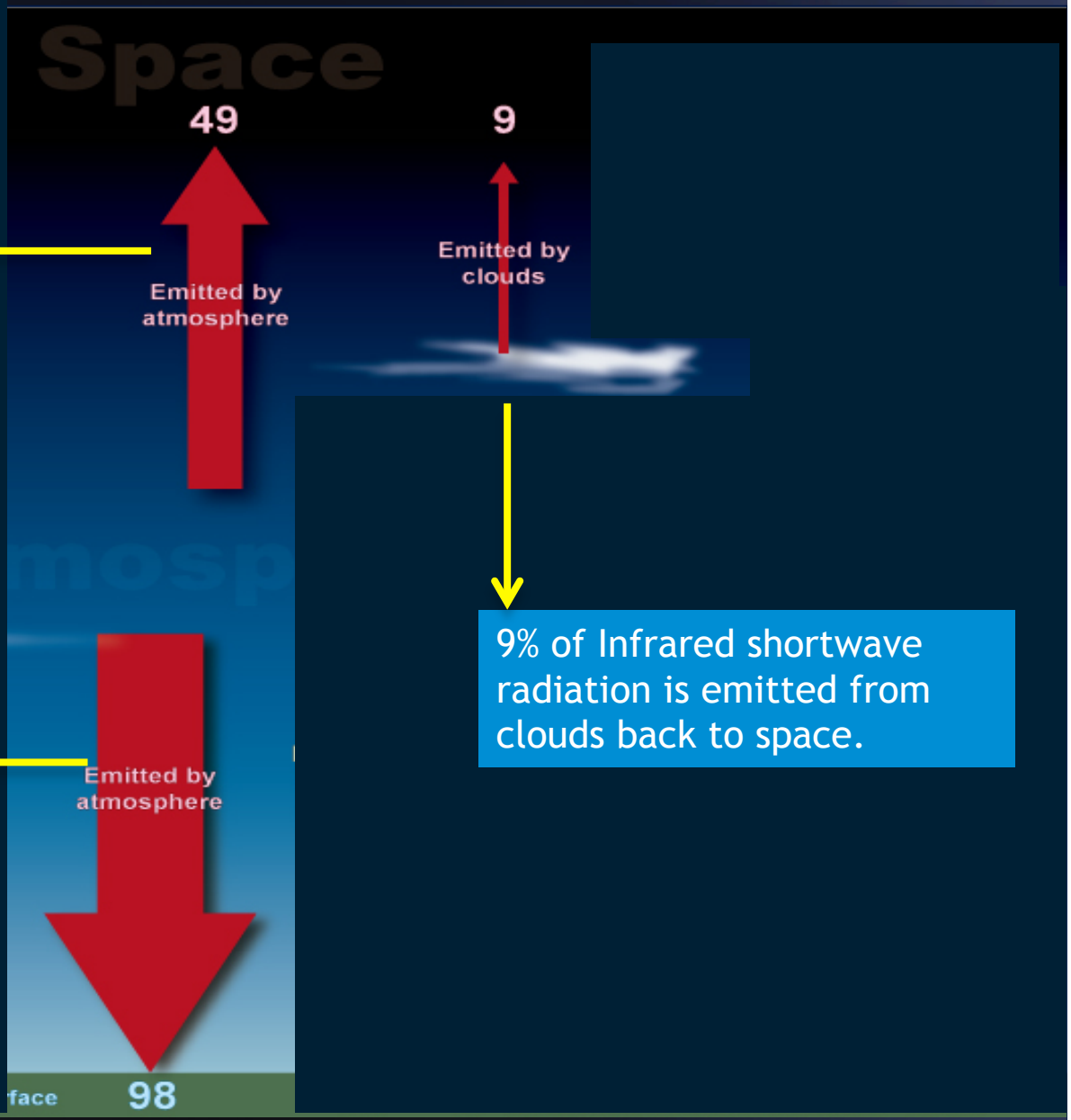
Two Types of Ultra Violet shortwave radiation (UVA and UVB) penetrate the ozone layer and the atmosphere. They help warm our plant. With high these rays are dangerous to humans.



Visible Light Radiation penetrates the atmosphere and provides energy to heat up our planet. Living organisms are dependent of this type of radiation to see and produce food through the process of photosynthesis.



A Closer Look at The Earth's Radiation Budget Chart



49% of Infrared shortwave radiation is emitted by the atmosphere back to space.

9% of Infrared shortwave radiation is emitted from clouds back to space.

98% of Infrared shortwave radiation is emitted by the atmosphere back to Earth.

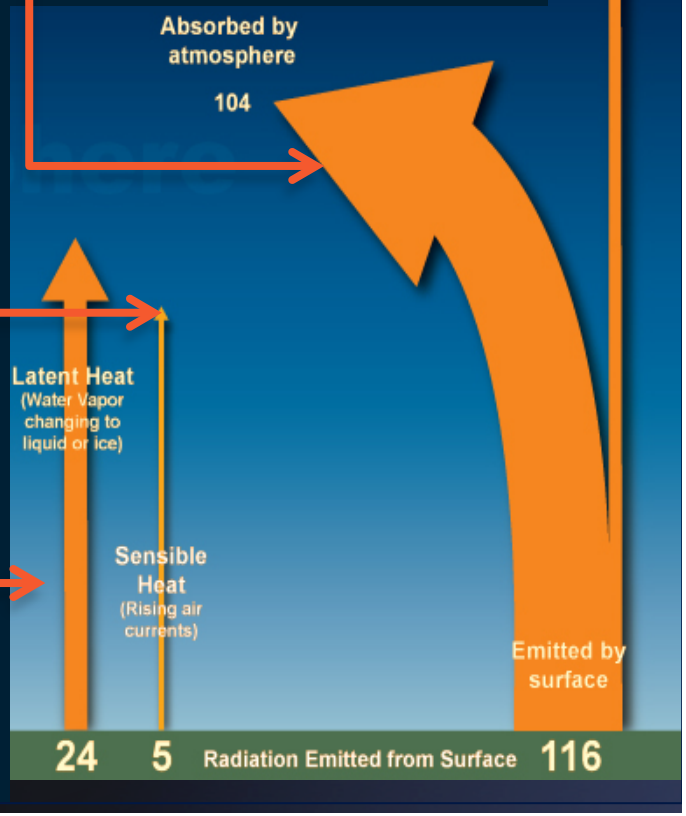
A Closer Look at The Earth's Radiation Budget Chart

12% of Infrared Radiation emitted from Earth to Space.

104% of Infrared Radiation emitted by the Earths surface is absorbed by the Atmosphere.

5% Infrared radiation emission from rising air currents.

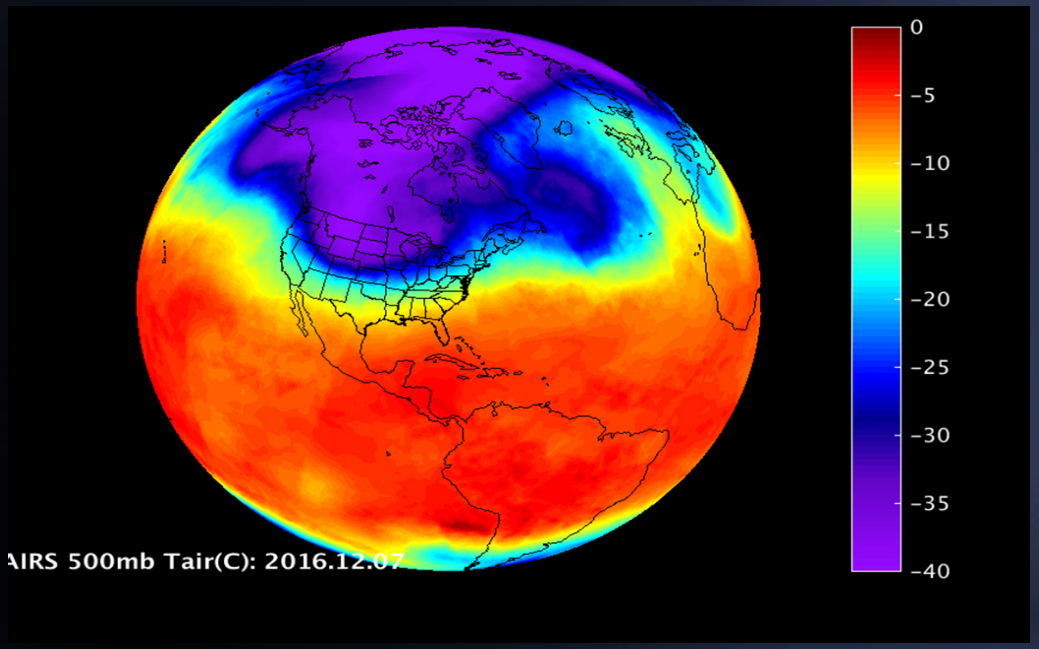
24% of Infrared Radiation emitted when water vapor undergoes a phase change to liquid or ice in the atmosphere. Water vapor gives off energy when it and condensates.



Infrared Shortwave Radiation Emissions

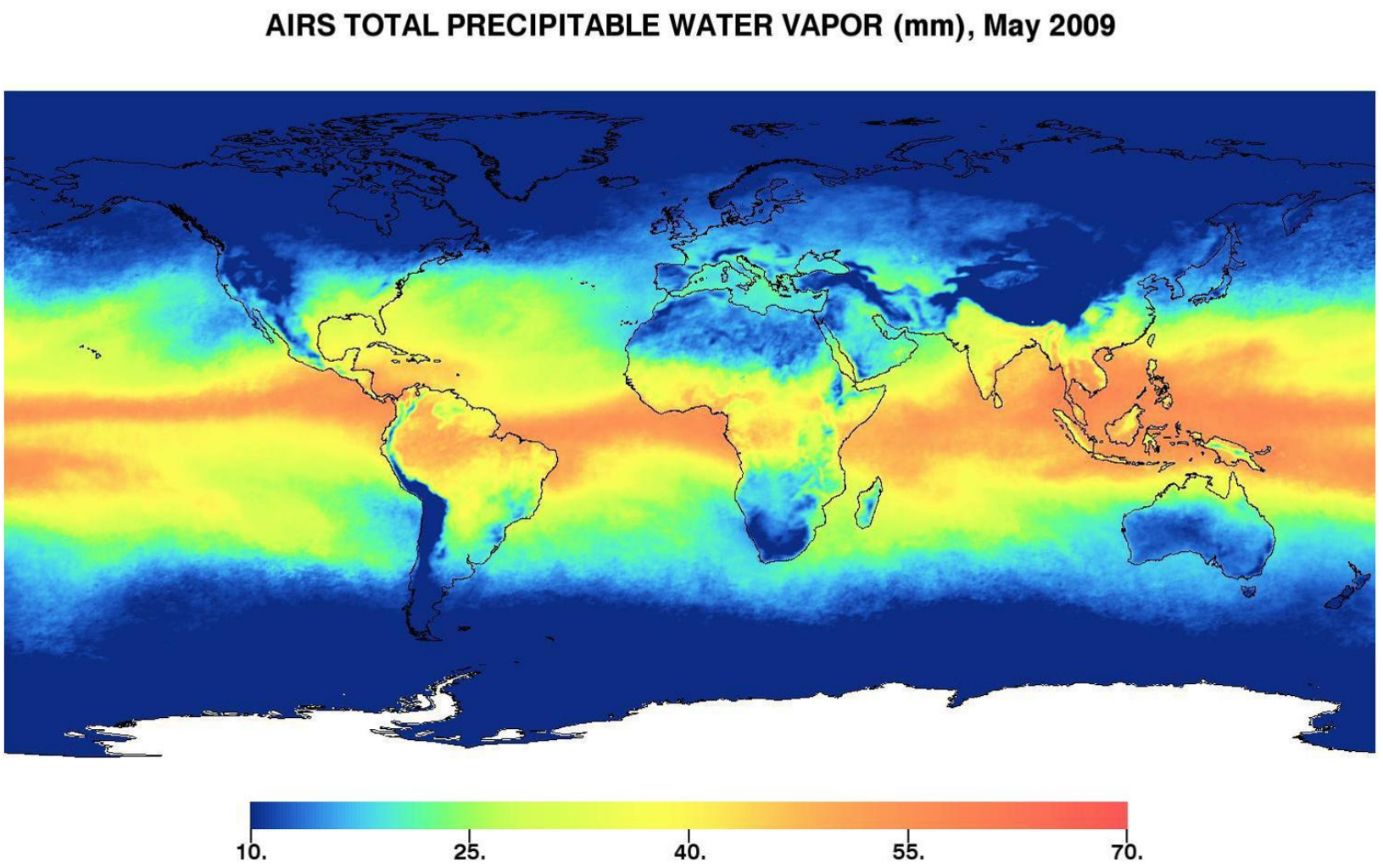
Longwave Radiation is thermal energy. It is the infrared radiation emitted by the Earth's Surface and Atmosphere on the Earth's Radiation Budget Chart.

The Earth and the Atmosphere absorb solar energy in the from of shortwave UV and Visible Light radiation. Causing them to warm up and emit longwave infrared radiation to release energy and cool down to keep a temperature balance.

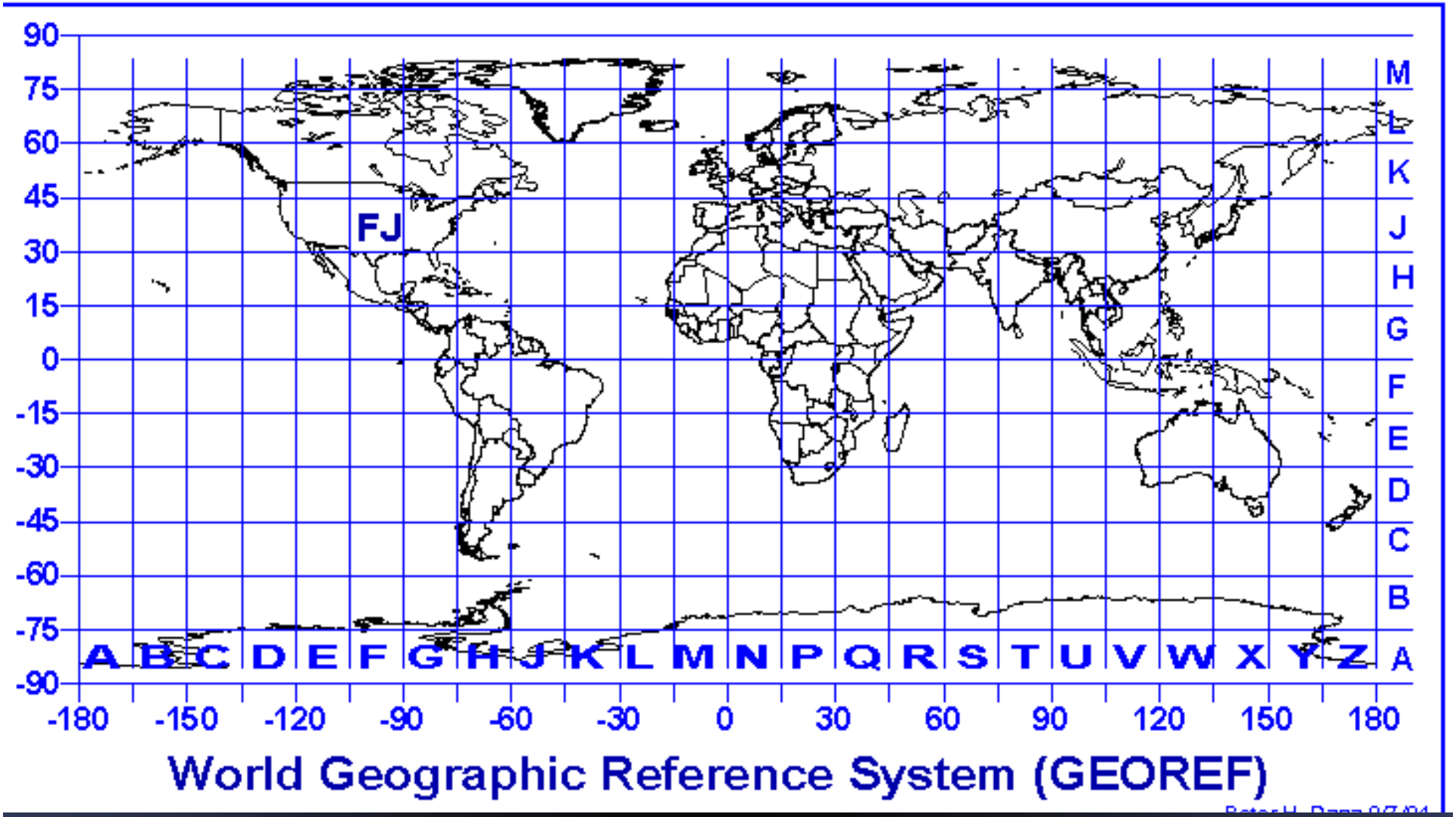


Infrared Image of Planet Earth.

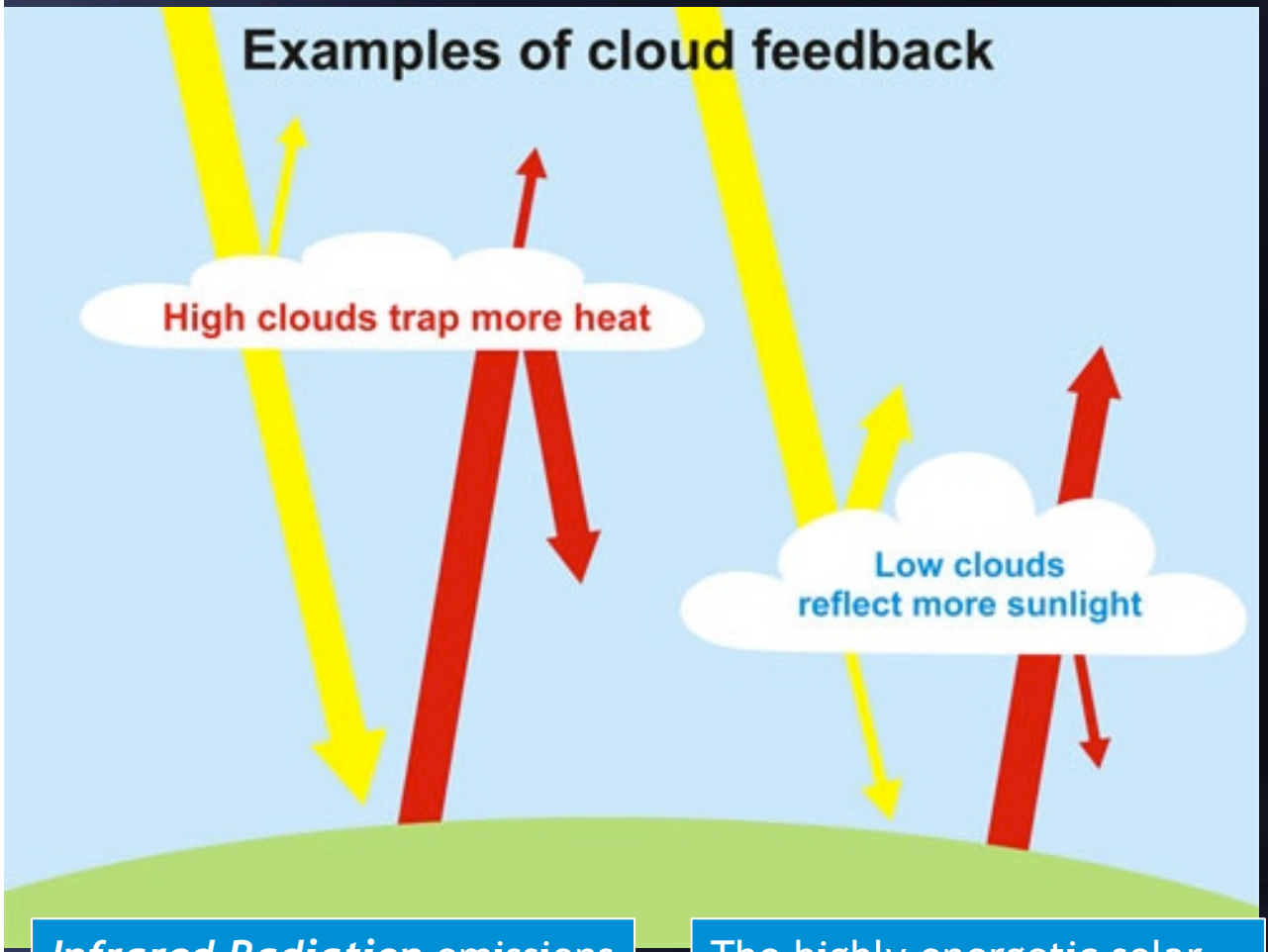
Infrared Image of Global Precipitable Water Vapor, May 2009



Global Coordinate Map



Light Reflection and Heat Absorption of Clouds



Low dense clouds reflect most of the incident shortwave rays of ***Visible Light and Ultra Violet*** radiation. Only a allowing a small percentage of the sun light to penetrate and reach the Earth.

Infrared radiation emissions from Earth penetrate the low clouds and are travel to space. A small amount of Infrared energy is emitted back to Earth.

Infrared Radiation emissions from the heated Earth are absorbed by ***high clouds*** and re-radiated most of it back to Earth and the rest to space.

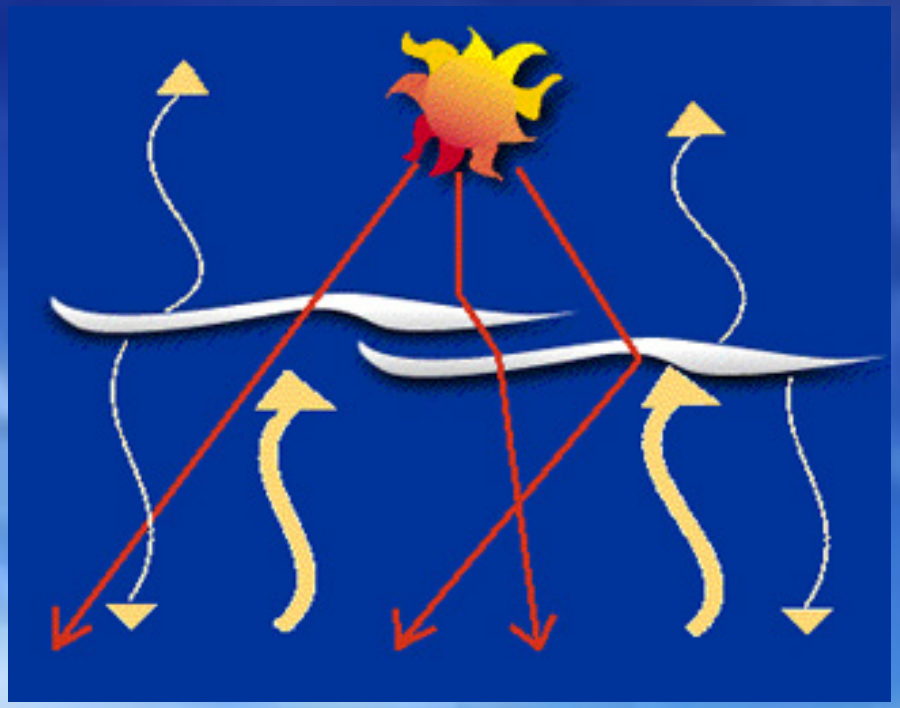
The highly energetic solar rays of ***Visible Light and Ultra Violent*** radiation penetrate ***high clouds*** and heat the Earth.

Heating Effect by High Cirrus Clouds

High Cirrus clouds are transparent to shortwave Visible Light and UV radiation. The sun rays reach Earth warming its surfaces.

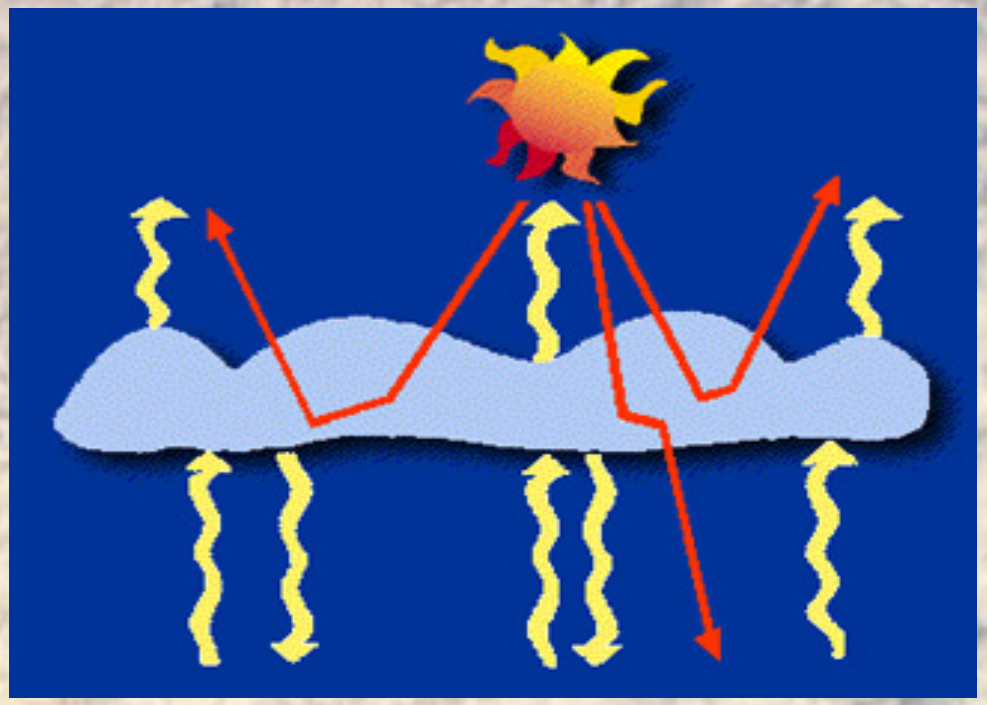
Cirrus Clouds have a low albedo forcing effect. This means that they don't reflect lots of solar radiation back to space.

These types of clouds absorb longwave Infrared radiation form Earth and emit back to space and Earth.



Cooling Effect of Stratuscumulus Low Clouds

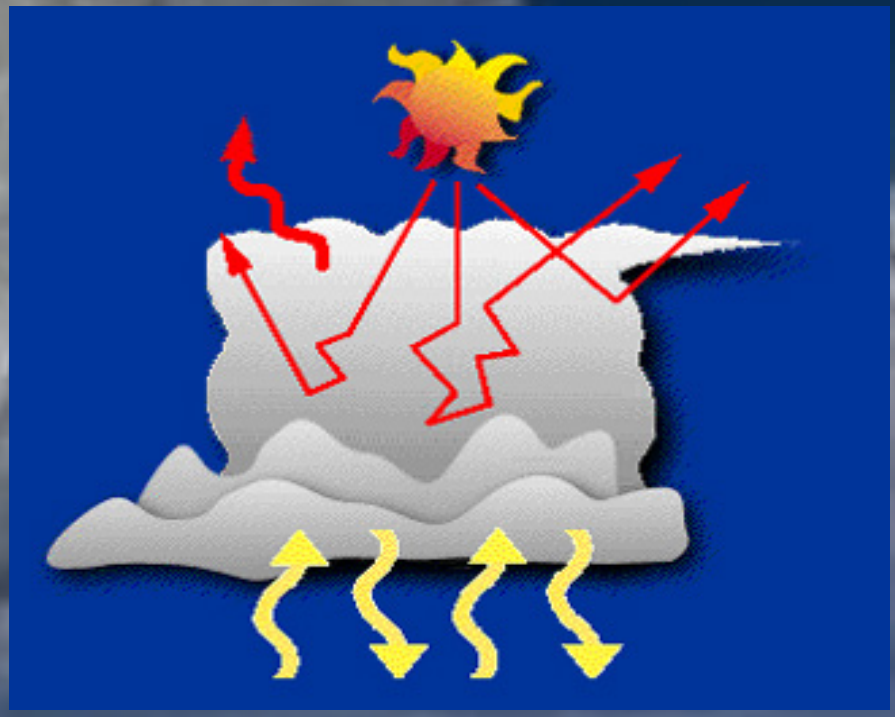
Low stratocumulus clouds have a cooling effect on Earth. These clouds are much denser than the high cirrus clouds. They block most of the incident highly energetic Visible Light and UV solar radiation and reflect it back to space. This effect is called large albedo forcing.



These clouds emit Infrared radiation towards Earth and out to space. Because they lie so low the temperature of the Infrared radiation is similar to the ground. The net warming effect is negligible.

Albedo – Is the amount of solar radiation that is reflected by a surface.

Deep Convective Cloud – Neutral



These huge Cumulonimbus Cloud don’t cool nor heat the Earth. Their height and thickness affect the amount of radiation it reflects and absorbs. The top of the cloud can reach up to 10km (33,000 feet) or more. The top of the cloud reflects most of the solar energy back to space. There cloud albedo forcing is high and also the greenhouse warming. They have a neutral net effect. No warming nor cooling.

How do Clouds Modulate The Earth's Energy Budget?

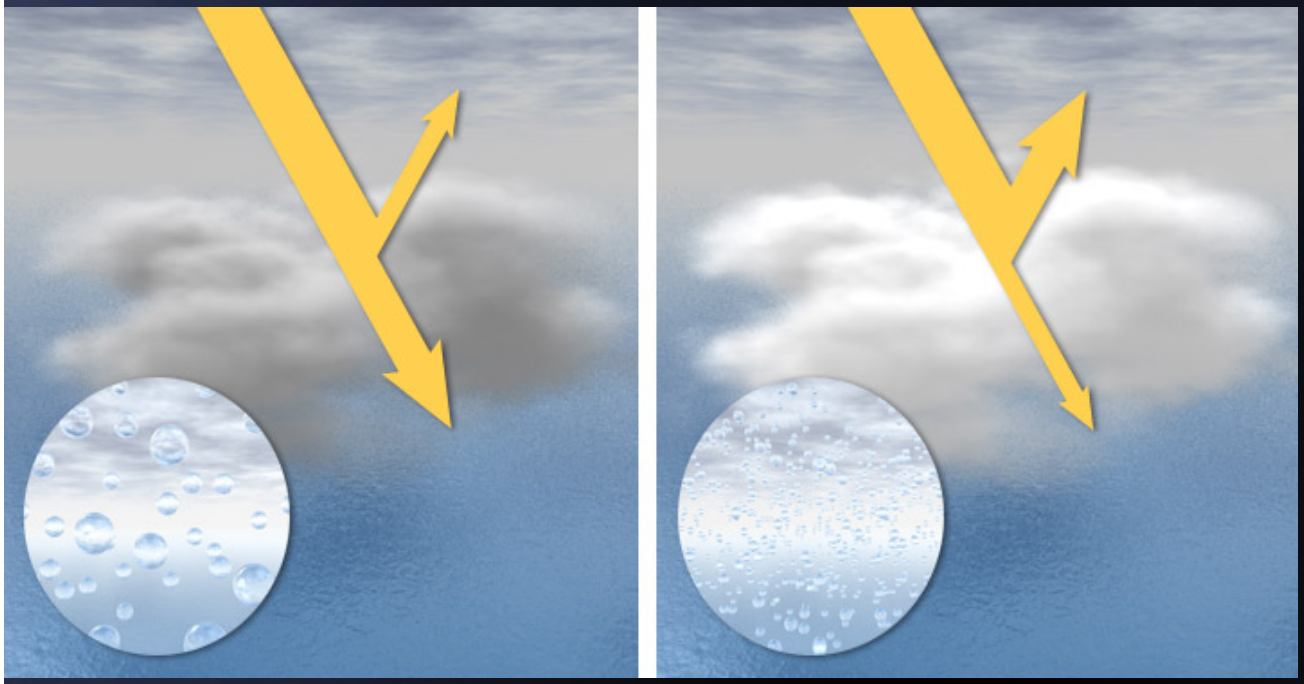
* Clouds cool the Earth's surface by reflecting incoming shortwave radiation back to space.

* Clouds absorb Infrared Radiation emitted by Earth surfaces and re-radiate back to Earth.

Summary: All clouds on Earth have a net radiative cooling and warming effect.

How do you think clouds may influence or affect climate?

How does Pollution of Aerosols Particles Affect Clouds and the Earth's Radiation Budget?



Clean clouds become gray because more light travels right through them. They reflect less solar radiation.

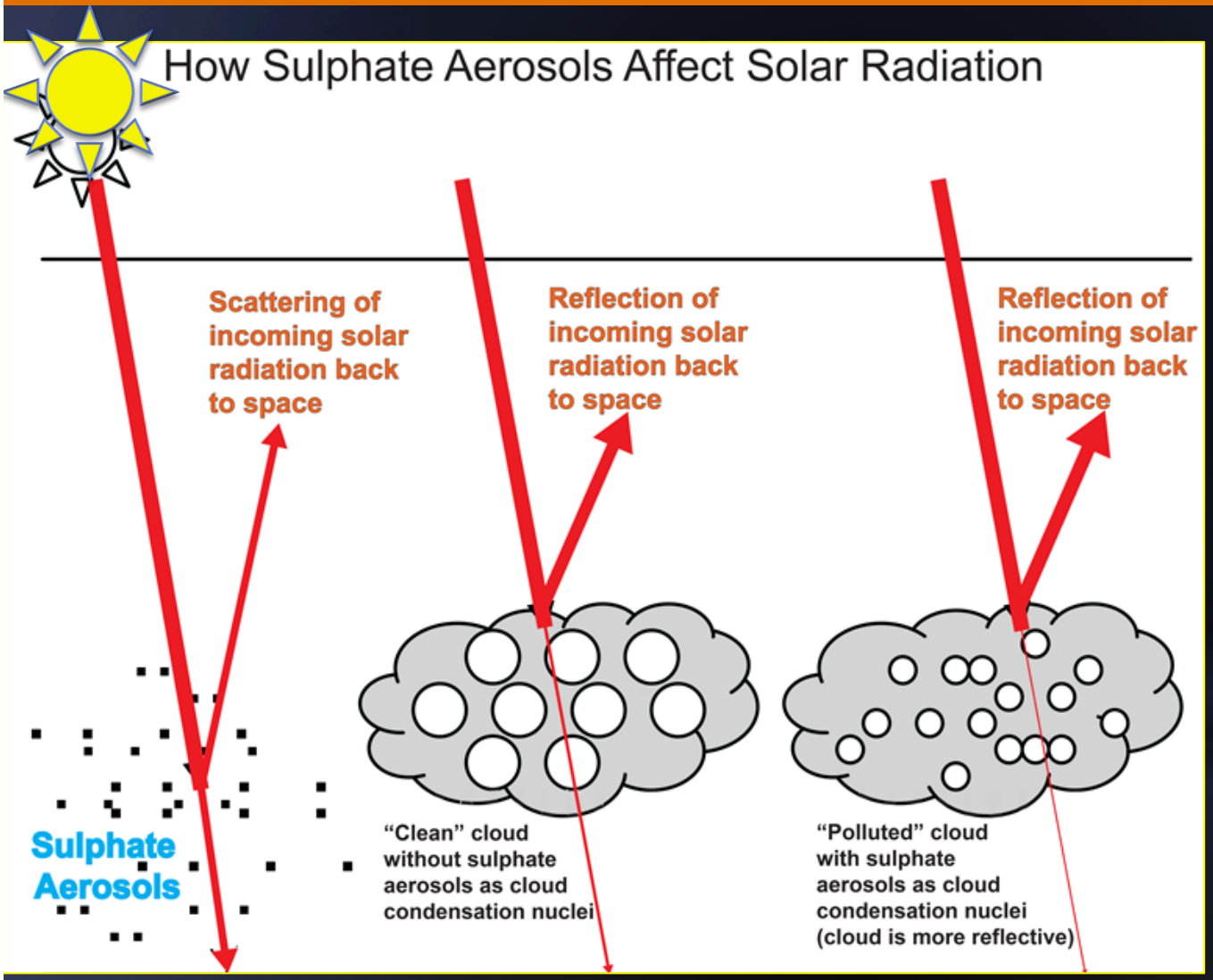
Polluted clouds become brighter because their ability to reflect solar radiation increases.

Aerosols have a direct impact on clouds:

The size of the cloud water droplet or ice crystal is larger in the clean cloud and smaller in the polluted cloud.

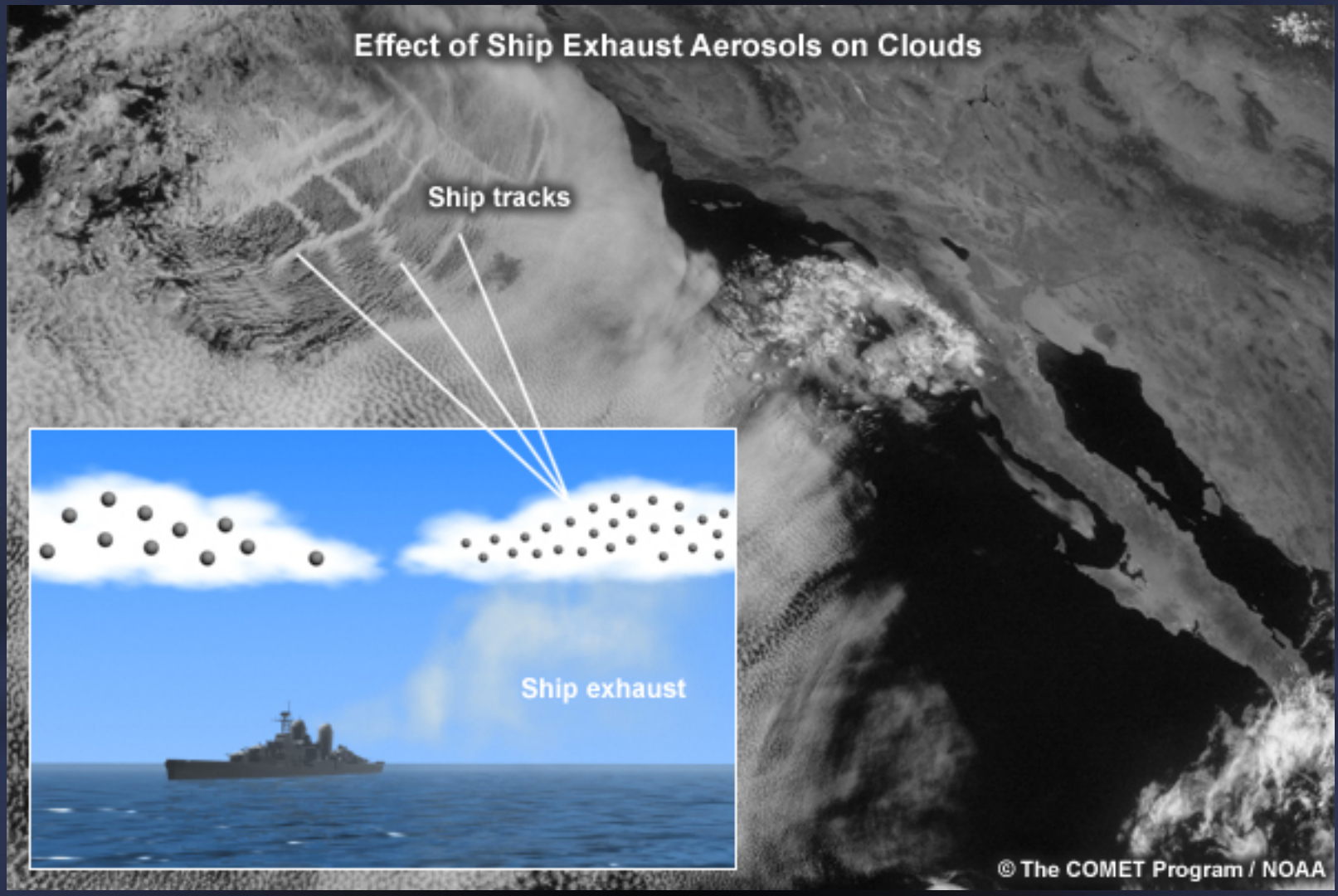
Clouds with larger water droplets or ice crystals reflect less solar radiation. Polluted clouds with smaller droplets and crystals reflect more radiation and have a cooling effect on Earth.

Effect Sulphate Aerosols on Clouds Solar Radiation Reflectivity

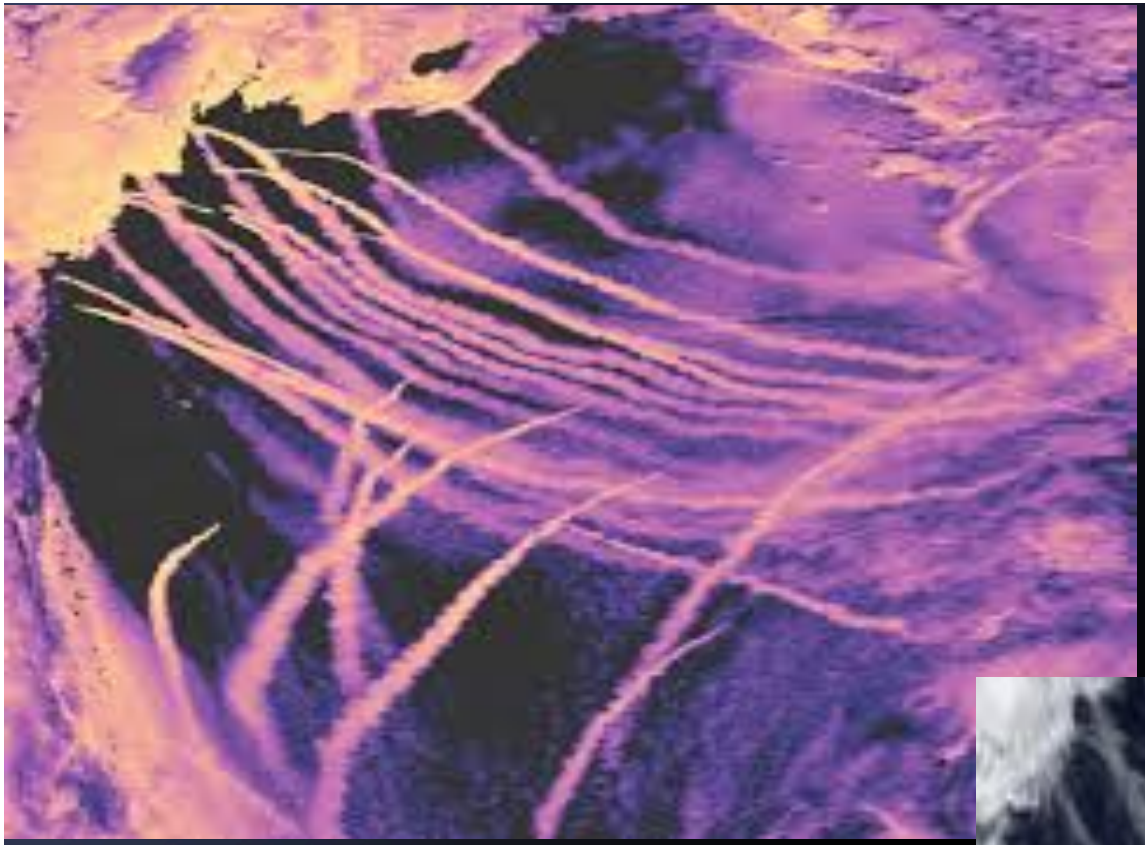


Sulphate Aerosol human-made particles are the most abundant aerosol produced by burning coal and oil.

Effects of Ship Exhaust Aerosols on Clouds



False Color Image of Ship Tracks over North Pacific Ocean



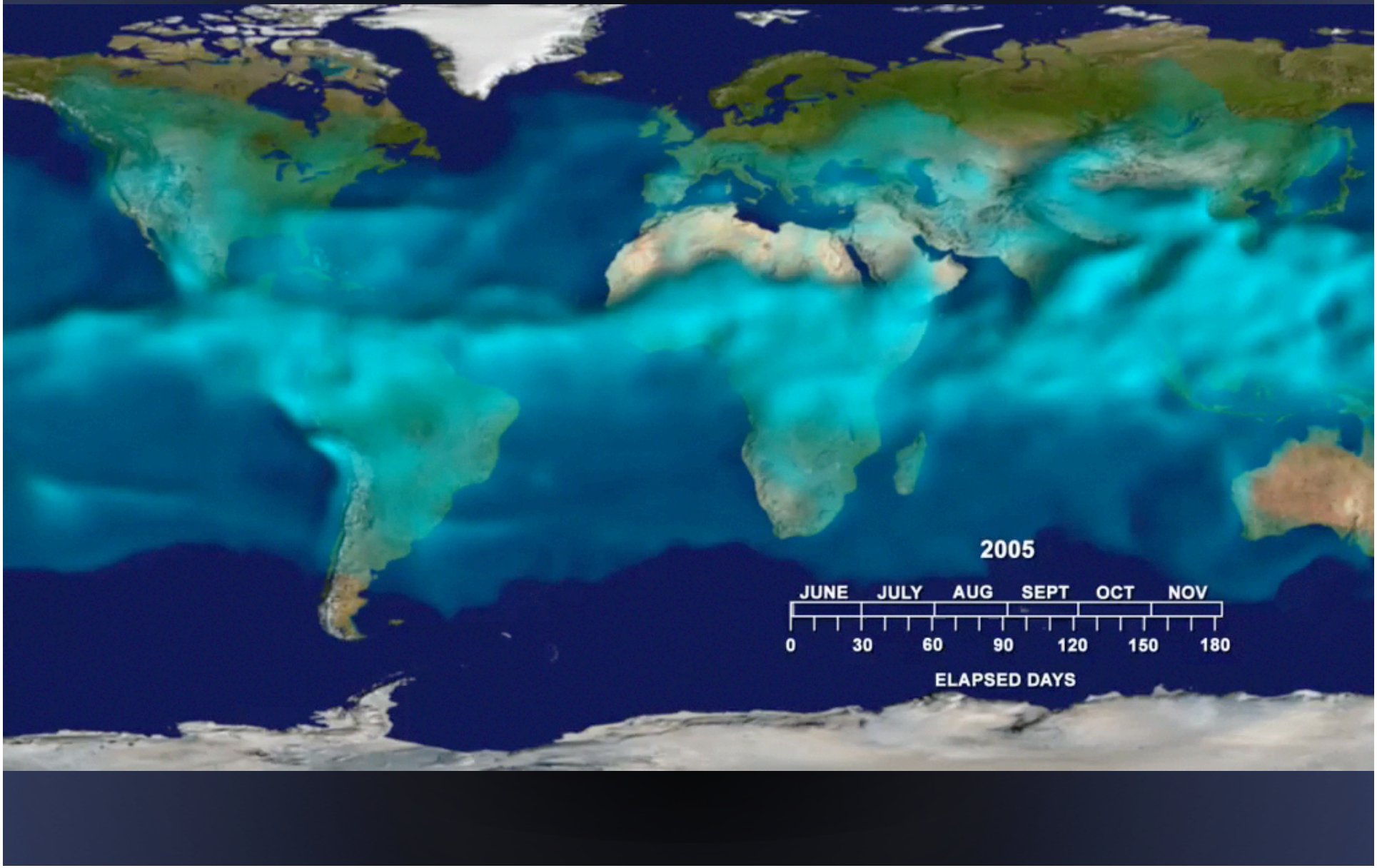
Aerosols from ship exhaust at sea combine with water vapor to form these highly reflective stratus cumulus clouds above the ocean.

Use the cloud droplet scale bellow to read the image above.

Cloud Droplet Radius (μm)

6 12 18 24 30

Animation of the 2005 Distribution of Global Water Vapor on Lowest 10 miles of the Atmosphere



Distribution of Global Water Vapor Chart

Questions: Write one or two questions of your own.	Answers: When answering please identify geographic areas. Use a map for reference.
1. What generalizations can you make by observing the video?	
2. Which geographic areas has the highest concentration of water vapor.	
3. Why do you think they only used data from the months June through October?	
4. Which geographic areas don't seem to have as much water vapor? Why do you think that is?	

Why Do Rain Drops Matter in Storms?

Video play button bottom left.

Video

Cloudy Climate Change: How Clouds Affect Earth's Temperature

Move cursor to find Play Button