Most of Earth's surface water originated from **outgassing of volcanoes**.

- Where the water came from is still uncertain
    - Carbonaceous chondrites contain water as hydrous minerals, suggesting some water originated from accretionary material and volcanic steam
    - Icy comets bombarded early Earth, bringing with them frozen water

The thermocline is a layer of ocean water that has a major **temperature** shift from the layer of water above.

- Seawater becomes **denser** as **temperature decreases** and as **salinity increases**
    - Three major depth zones
        - Surface zone: 100-500 m (mixed layer)
        - Thermocline (temperature), halocline (salinity) or pynocline (density)
        - Deep zone: contains 80% of ocean water

Salinity of ocean water is related to latitude, but also evaporation, precipitation of rain and snow, inflow of fresh river water and the freezing of sea ice.

Most of the heat supplied to the ocean originates from **the Sun**.

- Solar radiation provides heat energy, non uniform heating generates winds, which drive the movement of surface ocean water

The density of a parcel of seawater will increase when the salinity increases.

The three most important factors that affect wind wave development: strength of wind, fetch, and duration of wind.

Waves that move through water deeper than one-half their wavelength are known as **deep water waves**.

Highest high tides happen to ocean tides if the Earth Moon and Sun are all in a line.

Low lying coastal deltas are most likely to experience earthquake generated tsunamis.

The Antarctic Ocean have the greatest chance of heaving very large wind waves because of **long fetch**.

Ocean tides are a type of wave and all waves are composed of a crest and trough. With this said, **high tides are crests** and low tides are troughs.

The rising of cold water from deep layers (to replace warmer surface water) is known as **upwelling**.

Deep ocean circulation is driven by variations in water temperature and salinity. This is called **thermohaline circulation**.

The general order of events for the evolution of an island to an atoll:
Rapid extrusion of lava; subsidence (fringing reef becomes barrier reef); continued subsidence and upward reef growth.

Evolution of an atoll from a subsiding oceanic volcano.

A. Rapid extrusion of lava builds a shield volcano that begins to subside as the ocean crust is loaded by the growing volcanic pile; a fringing reef grows upward, keeping pace with subsidence.

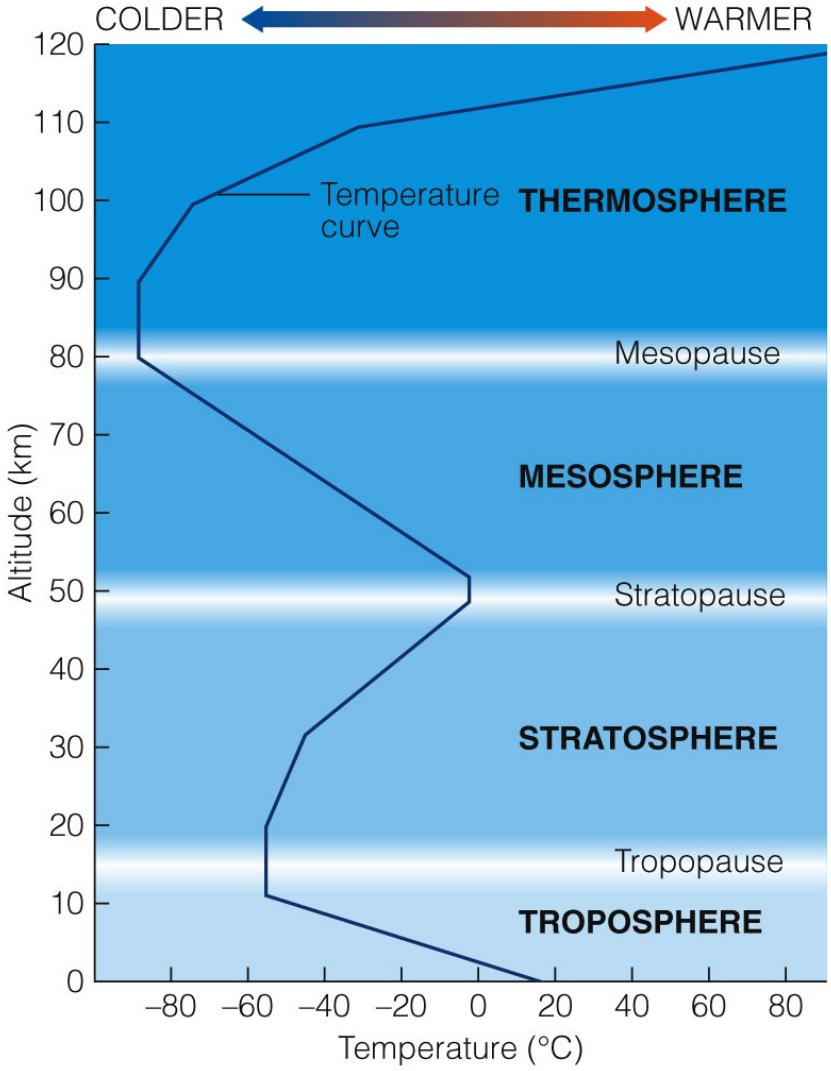
B. As subsidence continues, the fringing reef becomes a barrier reef, separated from the eroded volcano by a lagoon.

C. With continuing subsidence and upward reef growth, the last remnants of volcanic rock are submerged, leaving an atoll reef surrounding a central lagoon.

The secondary atmosphere of the Earth was composed mainly of **volcanic gases**.

Aerosols and water vapour of the Earth's atmosphere vary from place to place in terms of relative composition.

Tropopause: This is the coldest region of the atmosphere below 50 km altitude.



Thermosphere:
The thermosphere is the least dense layer of the atmosphere.
The thermosphere is above the mesosphere.

Temperatures increase with height in the thermosphere.
There is very little total heat in the thermosphere.

Atmospheric pressure does not crush our lungs because our lungs are also filled with air, so atmospheric pressure is balanced.

Evaporation is responsible for most of the water vapour that enters the atmosphere.

If a parcel of hot air rises **adiabatically**,
the relative humidity of the air increases;
the temperature of the air decreases;
the relative amount of oxygen stays the same;
the pressure decreases.

If clouds are composed of water droplets, they remain suspended in the atmosphere as the clouds only appear to be suspended; they are actually falling at a rate of 1 m per second.

Flat bottom of some cumulus clouds are because **the flat base marks the level of condensation**.

Three essential criteria for making a planet habitable are:
oxygen and temperature within a range of limits and water vapour.

Clouds are one of the great sources of uncertainty for understanding the global climate system because
a) Clouds can only cool the Earth's surface.
b) Clouds can only warm the Earth's surface.
c) Clouds **can both warm and cool the Earth's surface**.
d) Clouds form precipitation which washes pollutants out of the atmosphere.
e) Clouds form precipitation which cools the surface of the Earth.

With respect to winds on the Earth's surface, the pressure gradient force is:
The force of air pressure resulting from the change in air pressure over a certain distance.

The Coriolis Effect is the strongest at the **North and South poles**.

Generally, the Indian Monsoon is attributed to **a seasonal shift of the Intertropical Convergence Zone**.

If the Earth was not rotating on its axis (but was stationary instead), the wind would flow **directly from areas of high to low pressure**.

The land (offshore) breeze usually form **in the evening, flowing toward sea**.

A prolonged drought can lead to trees dying. The loss of vegetation can lead to the exposure of dry and bared soil. The soil can then become more easily eroded. The erosion may lead to dust storms and further erosion. The greater amount of erosion may lead to more vegetation loss, and so on. The above is an example of **positive feedback**.

Milankovitch cycle is a mathematical explanation of long term climate changes based on Earth-Sun geometrical relationships.

Tiny sea creatures called **foraminifera** equilibrate with the water around them, thus preserving a chemical record of past climatic changes.

Based on the study of past climate, we can conclude that future, long-term climates will be **variable**.

The Medieval Warm Period, began before the Little Ice Age, is an episode of relatively mild climate about 800 years ago.

The burning of **fossil fuels** has added largest quantities of carbon dioxide to the atmosphere.

Dendrochronology is the technique of establishing a date using **tree rings**.

During the warm Middle Cretaceous Period, about **100 to 200 meters** higher was sea level verses today.

Cold water absorbs more carbon dioxide than warm water. Assume a mechanism (such as the Milankovitch Cycle) leads to global cooling. The surface temperatures will then begin to decrease. Subsequently, more carbon dioxide will be removed from the sky (as it will be absorbed in large quantities by the cold water). As a result, atmospheric temperatures will get cooler. This process is an example of **feedback**.

Earth has been relatively warm for about **10,000 years**.

Sunspots is considered a short-term external climate change factor.

Assume you are a climatologist analysing carbon dioxide bubbles trapped in an ice core. The cross section of ice core you are looking at is 1 million years old. During your analysis, you find that there is a greater quantity of carbon dioxide in the ice core than there is today. This tells you that **the pass climate was warmer than today**.

Large volcanic eruptions (like Mount Pinatubo in 1991) can produce a veil of ash that envelopes the stratosphere. If this were to occur, the most likely temperature result at sea level would be **decrease in temperature**.

The increase in atmospheric CO2 since the Industrial Revolution has caused
sea ice to decrease;
plant communities to expand towards the poles;
glaciers to shrink;
oceans to become more acidic.

The climates of ancient times is known as **palaeoclimatology.**

Throughout much of western Europe and adjacent islands, the **Little Ace Age** climate was characterized by unusually cod, harsh conditions.

During the last **Glaciation**, the climate of the northern middle and high latitudes became so cold that a vast ice sheet formed over central and eastern Canada.

Pollen studies show that in glacial times the vegetation distribution was quite different from what we see today.

The 20th May 2013 was the first time that atmospheric CO2 levels reached 400 ppm in modern times. The last time this occurred was **the Middle Pliocene (3.6 Million years ago)**.

A **sunspot** is a temporary cool, dark spot on the Sun's photosphere.

Controlling the amount of carbon dioxide in the atmosphere requires **negative** feedbacks in the carbon cycle.

The two weather variable used most often as indicators of climate are **precipitation and temperature**.

In 2006, two independent international bodies reported very different CO2 emissions per capita for Singapore, it was because **one did not include air and sea bunkering**.

The 41,000 year cycle of the tilt of Earth's axis is called **obliquity (tilt) cycle**.

Precession of the equinoxes completes one full cycle in **23,000 years**

Axis **tilts** at an average angle of 23.5˚, and shifts about 1.5˚ to either side during a cycle of about **41,000 years**

Eccentricity of Earth's orbit is a measure of its departure from circularity, it changes over a period of **100,000 years**.