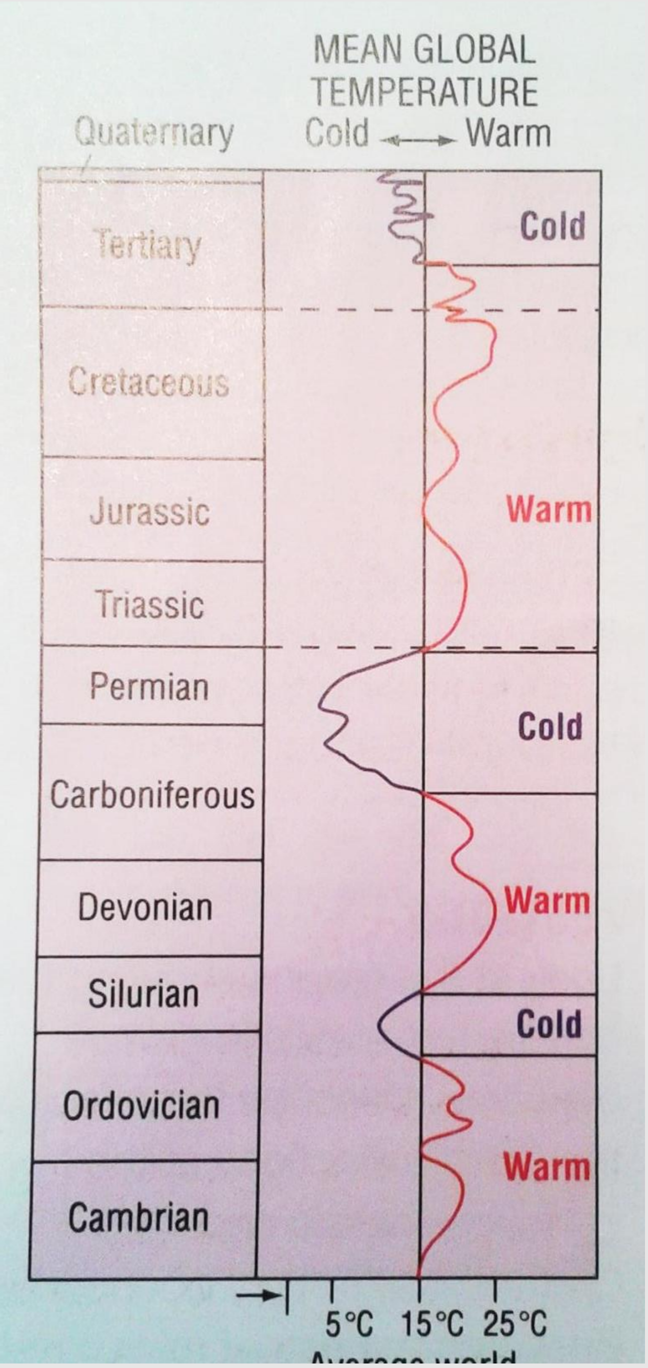
PREDICTING CLIMATE CHANGE

WHAT CAUSES CLIMATE?

The amount of heat energy from solar radiation reaching the Earth's surface varies according to the position on the planet. The Earth's axis is on a tilt and so an area of land near the poles receives far less solar radiation than the same surface area at the equator.

In higher latitudes, more solar radiation is reflected back out into space than is absorbed, while the opposite is true in equatorial latitudes. Heat energy in lower latitudes is presently distributed by wind systems and ocean currents, caused by convection, such as the Gulf Stream.



Some of the main drivers of climate today are:

- Solar **Insolation**
- Earth's Albedo
- Greenhouse gas concentration in the atmosphere
- Orbital dynamics

Solar insolation is simply the total amount of solar radiation energy received on a given surface during a given time.

Albedo is the term describing the reflectivity of a surface, how much solar radiation a surface reflects back into space.
Sea **ice and snow has a high albedo** and reflects much more incident radiation back into space. Conversely, sea water has a low albedo and absorbs much of the incident radiation.

Albedo – Positive Feedback Effects

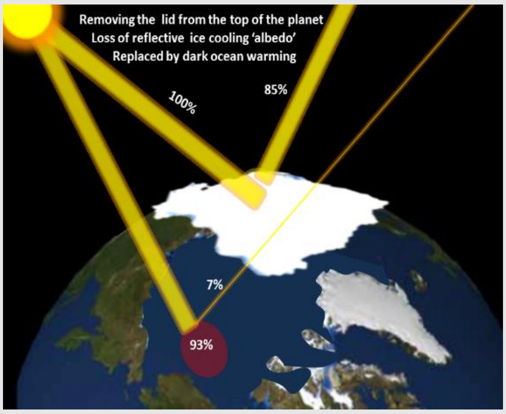
When an area's albedo changes due to snowfall, a snow–temperature feedback results.

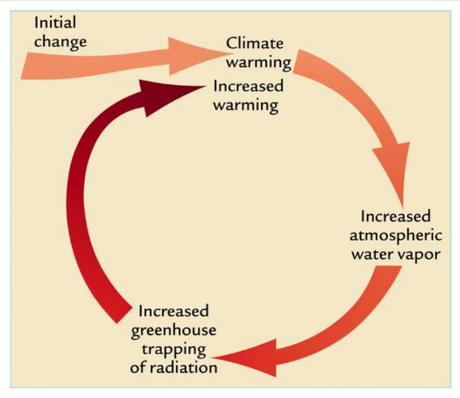
A layer of **snowfall increases the local albedo**, reflecting away sunlight, leading to local cooling.

In principle, if no outside temperature change affects this area (e.g. a **warm air mass**), the lowered albedo and lower temperature would maintain the current snow and invite further snowfall, deepening the snow–temperature feedback.

However, because local **weather is dynamic** due to the **change of seasons,** eventually **warm air masses** and a **more direct angle of sunlight** (**higher insolation**) cause melting.

When the melted area reveals **surfaces with lower albedo, such as grass or soil**, the effect is reversed: the **darkening surface lowers albedo**, **increasing local temperatures**, which **induces more melting** and thus reducing the **albedo further**, resulting in still more heating.





Greenhouse gas concentrations also follow a **positive feedback effect.** Greenhouse gases cause warming as less IR radiation is reflected back into space, it is trapped/absorbed. This releases more Co2, water vapour and methane (from methane hydrates) so exacerbates the greenhouse effect.

Surface	Albedo reflectivity (%)
Fresh snow	80-95
Ice	20-40
Desert sands	35-45
Forest	15-20
Water (solar elevation 30^0)	6
Water (solar elevation 60^0)	3

WHAT CAUSES CLIMATE?

- **Aphelion** is the point in a planet's orbit when it is furthest from the Sun. Usually an elliptical orbit.
- **Perihelion** is the point in a planet's orbit when it is closest o the Sun. Usually a circular orbit.
- **Ka** means thousands of years (kilo annum)

Climatologists such as Sir Nicholas Shackleton studied **geological data** and were able to **find patterns** that suggested global temperature rose and fell in a **predictable pattern** caused by **natural variations.**

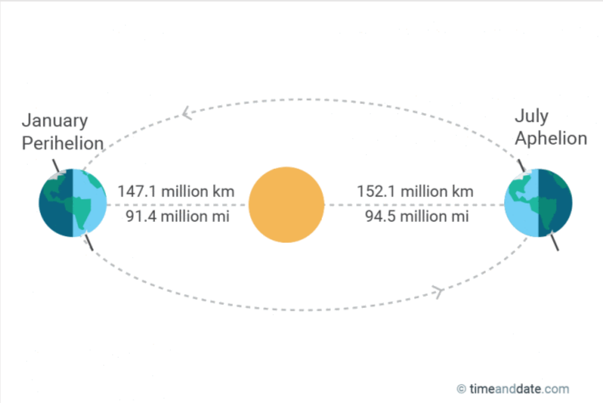
MILANKOVITCH CYCLES

The cycles are caused by changes in the amount of radiation reaching the Earth from the sun over time. This is due to variations in the orbital dynamics of the Earth about the sun, not the energy output of the Sun.

The orbit varies in three predictable cycles…

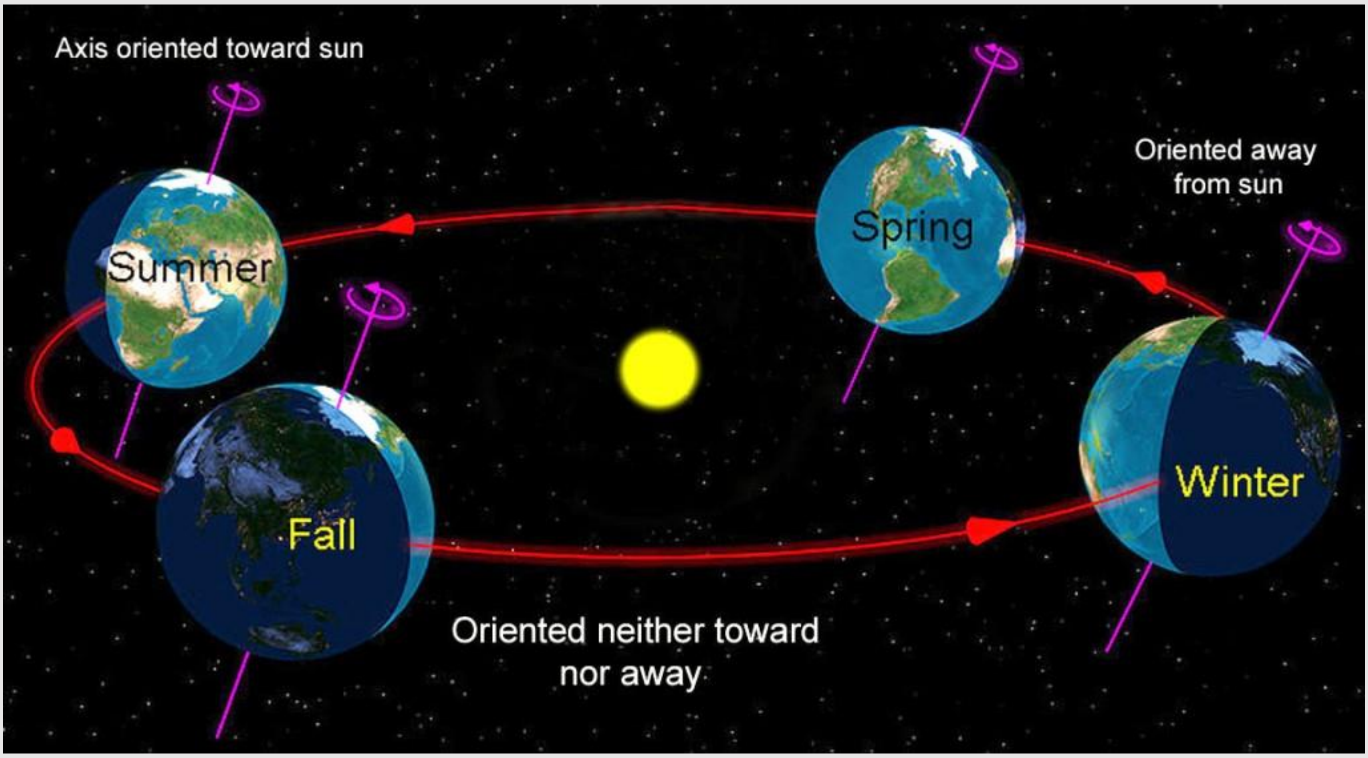
Eccentricity:

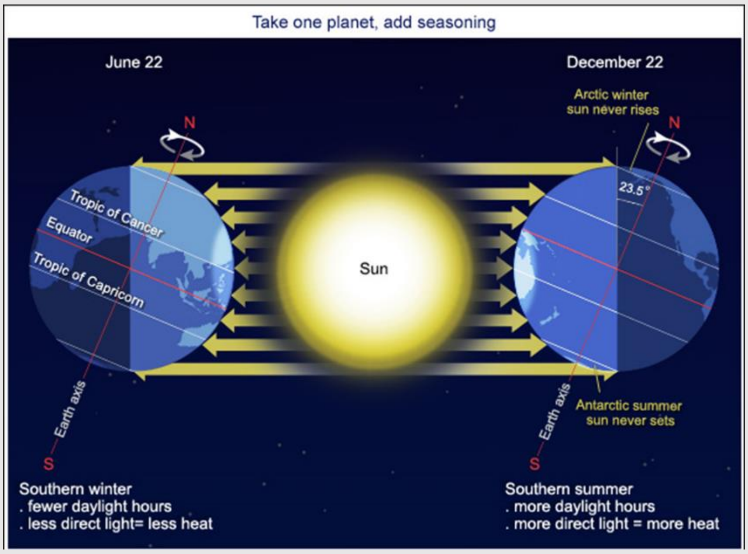
The Earth's orbit about the sun is not circular but eccentric. The Earth's orbit changes shape to become more elliptical over a period of 100,000 years. At the current stage, the eccentricity is almost minimum, with a 6% difference in received radiation between January and July. At maximum eccentricity, the difference is between 20-30% equating to massive variations in climate.



Obliquity:

The tilt of the Earth is **responsible for the seasons,** summer, winter, spring and autumn. The seasons result from the Earth's axis being of rotation being **titled with respect to its orbital plane** by an angle of **approximately 23.5^0**, the tilt is known as **obliquity**.





Obliquity can change up to 3^0 over a 41,000-year cycle. A smaller tilt promotes the growth of ice sheets as a warmer winter results in more moisture and snowfall.

Precession:

The **effect of obliquity and eccentricity combined** to cause this further cycle where the **inclination** of the Earth's axis (obliquity) changes in relation to **where it is in the orbit** (eccentricity). This cycle operates in periods of **19,000 and 23,000 years**. At present, we **are closest to the Sun** so **northern winters are slightly warmer** than 11,000 years ago when the planet was furthest from the Sun.

Slow changes in the direction of the axis of the Earth as it orbits results in **greater seasonal contrasts**.

i.e. perihelion and aphelion swap positions in Earth's orbit every 19,000 to 23,000 years.

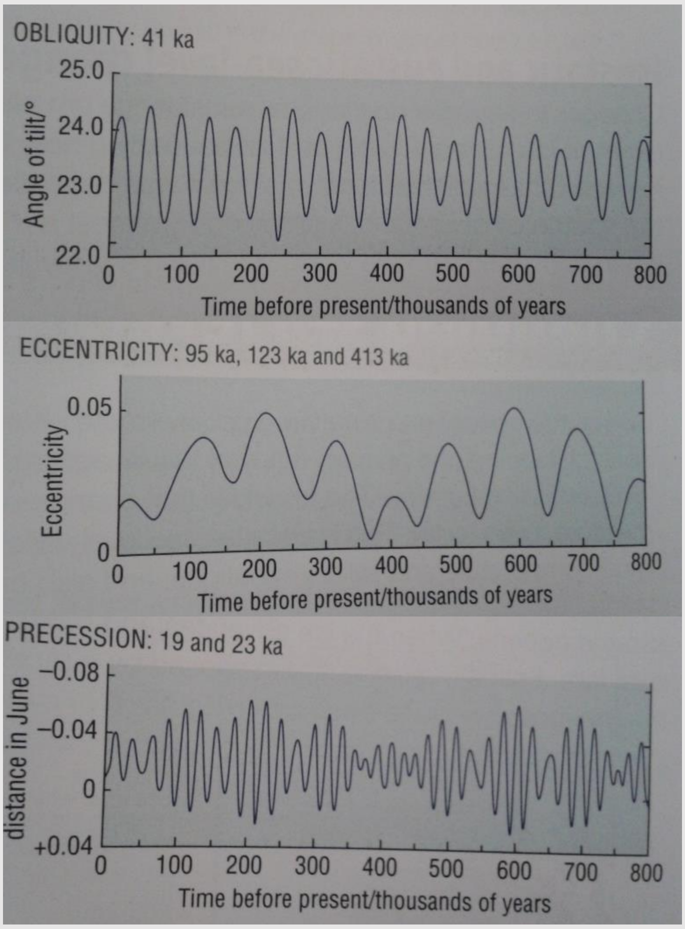
At the moment we are **closest to the sun during Northern Hemisphere winters**, making our winters relatively warmer. 11 000 years ago, the Earth was furthest from the Sun during Northern Hemisphere winters.
You can also think of this as the change in the position of 'summer' (when the northern hemisphere tilted towards the sun) with respect to the point in the Earth's non-circular (eccentric) orbit.

- **Precession** is the **trend in the direction of the Earth's axis** of rotation **relative to the fixed stars**. This alters in a cyclic pattern over a period of roughly 23,000yrs

In summary…

Milankovitch cycles are cyclical changes in the rotation and orbit of Earth, correlating with climatic effects.

As the main three components behind Milankovitch cycles change, they have a large impact on the solar insolation reaching the Earth and therefore a pronounced impact on the climate.

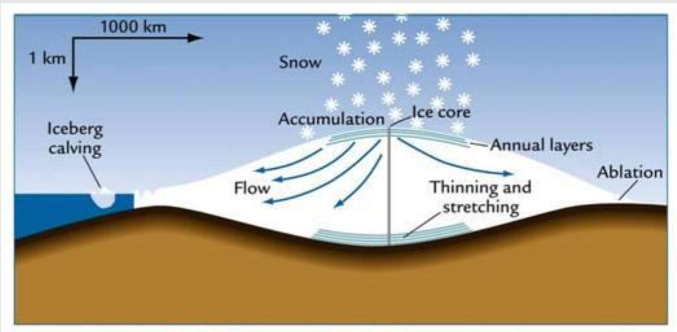


Another factor is continental drift. The position of the continents has a large role in global climate. The present distribution of continents encourages the ocean currents to redistribute heat energy around the globe through a system known as thermohaline circulation, the Gulf Stream is one part of this system.

If the continents were mainly positioned over the poles then it would encourage the accumulation of snow and ice, increasing Earth's average albedo value, reflecting more solar radiation and so further decreasing temperatures through a positive feedback effect. There would be a greater contrast between the temperatures at the poles and those at the equator.

EVIDENCE OF MILANKOVICH CYCLES

The work to identify the link between Milankovitch cycles and glaciations were carried out by painstaking analysis of oxygen isotopes of the recent geological past. Once this work was carried out, many geologists started to look for evidence of these cycles elsewhere in the stratigraphic record.



Sometimes bubbles of air are trapped in ice cores and allow for a direct measurement of CO_2 levels over the last 800Ka.

The Blue Lias and Kimmeridge Clay:

Alternating layers of **clay and limestone geologically date**d to show this cyclic variation occurs on a **41Ka cycle**. These are the **Blue Lias rocks** of the **Lower Jurassic in Lyme Regis, Dorset**.

The alternating strata show that the environment changes from a **low-energy, clay-rich** deeper sea, to a **limestone-producing warm shallow sea**.

This cyclic pattern correlates with the obliquity cycle of orbit predicted by Milankovitch cycles.

Attempts to identify a 100,000-year cycle have been met with lots of sceptics.

However, work carried out on **Kimmeridge clay at Kimmeridge Bay** in **Dorset, Upper Jurassic rocks**, has identified regular Milankovitch eccentricity (100,000-year cycles).