Ice Cores: Temperature Versus CO2

1. Media Unreliability

A couple of months ago there was an item on Radio 4's Today programme. They had dispatched one of their journalists to the British Antarctic Survey. Said journalist took a boat trip with one of the Survey's experts to look at the Western Antarctic sea ice. The expert told us that the Western Antarctic sea ice was diminishing. The item then cut to a laboratory in the UK where climate scientists were analysing ice core samples. These ice cores can provide data on both CO2 levels and local temperatures going back many hundreds of thousands of years, and hence covering a succession of ice ages and intermediate periods. The scientist informed us that "we see a relationship between the CO2 and temperature". That was the end of the news item.

I was very concerned about this Today piece. So much so that it provided the motivation to look in greater detail at a number of climate change issues, as posted on this site. My concern arose because, as it happened, I knew a little about the two issues covered in the programme and it was clear that the listener had just been seriously misled by the BBC.

The Western Antarctic sea ice is diminishing, and from this isolated fact alone the listener would have received the impression that climate change was having a real and observable effect in reducing Antarctic sea ice. But the BBC programme made no mention of the ***increasing*** sea ice in the Eastern Antarctic, and no mention that the Antarctic sea ice overall is ***not*** decreasing, and in fact might be increasing (see my piece Sea Ice: Trends?). The British Antarctic Survey expert would certainly have known this, and I doubt that he failed to mention it to the journalist. One is left with the unavoidable conclusion that the BBC deliberately misled the listener. Whatever the broader position on climate change might be, Antarctic sea ice does ***not*** provide evidence of a deleterious effect of climate change, directly contrary to the impression the Today piece created.

The ice core item was equally disturbing. The phrasing used by the scientist interviewed was correct – that there is a *relationship* between CO2 and temperature. But the listener was clearly being led to interpret this statement as meaning "ice cores show that CO2 causes temperature increase". In following the previous item, the listener was also being skilfully guided to conclude that CO2 increases are therefore causing the Antarctic sea ice to diminish.

But I knew that the *relationship* between CO2 and temperature from ice cores was not what the BBC was leading the listener to believe, namely that CO2 changes cause temperature changes. In fact, the ice core data shows that temperature changes come first and CO2 changes come later – perhaps 800 years later, if not thousands of years later. Again the BBC had seriously misled the listener, and it seems had done so deliberately. I make this accusation because it is inconceivable that the scientist being interviewed – a specialist on ice cores – would not have known about this "reverse time lag". It has been common knowledge for 20 years at least. Nor is it controversial. Nor is it likely that the scientist would have failed to mention this key fact to the BBC journalist.

Whatever the true scientific facts about climate change maybe, the public should be more aware of how willing the media are to place a political agenda ahead of balanced reporting. The above Today item is an indisputable example.

The rest of this article reviews the issue of the reverse time-lag in ice core data.

2. Vostok Ice Core Data

I do not need to review in great detail the relative timing of CO2 and temperature changes in the ice core data: it is not controversial. A brief review will suffice. In 2007 there was a New Scientist article which stated,

"*Ice cores from Antarctica show that at the end of recent ice ages, the concentration of carbon dioxide in the atmosphere usually started to rise only after temperatures had begun to climb. There is uncertainty about the timings, partly because the air trapped in the cores is younger than the ice, but it appears the lags might sometimes have been 800 years or more. This proves that rising CO2 was not the trigger that caused the initial warming at the end of these ice ages – but no climate scientist has ever made this claim*."

Well, perhaps no climate scientist has, but it seems the media might be willing to spin it that way, if only by clever implication.

However, the New Scientist article continued, "*It certainly does not challenge the idea that more CO2 heats the planet*". The article explained that the regular switching between ice ages and warmer interglacial periods is thought to be triggered by variations in Earth's orbit, known as Milankovitch cycles, which change the amount and location of solar power reaching Earth. However, the direct effect of Milankovitch-induced insolation variation is generally held to be insufficient to explain the dramatic temperature switches between ice ages and interglacial periods. It would appear that some positive feedback effect is required to amplify the temperature change triggered by the Milankovitch cycles. The New Scientist quotes work claiming that this is where the greenhouse effect of CO2 comes into the picture, despite the time lag.

I would only note in passing that there is a more immediate positive feedback effect available – if you believe the IPCC position on global warming models – namely water vapour and clouds. In the IPCC models, two-thirds of the warming predicted due to CO2 increases does not arise directly by CO2 forcing but indirectly due to the positive feedback of temperature on water vapour (greenhouse effect) and clouds (albedo effect). Whilst IPCC models are primarily concerned with global average temperature changes of the order of 1°C to 3°C, the ice cores reveal local temperature variations over a 10°C range, so the water vapour feedback would presumably be that much greater. In contrast, the variation of CO2 concentration from ice core samples is within about 190 and 300 vppm, which is less than the range considered by IPCC models (285 to 570 vppm). Even assuming one believes the IPCC position (and there is ample room to doubt the story on water vapour feedback) it seems that CO2 would play a third-order role in explaining ice age /interglacial temperature variations, after Milankovitch cycles and water vapour.

Ice core data is often displayed on too large a timescale to discern whether CO2 or temperature changes first. Figure 1, taken from Euan Mearns 2017, shows data over nearly half a million years. It is clear from this graph that temperature change precedes CO2 change during cooling periods (inception of ice ages), but the scale is too big to tell which comes first in warming periods (termination of ice ages). Figure 2 shows, from the same source, an expanded view of the end of the Eemian interglacial period and the inception of the following ice age, 128,000 years ago. (Note that time runs from right to left in Figure 2). This shows very clearly that temperature reduction leads CO2, which changes little over the timescale of this graph.

Joanna Nova has graphs covering the whole time range on an expanded scale. Several purport to show that temperature leads CO2 change during the warming phase (termination of ice age). In my opinion, though, it is not easy to draw this conclusion simply by looking at the

graphs – and one has to be wary of a false conclusion in this respect due simply to the relative y-axis scales used for CO2 and temperature.

Figure 1: from Euan Mearns 2017.

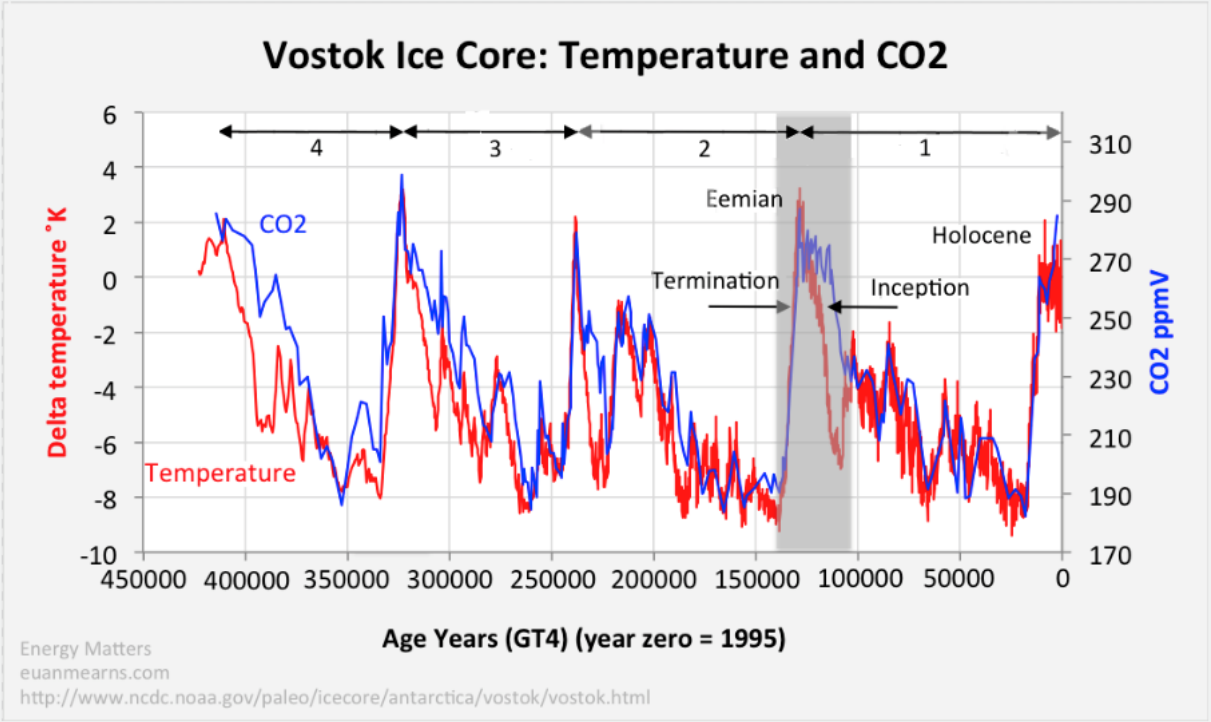
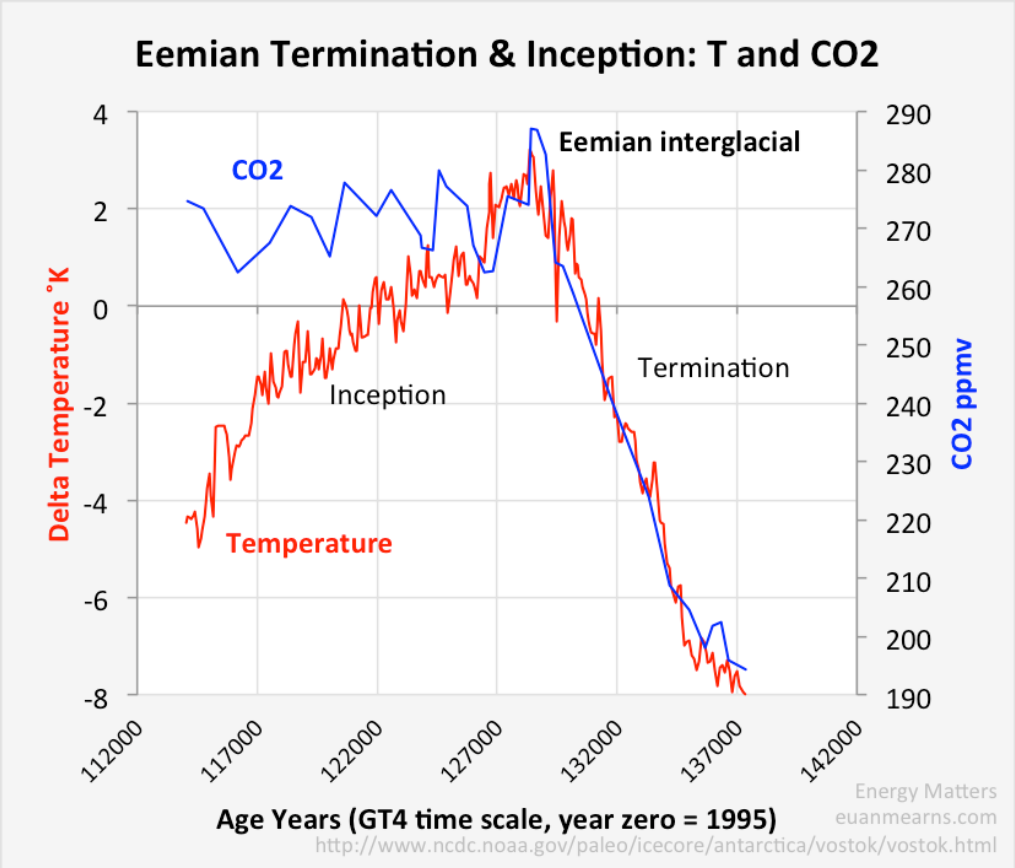


Figure 2: from Euan Mearns 2017. Example of temperature leading CO2 in a cooling phase. Note that time runs from right to left in this graph.



However, there have been numerous detailed analyses of the Vostok data and as far as I am aware they all conclude that CO2 lags behind temperature, albeit by various different amounts. I shall refer to one: *Timing of Atmospheric CO2 and Antarctic Temperature Changes Across Termination III* by Caillon, et al (in Science, 2003). The Abstract reads,

"*The analysis of air bubbles from ice cores has yielded a precise record of atmospheric greenhouse gas concentrations, but the timing of changes in these gases with respect to temperature is not accurately known because of uncertainty in the gas age–ice age difference. We have measured the isotopic composition of argon in air bubbles in the Vostok core during Termination III (~240,000 years before the present). This record most likely reflects the temperature and accumulation change, although the mechanism remains unclear. The sequence of events during Termination III suggests that the CO2 increase lagged Antarctic deglacial warming by 800 ± 200 years and preceded the Northern Hemisphere deglaciation*."

Extracts from the text of the paper are,

"*This confirms that CO2 is not the forcing that initially drives the climatic system during a deglaciation. Rather, deglaciation is probably initiated by some insolation forcing which influences first the temperature change in Antarctica (and possibly in part of the Southern Hemisphere) and then the CO2*."

However the authors also state that, "*This sequence of events is still in full agreement with the idea that CO2 plays, through its greenhouse effect, a key role in amplifying the initial orbital forcing*". They do not claim that the CO2 rise is causally implicated in the later Northern Hemisphere deglaciation, only that it does precede it. As regards the mechanism of CO2 rise following Antarctic temperature increase they opine,

"*The similarity between CO2 and Vostok temperature and the associated short time lag support the suggestion of Petit et al. that CO2 may be controlled in large part by the climate of the southern ocean. Although there is not yet clear support for this assertion (through models, for example), a delay of about 800 years seems to be a reasonable time period to transform an initial Antarctic temperature increase into a CO2 atmospheric increase through oceanic processes*." They are referring here to outgassing as ocean temperature rises.

There have been attempts to claim that the apparent time-lag is actually an artefact of the measurements caused by the air bubbles entrapped in the ice being of a different age than the surrounding ice itself. This, it is claimed, comes about because air initially diffuses through the compressed snow, and this terminates only when the ice has recrystallised enough to form closed cavities, preventing further diffusion. However, Parrenin et al (2013) still find a time lag in the warming phase, albeit much reduced. It seems unlikely, though, that this effect could account for the time lag in the cooling phase, which is more like 14,000 years. The balance of opinion, whether from climate change adherents or from sceptics, is that CO2 changes do lag behind local temperature changes in ice core data.