Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Greenhouse Earth - The inconstant sun.*

This is the first of two podcasts on what astronomy can tell you about climate change and global warming.

Earth is a fairly dynamic sort of planet and has experienced a good deal of generally gradual, but sometimes dramatic, climate change over its 4.5 billion year history. Leaving people out of the equation for the moment and looking at timescales of a more geological or astronomical nature – it's certainly the case that climate change on Earth is more the norm than the exception.

There's two areas of influence to deal with here – firstly how and when solar radiation hits the Earth – which is all about astronomy. And then what happens to that radiation when it's absorbed by Earth – which is still a bit about astronomy and a lot about geology, hydrology and biology.

Climate change within the last million years or so, seems to be all about Milankovitch cycles – which are characterised by a cold snap, with increased glaciation, every 40,000 years or so within a overlying cycle that repeats every 100,000 years or so.

We are currently living in an ice age. It commenced about 30 million years ago and it's unclear exactly when it will end. Like any other ice age in Earth's history, it's characterised by those big patches of white stuff that are present today at each pole. Over the whole history of Earth, there's been many eras when there's been almost no ice at the poles at all.

So, when we talk about the 100,000 year Milankovitch cycle – we are operating in a much narrower scale. The current Milankovitch cycle of glaciation had its last maxima around 20,000 years ago and has declined since.

In a glacial maxima, glaciers can start descending across temperate and even semi-tropical mountain ranges – as well as the polar ice sheets extending out several hundred kilometres further than they do now. But to give you a sense of scale, in the maxima of an ice age you are taking about continental scale glaciers and sea ice extending down toward the Equator. And if that sounds at all interesting maybe you should tune in for next week's podcast.

But anyway, at least in the last 800,000 years – which is how far back we've gone with ice core samples – there's a clear 100,000 year cycle in temperature levels. We know the tilt of the Earth's axis has a bit of a wobble in it – in fact a 26,000 year cyclic wobble which causes the precession of the equinoxes.

Also you probably know the Earth is tilted at 23.4 degrees to its orbital plane but did you know that the tilt actually shifts between 22.1 and 24.5 degrees and back again – over a 41,000 cycle. We are currently trending towards the minimum tilt of 22.1 degrees and will get there around the year 10,000.

On top of all that, the eccentricity of Earth's orbit varies over a 400,000 year cycle – from an almost circular orbit, with an eccentricity of 0.005, to a maximal eccentricity of 0.058. At the moment, the eccentricity is 0.017, which means there's only a 7% difference in solar radiation between perihelion, when the Earth is closest to the Sun – and aphelion, when its furthest away. But, when the Earth orbit is at its most eccentric, this difference in radiation is 25%. Most of these orbital changes are due to the faint influence of the gas giants Jupiter and Saturn. The gas giants also cause a steady 112,000 year cyclic precession of the entire orbit of Earth.

Despite all these changes, Earth keeps obeying Kepler's third law of planetary motion because its semi-major axis (essentially the radius of an ellipse) doesn't change, so its mean orbital period, that is a year, never changes either. This means there's no change to the mean amount of solar radiation received by the Earth. What does change is that there's more Sun on the poles at a maximal tilt – and more overall cooling at the aphelion of an eccentric orbit.

Climate change resulting from the Milankovitch cycle seems to be partly about seasonal variation – and also about ice. Being white, ice has a much higher albedo than either land or water. Any accumulation of ice results in more of the Sun's radiation being reflected back into space – which drops the mean global temperature – and that results in more ice. It's a positive feedback loop.

Under other conditions though, with a little extra warmth to melt the ice, it really starts melting, because less ice means more radiation is absorbed by land and water – raising the mean global temperature and melting more ice. It's another positive feedback loop in the other direction.

Now something else we see in the ice cores is a cyclic change in CO_2 levels. The ice cores contain small bubbles which is trapped atmosphere from historic times going back 800,000 years. What we see is a correlation between temperature and CO_2 levels. And it's speculated that when Earth goes into a glacial maxima, there's less active photosynthesis and less exposed silicate rocks which absorb CO_2 to form bicarbonates and calcium carbonates so CO_2 increases in the atmosphere, which warms the atmosphere and hence puts a limit on how much ice can be formed.

And once the ice starts melting, plant life starts picking up again and there's more exposed silicate rock surface area – so CO_2 levels start to decline, the atmosphere cools and that puts a limit on how much melting occurs.

So for all these reasons, glaciation noticeably swings back and forth over an approximately 100,000 year cycle. Of course all this suggests the radiation from the Sun is an unchanging quantity. In fact we know there is a solar cycle of roughly 11 years – where, largely due to fluctuations in its intense magnetic field, the Sun cycles from a solar maxima with lots of sunspots and solar flares to a minima with hardly any. It's not apparent from the ice core data that the solar cycle contributes more than a background hiss to the big swings of the Milankovitch cycles.

So what conclusions can we draw here? What the ice cores do unequivocally show is that the biggest rise in CO_2 over the last 800,000 years has been in the last 150 years. Beyond that, there are other data sources showing small upward trends in global temperature and sea level at rates that cannot obviously be reconciled with the Milankovitch cycle – or indeed with the solar cycle which had its last maxima in 2001, with next one due in 2012.

People reasonably debate the validity of drawing firm conclusions from temperature and sea level records that go back less than two hundred years. But if the Milankovitch cycle is real, the current decline in glaciation should be matched by a decline in CO_2 – and it clearly isn't. So, at least theoretically, we humans have removed the factor that has limited global ice melting in those previous Milankovitch cycles.

Here at Cheap Astronomy we're old enough to remember when pumping pollution into the atmosphere was a bad thing all on its own – and we're happy not to wait around for unequivocal proof of whether or not elevated CO_2 levels will kill all the polar bears. Let's just fix it now.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where you can think globally and save locally. No ads, no profit, just good science. Bye.