

Stuart Clark

Ice-age Earth

According to filmmaker Roland Emmerich, 28 May is the day Earth plunges into a new ice age. That, at least, is the date when his new glacier-laden movie, *The Day After Tomorrow*, hits cinemas to tell the grim tale of mankind's struggle with the approaching ice sheets.

Doubtlessly many people will leave the movie theatres comforted by the fact that it is just a flight of fancy. But is it? During the past two million years, there have been twenty ice ages. The total time that the Earth has spent in these cold snaps is a staggering 1,800,000 years (90% of the period). We are incredibly lucky, it would seem, to be alive in an era of such clemency.

Some climate scientists prefer to call the twenty most recent ice ages 'glaciations', reserving the term ice age for the over-arching period of time, when there are major ice sheets somewhere in the world. By that measure, with the ice sheets of present-day Greenland and Antarctica, we remain in the current ice age. The relative warmth of today is simply a brief respite known as an interglacial, which will persist for an average of 10,000 years. Perhaps worryingly, we have now been in our current interglacial period for about that same length of time.

Ice ages and their associated glaciations are linked to the water cycle. In a stable situation, sunlight evaporates water from the ocean. When it rains, this water either falls back into the ocean directly or hits the land where rivers channel it back to the sea. In winter, some of the water will fall as snow and ice but in summer, this will melt and keep the cycle constant.

The key factor in maintaining the status quo is obviously the temperature. However, if the temperature drops, not so much of the snow and ice will melt, so it becomes stuck on land. Gradually, the amount of water in the oceans drops compared to that stored on land as the ice sheets build up.

The last glaciation (although often you will hear it referred to as the last ice age) began some 115,000 years ago. Temperatures began to slide, reaching about 7–10 degrees C lower than average temperatures today. By 18,000 years ago, things were at their peak with vast ice sheets, several kilometres thick suffocating much of North America and northern Europe. The creep of arctic sea ice was a permanent

feature along the eastern seaboard of America and around the United Kingdom.

Then, quite quickly, it all began to change and by 10,000 years ago the glaciation was over. There have been tiny hiccups since. The Little Ice Age lasted approximately from 1350 to 1850. During this period agriculture suffered badly and famines became widespread. The Thames regularly froze, encouraging Frost Fairs to be held on the ice. So did the canals in the Netherlands (as shown in the recent film *Girl with a Pearl Earring*). In 1780, New York harbour froze and it became possible to walk from Manhattan to Staten Island.

So what causes the temperature of the Earth to vary? This is the sharp edge of climate science and there are a number of competing theories. Almost certainly, all contribute to greater or lesser extents.

In the coldest period of the Little Ice Age, sunspots virtually disappeared from the Sun. Sunspots are dark marking that signpost raised solar magnetic activity and the so-called Maunder minimum of 1645-1715 encourages scientists to believe that our planet's climate must somehow be linked to the Sun's magnetic field. Volcanic eruptions can also produce global cooling by pumping dust into the upper atmosphere, which reflects sunlight into space, preventing the Earth from receiving it, and the Little Ice Age was almost certainly exacerbated by this mechanism. In 1815, Indonesia's Tambora volcano enswathed the world in ash, causing 1816 to be 'the year without a summer'. Neither of these variations seems potent enough to produce a full blow glaciation, however, so scientists have looked elsewhere.

Milutin Milankovitch (1879-1958) was a Serbian astrophysicist who developed the theory that ice ages were the result of variations in the Earth's orbit around the Sun. There are three Milankovitch cycles. Firstly, variations can occur in the shape of Earth's orbit around the Sun (known as eccentricity). Secondly, Earth can tip over, thereby changing the angle between its rotation pole and its orbit (known as obliquity). Thirdly, Earth's rotation pole can change the direction in which it's pointing, rather like a spinning top oscillates around the vertical (known as precession).

These all affect the amount of absorbed sunlight and Milankovitch calculated the effects of these variations for the past 600,000 years, correlating them to the glaciations. Although the idea showed promise, the scientific community was slow to accept it until the mid 1970s, when new data appeared to corroborate the ideas.

The main effect appears to be the eccentricity, which varies on a timescale of around 100,000 years – the same timescale for the onset of the glaciations. However, not everyone is convinced. Richard A Muller, Lawrence Berkeley Laboratory, California, believes that, whilst Milankovitch was on the right lines, there is a flaw in the methodology. “The eccentricity is actually a weak effect and also the ice ages seem to be out of step with the variation; they start a little early.”

Muller believes that it is another orbit cycle, unconsidered by Milankovitch, which is to blame: the orientation of the Earth’s orbit, which changes with respect to the equator of the Sun. When it closely matches the plane of the Sun’s equator, Earth finds itself ploughing through the zodiacal dust, which is created by evaporating comets and colliding asteroids. Just like the eruption of volcanic dust, this cools the Earth.

However, when Muller went searching for the dust in the Greenland ice sheets he got a surprise. “There was much less dust than I thought,” he admits, “So I have to rely on amplifying factors on Earth to trigger the ice ages. But then so do the Milankovitch people.”

Whilst Milankovitch cycles – or something similar to them – may explain individual glaciations, what about the over-arching ice ages, themselves? Before the modern ice age started 2.5 million years ago, there was a warm period that lasted for several hundred million years. Before that there was the 60-million-year-long Permo-Carboniferous ice age and looking back another several hundred million years, there were the super glaciations of between 500 and 800 million years ago (see *Snowball Earth*).

The answer seems to lie in the positioning of the Earth’s continents. “The standard thinking is that you need a large amount of land at the poles,” says Muller, “That way ice sheets can accumulate and creep downwards.”

Ice finds it very hard to collect in large quantities on water. For evidence Muller points to the ice sheets of Greenland, which extend much farther south than the frozen wastes of the arctic ice sea. With land to channel the glaciers down from the poles, the bright ice begins to reflect sunlight into space, cooling the Earth even more.

So when will the next glaciation occur? Some scientists believe that the current global warming – whether man-made or not – will paradoxically catapult us

into the next glaciation, plunging average temperatures by several degrees in merely a few decades.

The idea is that as the arctic ice melts, it will disrupt the deep-water currents responsible for the Gulf Stream, which transports warm equatorial water to northern Europe. Shut off the Gulf Stream and their temperatures will plummet. Britain will freeze.

Perhaps it's time to stock up on a few extra pairs of thermal undies, just in case. Muller seems far less concerned, saying, "Next ice age? It'll happen any millennium now."

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Time line:

The PreCambrian ice age (500-800 million years ago)

This is the so-called Snowball Earth period, caused by the breaking up of the super-continent Rodinia. Ice sheets covered almost the whole Earth.

Palaeozoic Warm Period(640-320 million years ago)

This is the Garden-of-Eden period for life on Earth. Super warm temperatures seem to have driven an extraordinary burgeoning of multi-cellular life, known as the Cambrian explosion.

Permo-Carboniferous ice age (340 – 240 million years ago)

The continents converge into a super-continent called Gondwana, situated on the South Pole. Glaciers migrated back and forth for over 100 million years.

Mesozoic (245-35 million years ago)

Another warm period and another time of great evolutionary change, this era encompasses the age of the dinosaurs and also heralded a wide diversification of plant life.

Global cooling begins (15 million years ago)

Global cooling, possibly caused by the movement of continents, begins. Antarctica separates from South America, allowing cold water to flow all around the polar continent.

Onset of the current ice age (2.5 million years ago)

The Panama Isthmus, a large natural sea channel, closes. This prevents warm, equatorial water from the Pacific mixing with the Atlantic waters.

Last glaciation begins (115,000 years ago)

Ice sheets begin to creep across the continents of the northern hemisphere. At their peak, they covered about 30% of the landmass in the world.

The Younger Dryas (10,900 - 9600 BC)

A period of intense, rapid temperature fluctuations signals the end of the last glaciation. The glaciation ends when average temperatures rise almost 10 degrees in just 50 years.

Medieval Warm Period (approximately 800-1350AD)

In this warm period of prosperity and exploration, the Vikings settled Iceland and Greenland and wine crops were grown in abundance in England.

Little Ice Age (1350 - 1850 AD)

The climate takes a downturn that results in severe winters, hardship and famine. Disease and ill-health are rife.

Current 'Super Interglacial'

The current warm period is generally blamed on industrial output of greenhouse gases. The temperature rise is 0.1 degrees per decade, modest compared to the Younger Dryas.

Next glaciation (2030 or 3030?)

Some scientists believe that the melting arctic ice could trigger a glaciation in the next few decades. Some believe it will be millennia yet.

Snowball Earth

So, what's the worst that can happen? Imagine the Earth gripped in a global ice age with glaciers and sea ice reaching almost to the equator. Scientific evidence suggests that Earth found itself in just such an icy grip not once but twice between 550 million and 800 million years ago. Each big freeze lasted for a staggering 10 million years.

At that time, all land had converged into a super-continent known as Rodinia. Snowball Earth was triggered by the break-up of this landmass, which caused large volcanic eruptions. Rainwater washing over the newly formed volcanic rocks triggered a chemical reaction that scrubbed carbon dioxide from the air, allowing the temperature to plunge.

During this time, life survived in pockets around the hot-water vents on the frozen ocean's floor. As the rocks were covered in ice, volcanic activity gradually built up the carbon dioxide again in the atmosphere, finally releasing Earth from the mega-Ice age.

Jargon Busters:

Ice age – the over-arching period of time in which global average temperature is low.

Glaciation – the times when ice sheets and glaciers cover much of the mid-latitude continents (what you and I would call an ice age).

Interglacials – the warmer times during an on-going ice age when the ice sheets are in retreat.

Interstadials – the rapid periods of great natural warming. Typically temperatures can rise by several degrees per decade.

Find Out More:

Earth Story, chapter 6, Simon Lamb and David Sington, BBC Books.

Ice Ages and Astronomical Causes, Richard A Muller and Gordon J MacDonald, Springer-Praxis.

NOAA Paleoclimatology Programme,

<http://www.ngdc.noaa.gov/paleo/glaciation.html>

Portrait of an Ice Age:

<http://www.carleton.ca/~tpatters/teaching/climatechange/glacial/glacial1.html>

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Advance and retreat of the ice sheets

The last two million years have seen the Earth in the grip of an ice age, with ninety percent of its time spent in glacial periods. During this time gigantic ice sheets have crept across the northern continents, slowly moving towards the sea. Once at the water, the ice does not usually extend far out to sea; instead, it breaks off to form icebergs. During most glaciations, the equatorial regions are little changed in temperature; just the higher latitudes suffer.

Only during brief interglacial periods have the ice sheets retreated into more mountainous regions. In these temperate times, the evidence for previous glaciations can be seen in the U-shaped valleys cut by the glaciers and the debris, known as moraine, abandoned by the now-melted glaciers.

Milankovitch Cycles

The distance and orientation of Earth from the Sun is widely thought to be responsible for the advance and retreat of the ice sheets during ice ages. There are three, traditionally recognised cycles.

Eccentricity – The Earth's orbit varies its elliptical shape over 100,000 years. At maximum eccentricity the temperature differences between summer and winter should be at their greatest.

Obliquity – The tilt of the Earth's axis with respect to its orbital plane (the ecliptic) varies by 3 degrees over 41,000 years. This variation affects how much solar radiation enters the planet through the Polar Regions.

Precession – The axis of Earth also shifts direction like a wobbling spinning top,

independently of its obliquity. This precession takes 23,000 years to complete a cycle. It varies the Earth's proximity to the Sun during northern hemisphere winter.

Northern Hemisphere Glaciation

Continents that cross the Arctic Circle are essential to guide the ice downwards during a glaciation. During the last glacial event, the continents of the northern hemisphere were bulldozed, mostly by the advance of Arctic ice.

During:

Ice sheets cover most of Northern Europe and northern North America.

Sea levels drop as can be most easily seen by comparing the shape and size of Florida. The large tracts of ocean surrounding Antarctica in the south provide an effective buffer, protecting the southern hemisphere continents.

After:

During the current interglacial period, ice has retreated back into the Polar Regions. In the northern hemisphere, only Greenland remains covered in an ice sheet. The ice floes of the Arctic Ocean have shrunk considerably and the sea level has risen.