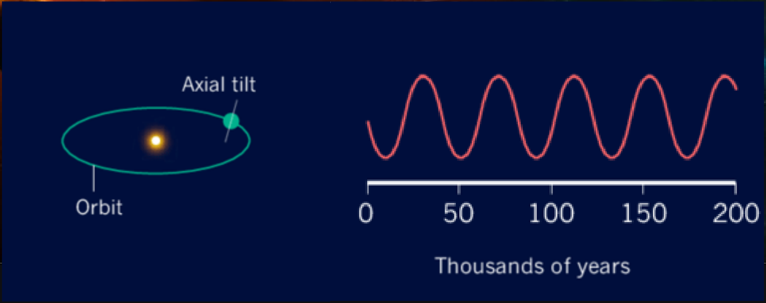
Milankovitch cycles

First Cycle : The variation in the obliquity of the axis of rotation



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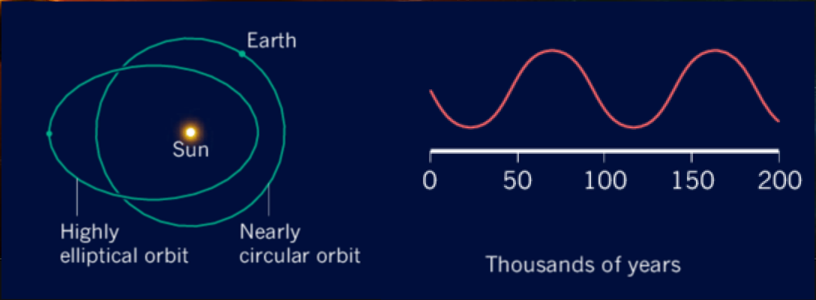
Earth's axis of rotation is not perpendicular as it spins around the Sun, but sloped. Its axis will vary between 24° and 22.5° in a cycle of 41 000 years, because of the gravitational pull of the

Moon and the other planets in the solar system.
The obliquity does not impact the quantity of solar radiation received, it will have an impact on the repartition on Earth over time. The smaller the angle is, the softer the summers are.

Milankovitch cycles

Second Cycle : The variation of the eccentricity of the Earth’s orbit



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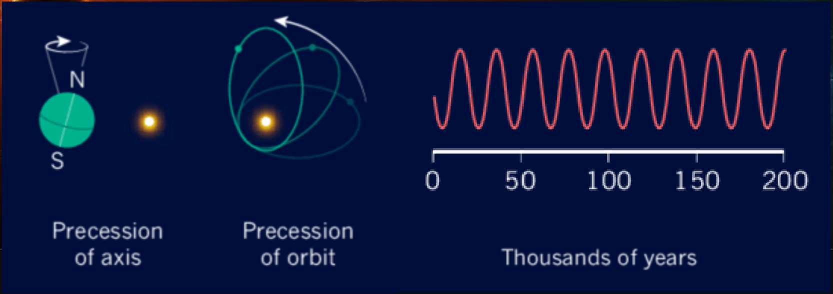
The planet trajectory around the sun is elliptical and it is characterised by its eccentricity. For a circular trajectory, eccentricity equals 0, and for an elliptical boundary path, 1.

Every planet practises a pull on its neighbours by gravity. Since they don’t all have the same rotation, it can modify other’s ellipses.

Earth’s eccentricity varies between 0 and 0.06 every 100 000 years. It has consequences on the planet’s seasons, by modifying the total solar flux on earth . Depending on where the planet stands on its orbit, it will get more or less solar radiation. The closer we are, the more solar radiation we’ll receive, leading to hotter or colder seasons.

Milankovitch cycles

Third Cycle : The precession of the rotation axis



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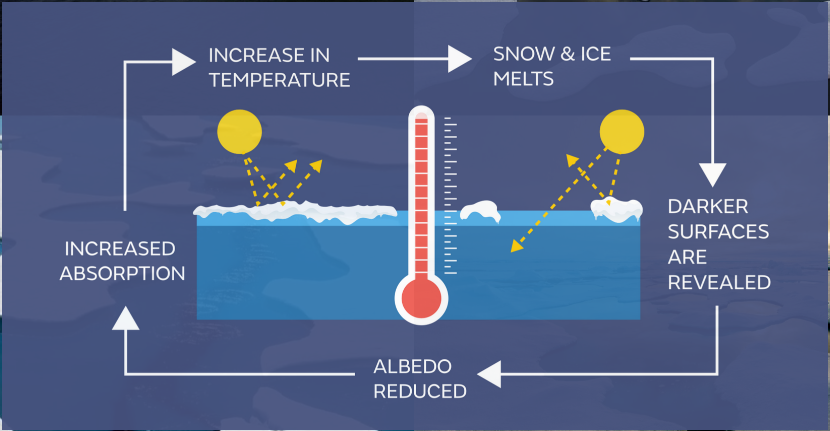
The third cycle concerns the precession of the rotation's axis. Earth's rotation axis is sloped regarding the ecliptic plane, but the direction of its tilt changes throughout time : it's called precession. Precession represents the axis' rotation of the Earth around the axis at 0°.

The complete recession of Earth last 20 000 years and has consequences such as a reversal of the hemisphere's seasons, leading to climate disruption. It does not have an impact on the received quantity of solar radiation, but just as the first cycle, these solar radiations won't touch the Earth in the same place regarding its axis.

Ice Feedback Loop



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Temperature rises -> Ice melts -> ice turns into water -> ice albedo is higher than water albedo -> more solar energy absorbed -> Temperature rises

Because this cycle occures at the pole, at the begining of the intergalcial period , it is one of the most important feedback loop that rules climate variability.

it is important to notice that feedback loops can change direction and thus have opposite effects depending on their initial condition


Other Feedback Loop
Positive feedback loop
Negative feedback loop
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Negative feedback loop :

Temperature increases -> + evaporation -> +Humidity in the air -> +clouds -> Solar flux decreases

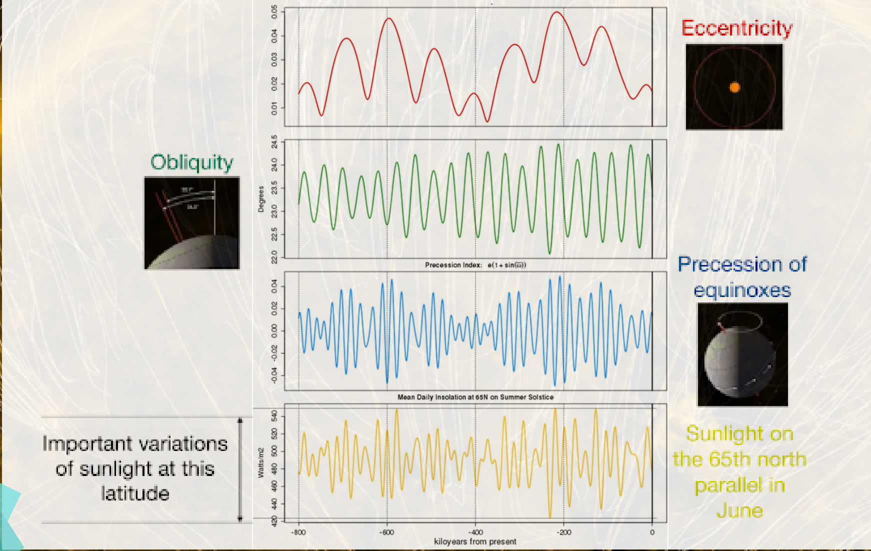
Positive feedback loop :

Temperature rises -> Ocean stores less CO2 -> more CO2 in the atmosphere -> more greenhouse effect -> Temperature rises

Temperature increases -> Melting of permafrost -> Release of GHG -> Greenhouse effect increases -> Temperature increases

Temperature increases ~~~> Drought -> more fires -> GHG release + less GHG absorbed -> Greenhouse effect increase -> Temperature increases

Local solar fluxes changes



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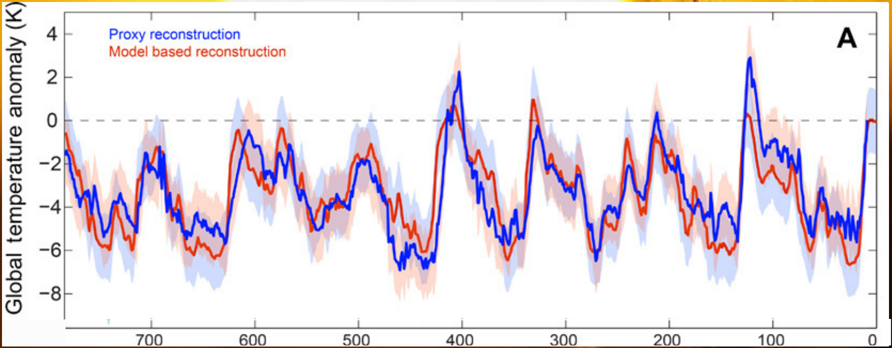
By grouping the data from the 3 Milankovitch cycles, we can obtain the change in solar power received over the northern latitudes.

We can see that the amplitude of the changes is very important, the order of magnitude is a hundred W/m^2 which is enormous and can cause significant temperature changes.

Global Temperature Changes



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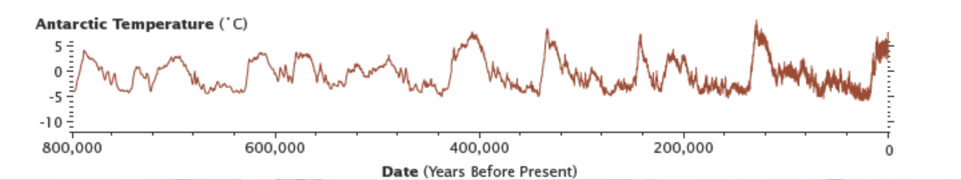
The modification of the Earth's solar radiative forcing through the different feedback loops leads to global temperature changes over time.

Local changes therefore eventually translate into global changes.

Local Temperature Changes



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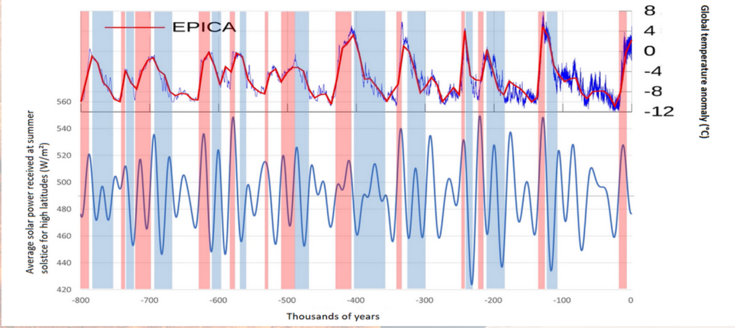
Precious information on past climate changes can be provided thanks to the poles' ice. One way to find evidence on the events is to dig inside polar ice. During their creation, they imprison bubbles, sediments, rocks and some radioactive substances as well. All these are stored in the ice, reflecting all the characteristics of an era, like atmospheric and environmental ones.

By annalyzing these data it is possible to estimate the local temperature at the pole in the past.

Climate Periodicity



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As global temperature changes are initiated by Milankovitch cycles and concretised by numerous feedback loops, we see a periodicity of glacial and interglacial periods. The average temperature difference between these two types of period is about 6 degrees Celsius.

However, it can be seen that Milankovitch cycles are necessary but not sufficient to achieve a transition between glacial and interglacial periods. Other phenomena are at play and their understanding is not yet complete.