Arctic sea ice thermostatic control of global temperature

John C.D. Nissen
jn@cloudworld.co.uk
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Before I start the presentation proper, I would like to acknowledge the support of Professor Peter Wadhams, of Cambridge University, who encouraged me to write a paper for the EGU about the role of the Arctic sea ice in the control of global temperature – a crucial function for the future of the planet.

This presentation will progress by dealing with the following five questions:

- What happened in the past 2.5 million years?
- Why did it happen?
- How does the control system work?
- What will happen next, if we do nothing?
- What is to be done?

1. What happened in the past 2.5 million years?

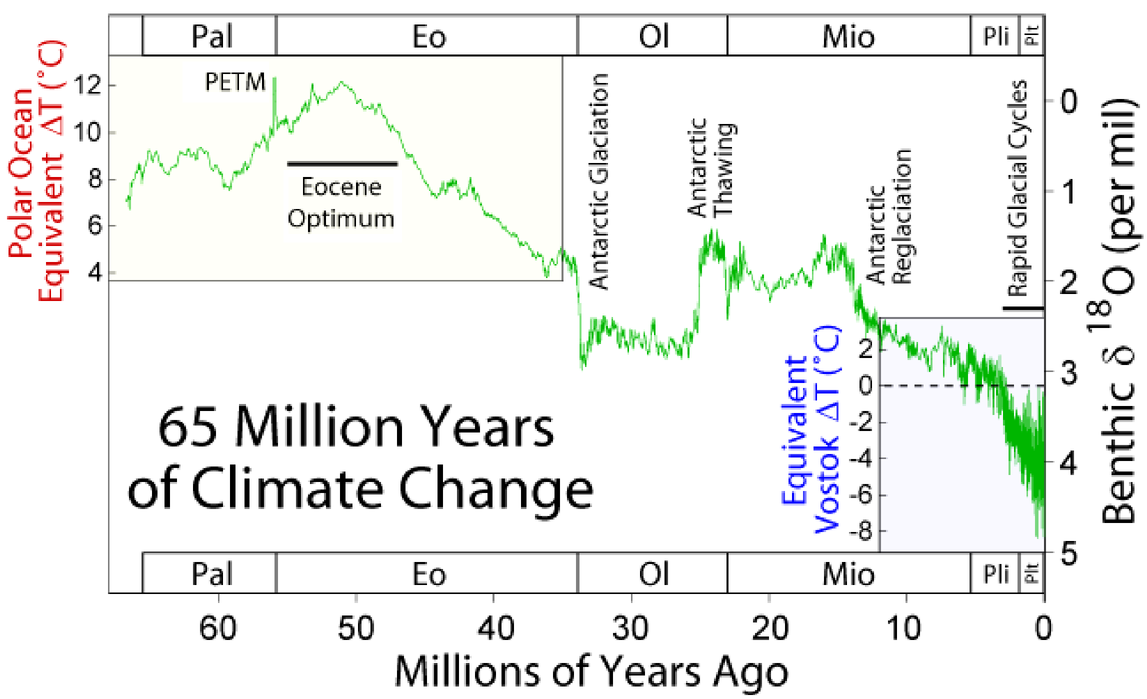


Image created by Robert A. Rohde / Global Warming Art [1]

During 2.5 million years of our planet's history (the Pleistocene) there has been an extraordinarily regular oscillation of temperature, CO2, methane and sea level, between constant limits. For example the temperature has varied by about 10 degrees C; the sea level has varied between 120 metres below todays and a few metres above todays. This oscillation is synchronised with certain Milankovitch cycles of the planet's orbital and tilt values.

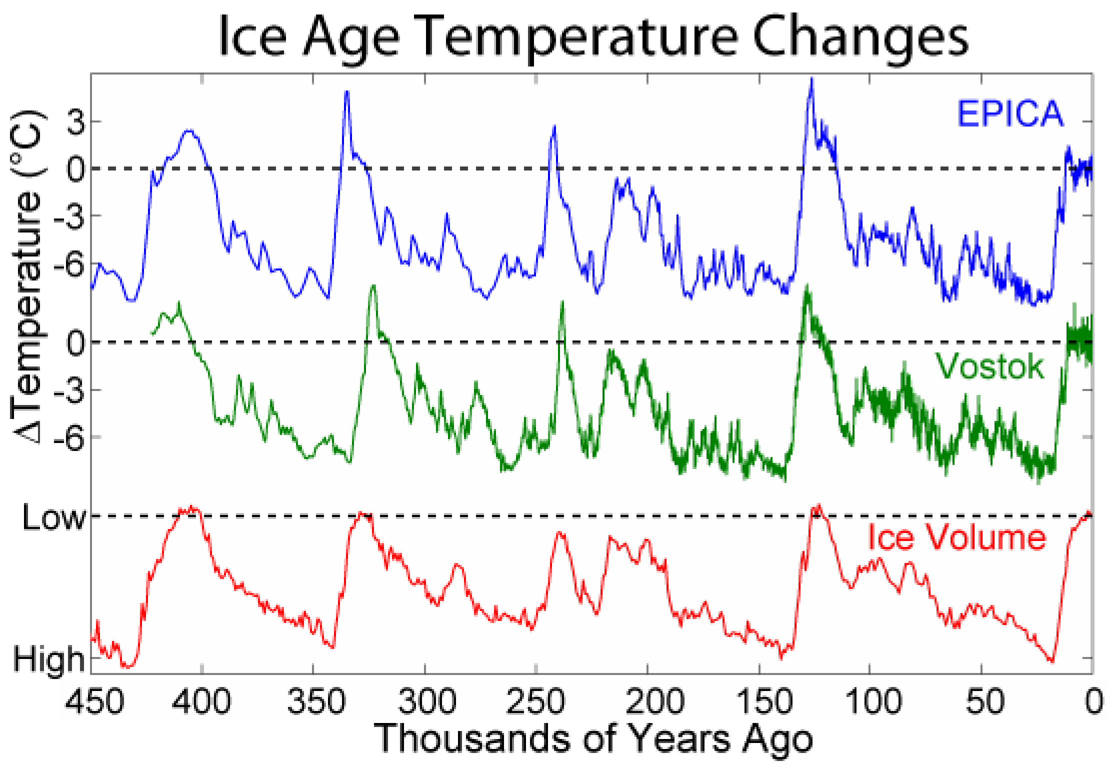
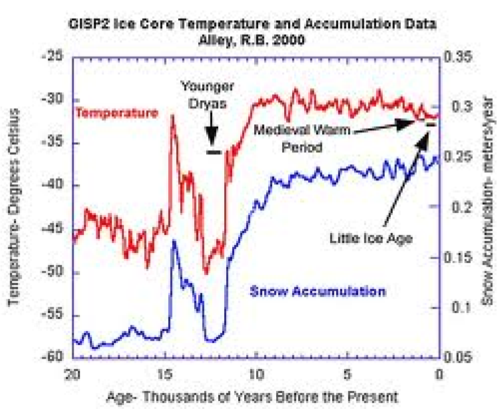


Image created by Robert A. Rohde / Global Warming Art [2]

However for the past 8000 years humankind has enjoyed a remarkably stable environment with respect to the previous 2.5 million years – with only a relatively small variation in temperature and sea level.



Global change master directory [3]

According to the Ruddiman Hypothesis, this stability has been obtained largely as the inadvertent result of mankind's own warming influence on the Earth system – clearing forest, grazing cattle and growing rice – just balancing a cooling trend from Milankovitch cycles. Therefore he has used the term ‘Anthropocene’ to cover this period.

2. Why did it happen?

Why did the temperature oscillate for 2.5 million years and then remain steady for 8000 years? This is a philosophical question, but it can be argued that the climate oscillation provided a stimulus to human brain development and the 8000 years was necessary for the agrarian revolution, the industrial revolution and development of the global civilisation we have today, with approaching 7 billion people. You could say it was luck. But if it hadn’t happened, we would not be here to observe it! That is the anthropic principle. It highlights the very special conditions and processes of the Earth System and its external relationships that allow us to be here today, but it makes no promises for tomorrow, as mankind destabilises the planet with an excess of greenhouse gases.

3. How does the control system work?

What is the mechanism that produced these well-defined oscillations, and how were they dampened over the past few thousand years? (I will leave the implications for the future till later in the presentation.)

Reverse engineer the Earth System!

(A slide was presented showing a fluidic switch on the front cover of Scientific American, December 1964. It was rotated so that fluid entered on the left.)

Can anybody see how this works? The main fluid flows in from the left, and can exit from either of two outlets on the right, according to a small signal entered from the top. The signal can switch the main fluid between the two outlets. It is this kind of mechanism that I can see working in the North Atlantic. But let’s go back to first principles.

If you were going to design a system to make temperature oscillate and then stay steady for 8 thousand years or so, how would you do it? First of all you have to have a temperature reference, and a property of a substance which changes at that temperature – that is going to be water. It has been given it the unusual property that the solid is less dense than the liquid at freezing point. So ice has to be part of the thermostatic control.

Then you have to have an external signal for the oscillation. This has to be something to do with the Earth orbit or spin, unless sun already has such an oscillation (which is very difficult to arrange over thousands of years). The orbit is slightly affected by other planets, the ellipticity changes, and the spin has precession and a tilt of the axis (currently 22.6 degrees) which varies.

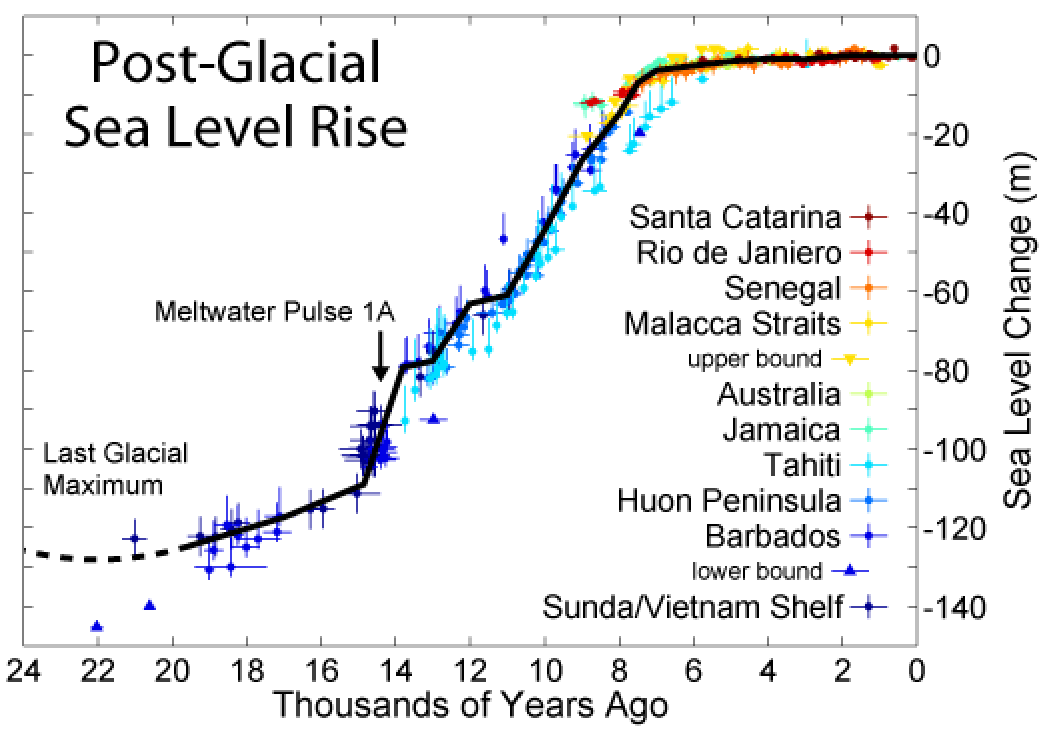
Then you don’t want this signal to be too strong, otherwise you can’t achieve the steady state for a few thousand years. You need to find a mechanism to counter the signal – and it can be biological – so you choose some biological generation of greenhouse gases to offset what would have been a continuing of the oscillation into a cold period.

But you are left with a weak signal to produce the oscillations. So there has to be an amplifier – and it has to use the melting point of water. So the orbit/spin of the Earth changes heat input – then some of that input signal is amplified in a positive feedback.

The obvious mechanism is albedo flip. There needs to be a big pool of ice floating on water which can be warmed or cooled by a current carrying the signal. The pool has to be near a pole. And the current has to come a long way, from near the equator or beyond, in order to pick up the signal.

Now with design of an amplification or control system, you can introduce negative feedback to improve the performance. But the negative feedback has to be carefully designed to prevent any instability and oscillation. With the Earth system, you don't mind some oscillation superimposed on the amplified signal. Indeed such oscillation is observed.

With our mechanism for positive feedback, the obvious way to provide negative feedback is to divert the current. In the case of the warming part of the Milankovitch cycle, the polar region is warming rapidly, so we can use that warming to melt some snow and ice and produce a meltwater stream to divert the current. We can see exactly such a mechanism in the North Atlantic, with the main current as the Gulf Stream crossing from south-west to north-east, while meltwater can come in from the north-west to divert it into a more southerly route.



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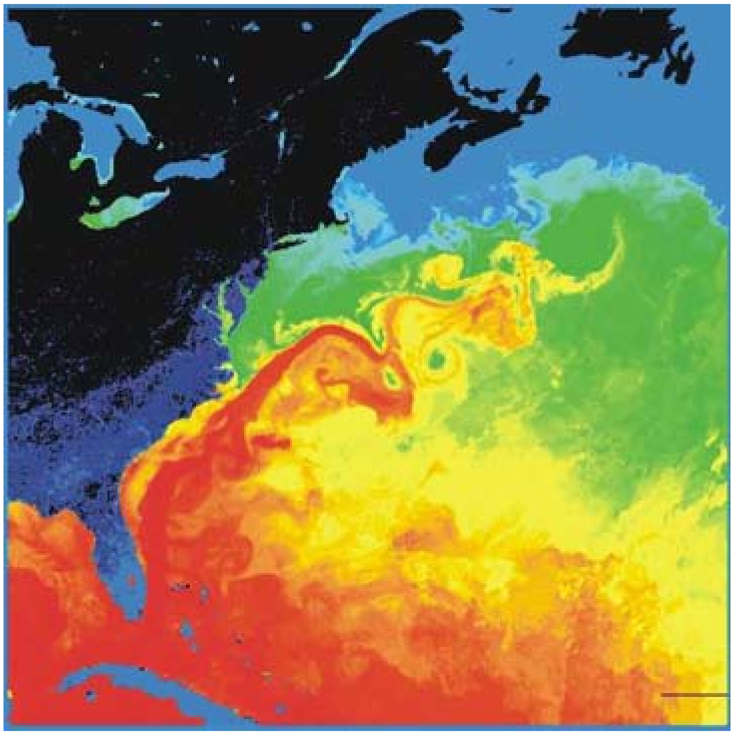

Gulf Stream - image created by NASA [5]

The Gulf Stream is a remarkable mechanism, apparently finely tuned to produce a jet of water which crosses the Atlantic, becoming the North Atlantic Current. West of Ireland it splits in two, with most of the current continuing up the north-west coast of Europe while the rest swings southwards, becoming the Canary Current. The Gulf Stream picks up the 'warming signal' in the northern hemisphere produced by the Milankovitch cycles, and sends it towards the Arctic Ocean, where it is amplified by the Arctic sea ice positive feedback. The negative feedback of a meltwater pulse diverts the North Atlantic Current southwards, so that most flows into the Canary Current. Thus the heating of the Arctic is switched off, and the sea ice is allowed to grow again.

In the cooling part of the Milankovitch cycle, we can see the same negative feedback mechanism at work. In particular, during the last glaciation, we observe several moments of negative feedback associated with Heinrich events. Icebergs are flowing across the Atlantic and diverting the Gulf Stream, thus choking off the amplification of the cooling signal. I will not say more about the cooling part of the cycle, because it becomes very speculative.

In the case of the warming direction, there has to be a mechanism to prevent runaway warming. The meltwater feedback can prevent too rapid warming, and we see meltwater which could have slowed the warming after the end or the last glacial maximum. At the peak of the warming cycle, there has to be something more dramatic to halt the warming, and we saw the Younger Dryas period. Indeed the conventional view, which I support, is that this colder period was initiated by a massive influx of meltwater, probably from Lake Agassiz. The latest theory, which I heard at this conference, is that Lake Agassiz drained to the north-west into the Arctic Ocean and the water flowed from there into the North Atlantic, diverting the Gulf Stream and producing same negative feedback that we expect from meltwater.

We observe that the temperature never went above a certain value during 2.5 million years. The hottest point may have been at the end of the Eemian warming, when there were hippos in London. It is possible that the whole of the Arctic sea ice had melted by then, thus giving no further amplification of warming. But the warming up to that moment had not been so rapid as to produce much CO_2 or methane emissions.

4. What will happen next, if we do nothing?

The anthropogenic CO_2 in the atmosphere is producing an estimated 1.6 Watts per square metre of radiative forcing. That is several times greater than the Milankovitch signal and is the dominating forcing of the climate system. This CO_2 warming is being amplified through the Arctic sea ice, so global warming will accelerate. There is little negative feedback from meltwater in prospect, unless the Greenland ice sheet collapses. And there is no negative feedback from biological processes. On the other hand, there is an enormous quantity of carbon in permafrost, which could potentially be emitted as methane.

Thus the danger today is that we are having extremely rapid warming, being amplified by the Arctic sea ice, while there is an excess of CO_2 in the atmosphere and potentially an excursion of methane. The methane is liable to come from permafrost in vast quantities. There is potentially enough methane to cause runaway global warming, and unfortunately there seems to be no natural mechanism to prevent this.

5. What is to be done?

Mankind has injected a colossal pulse of CO_2 into the atmosphere which is threatening to destroy the temperature control system of the planet. The only way forward is for mankind to seize the initiative and re-engineering the climate system to save the Arctic sea ice, prevent a methane excursion and maintain the stability of the climate system that civilisation has enjoyed for the past 8000 years.

Source of figures

[1] http://www.globalwarmingart.com/wiki/File:65_Myr_Climate_Change_Rev_png

[2] http://en.wikipedia.org/wiki/File:Ice_Age_Temperature.png

[3] http://gcmd.nasa.gov/index.html

[4] http://en.wikipedia.org/wiki/File:Post-Glacial_Sea_Level.png

[5] http://en.wikipedia.org/wiki/File:Golfstrom.jpg