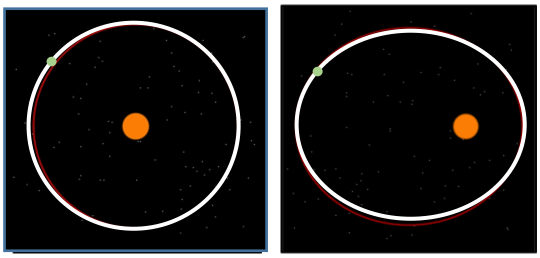
The Earth and Milankovitch cycles – by hand
Modelling the Earth's squashed orbit, tilt and wobble using your hands

One of the reasons why the average temperature of the whole Earth changes over geological time, is because the amount of energy from the Sun that the Earth receives also changes. This change in solar radiation received by the Earth was studied by Milanković, and the variations he discovered are now called Milankovitch cycles (Milankovitch is the English version of his name).

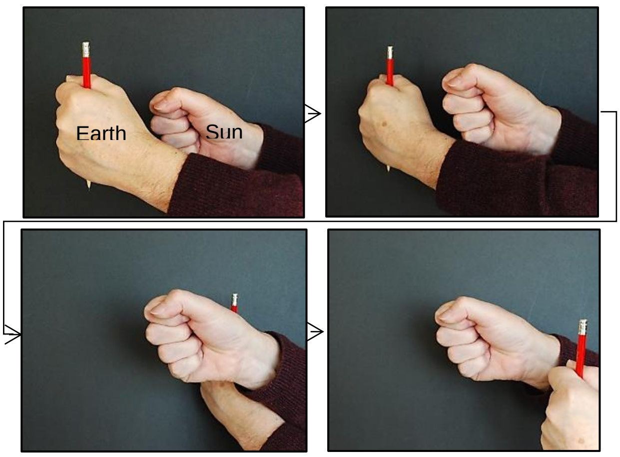
Milankovitch recognised that the amount of solar radiation received by the Earth changed for three main reasons.

Earth's squashed orbit (orbital eccentricity)
The orbit of the Earth changes over a regular cycle from being near circular (left image) to being more 'squashed' or elliptical (right image).

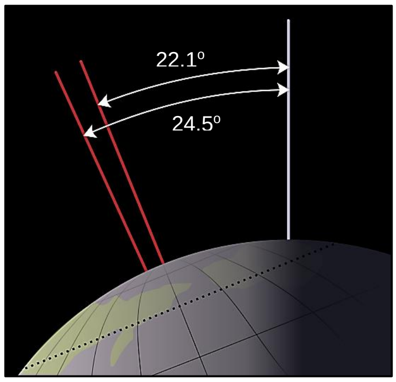


When the orbit is near-circular, about the same amount of solar radiation is received by the Earth all the time, but when the orbit is squashed, more radiation is received when the orbit is closest to the sun and less when it is further away. This follows a 90,000-100,000 year cycle.

You can model the Earth's orbit and its changes with your hands. The hand holding the pencil represents the Earth and its axis, the other hand represents the Sun. Try modelling first a less 'squashed' (more circular) orbit, and then a more 'squashed' (more elliptical) orbit.

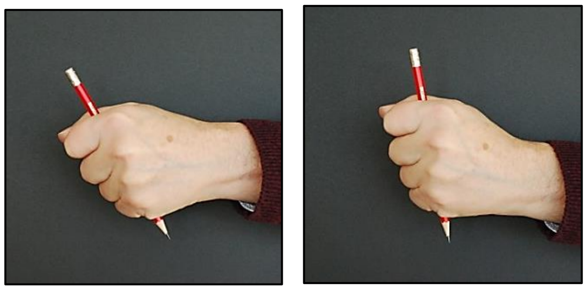


The tilt of Earth's axis (axial obliquity)
The angle of the Earth's axis to its plane of rotation changes over time. It is 23.5° at the moment, but changes between around 24.5° and 22.1° over a 40,000 year cycle.

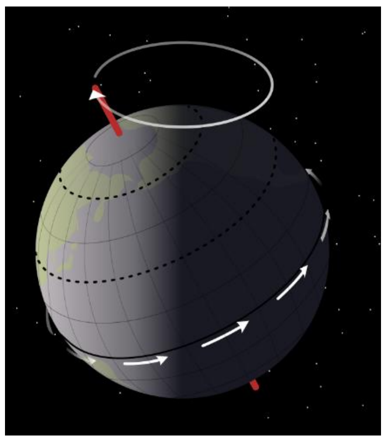


When the tilt is small there is less variation in seasons; winters are warmer and summers cooler. With warmer winters, there is more snowfall near the poles and less of this melts during the cooler summers – so there is more ice in polar regions. With larger tilt, winters are colder and summers warmer, producing less ice at the poles.

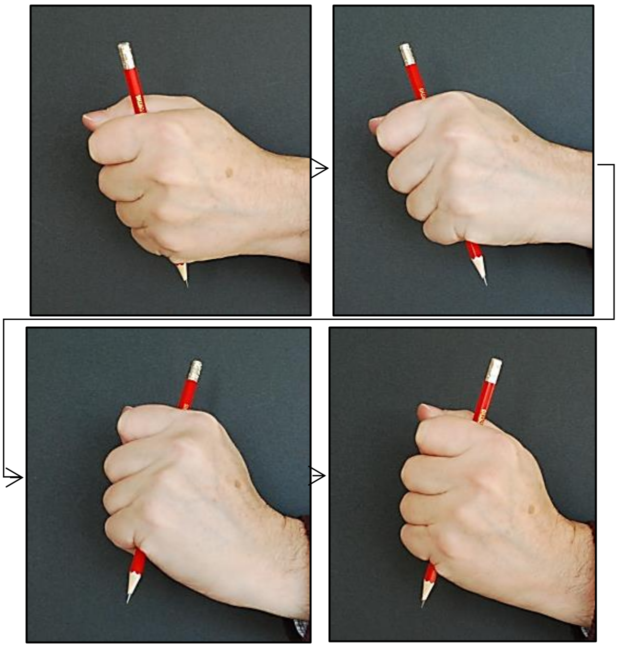
Model the changing tilt of the Earth's axis with your hand holding a pencil.



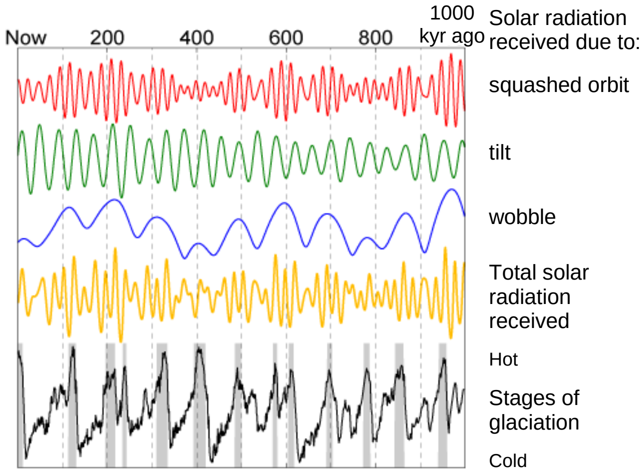
Wobbles of the Earth's axis (axial precession)
The Earth's axis wobbles, with the end of the axis tracing a 'circle in the sky' over a 26,000 year cycle. When the tilt of the axis is greatest, the Earth's seasons are more extreme. If an extreme season in the Northern Hemisphere coincides with the time when the Earth is receiving more solar radiation because of one of the reasons described above, then it will become hotter. The opposite is also true.



You can model this axial wobble using your hand.



The effect of these three cycles is shown in the graph. When they are added together they produce the yellow line on the graph, which shows the total amount of solar radiation received by the Earth over time. The link between this and the stages of glaciation of the Earth, recorded in ice cores, is shown by the black line at the bottom of the graph. This seems to show a close link between Milankovitch Cycles and the recent glaciations on Earth.



(kyr = 1000 years, so 1000 kyr ago = 1 million years ago)

Image credits:

- *Earth images, taken from https://earthobservatory.nasa.gov/Features/Milankovitch/milankovitch_2.php are in the public domain because they were solely produced by NASA.*
- *Graph produced by Robert A. Rohde and released under the Creative Commons Attribution-Share Alike 3.0 Unported license.*

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The back up

Title: The Earth and Milankovitch cycles – by hand.

Subtitle: Modelling the Earth's squashed orbit, tilt and wobble using your hands.

Topic: Pupils can find the Milankovitch cycles, of the variation in the solar radiation received by the Earth, difficult to understand. This activity uses hand modelling to consolidate learning.

Age range of pupils: 16 years+

Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:

- describe the variations in Earth's orbit and tilt that lead to the Milankovitch cycles;
- model these with their hands.

Context:
The work of the Serbian astronomer Mulitin Milanković, in the 1920s, was based on earlier ideas by the French mathematician Joseph Adhémar and the Scottish scientist James Croll. Three causes of variation are described below.

The Earth's squashed orbit (orbital eccentricity)
The more elliptical the orbit the more difference in distance there is between the Sun and Earth at the orbit's closest point and furthest point. When the orbit is near-circular (low eccentricity) there is around 7% variation in the energy received. But when the orbit has maximum eccentricity, the variation in energy received is around 20%. The change in orbital eccentricity occurs over a 90,000-100,000* year cycle. Currently the eccentricity is low and decreasing.

The tilt of Earth's axis (axial obliquity)
The axial obliquity varies from around 24.5°* and 22.1°* over a 40,000* year cycle, with smaller tilts leading to less seasonality and more polar ice, and *vice versa.* The current tilt is 23.4° and is decreasing.

Wobbles of the Earth's axis (axial precession)
The wobbles of the Earth's axis have a similar effect to the variations in tilt, except that they occur over a 26,000* year cycle, resulting in changes in the solar radiation received by the Earth over this time. At the moment, seasonal variation in the northern hemisphere is more extreme and that in the southern hemisphere is less extreme, in another 13,000 years the opposite will be the case.

* Note: Different sources give different figures. The figures used here are those given by the US National Aeronautics and Space Administration (NASA) at: https://earthobservatory.nasa.gov/Features/Milankovitch/milankovitch_2.php and https://starchild.gsfc.nasa.gov/docs/StarChild/questions/question64.html

Following up the activity:
Ask the pupils to find animations of the Milankovitch cycles on the internet.

Underlying principles:

- The solar radiation received by the Earth varies over cycles that were first described in detail by Milankovitch, now called Milankovitch Cycles.
- One cycle is caused by the eccentricity (squashing) of the Earth's orbit; when the orbit is nearly circular, similar amounts of radiation are received by the Earth all the time, but when the orbit is more squashed (oval or elliptical) more radiation is received when the Earth is nearer to the Sun and less when it is further away.
- Another cycle is caused by changes in the tilt of the Earth's axis; when the axis has least tilt there is less seasonality, warmer winters have more snow, which melts less in the cooler summers, and ice sheets grow; with more tilt, the opposite conditions apply.
- A third cycle is caused by the wobble of the Earth's axis; when the Earth is tilted towards the Sun, seasons are more extreme; if an extreme season in one hemisphere happens at the same time as increased solar radiation due to one of the other cycles above, it will become even more extreme; the opposite is also true.

Thinking skill development:
Modelling of these processes involves construction of patterns, 3D modelling skills and bridging the patterns to the results. In discussion, cognitive conflict and metacognition are often involved as well.

Resource list:

- your hands
- a pencil

Useful links:
See:
https://earthobservatory.nasa.gov/Features/Milankovitch/milankovitch_2.php

Source: Devised by Chris King; 'hand' photos by Peter Kennett, both of the Earthlearningidea Team.

The Earthlearningidea hand-modelling activities	
Modelling Earth processes	The rock cycle at your fingertips: modelling the rock cycle with your fingers
	Plate margins by hand: modelling plate margins and plate movement with your hands
	Modelling by hand 'when the youngest rock is not on top': illustrating how rock sequences can have older rocks on top of younger ones
	Modelling unconformity – by hand: using your hands to demonstrate how unconformities form
Modelling structural geology nomenclature	Modelling Earth stresses: hand modelling of compression, tension and shear in the Earth
	Modelling folding – by hand: using your hands to demonstrate different fold features
	Right way up or upside down? - modelling anti- and synforms by hand: use your hands to show how folds can be the right way up or inverted
	Visualising plunging folds - with a piece of paper and your hands: using your hands and folded and torn paper to show the patterns made by plunging folds
	Modelling faulting – by hand: using your hands to demonstrate different fault features
Climate change activities	The Earth and Milankovitch cycles – by hand: modelling the Earth's squashed orbit, tilt and wobble using your hands
	Modelling tipping points – by hands: demonstrating tipping points in the Earth's system with the hands of three pupils