

## EXTENSION

## Is there a causal link between carbon dioxide and temperature in explaining glacial cycles?

Look at Figure 4. By superimposing the carbon dioxide and temperature curves for data obtained from the Vostok ice core, it can be seen that the two curves do not match perfectly. Assuming that the data are correct (this is an important assumption), there appears to be a time delay between temperature change and changes in the level of carbon dioxide.

Some scientists believe that the trigger for these long-term trends in temperature and carbon dioxide is orbital change – the Milankovitch Cycles.

These regular cycles of orbital eccentricity cause slight variations in the amount of the sun's radiation that warms up the Earth. So, as temperatures start to rise at the end of a glacial period (triggered by orbital change), there is a surge of carbon dioxide released into the atmosphere by the warming of the oceans and the 'unlocking' of the land surface that had previously been frozen. This surge of carbon dioxide enhances the greenhouse effect, amplifying the warming trend. This is an excellent example of a positive feedback loop.

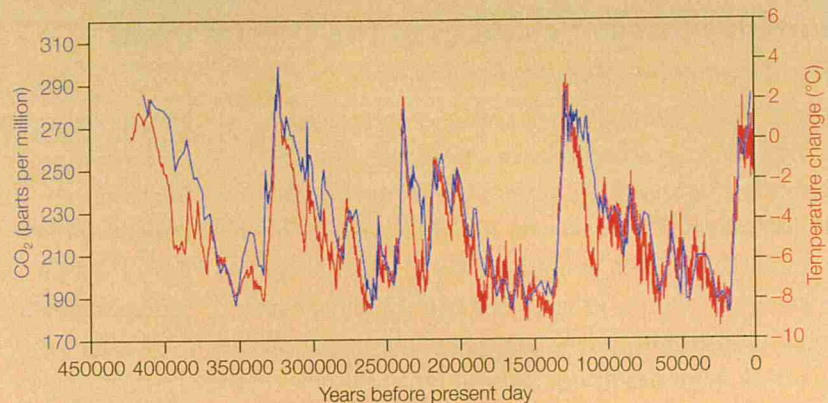
A study in 2012 by Shakun et al. looked at temperature changes during the transition from the last glacial period to the current warmer period, about 20 000 years ago.

They found that:

- ◆ the Earth's orbital cycles triggered warming in the Arctic approximately 19 000 years ago, causing large amounts of ice to melt, flooding the oceans with fresh water
- ◆ this influx of fresh water then disrupted ocean current circulation, in turn causing a see-sawing of heat between the hemispheres
- ◆ the southern hemisphere and its oceans warmed first, starting about 18 000 years ago. As the Southern Ocean warmed, the solubility of carbon dioxide in the water fell and this causes the oceans to give up more carbon dioxide, releasing it into the atmosphere.

So, there is evidence to suggest that orbital cycles triggered the initial warming at the end of the last glacial period leading to a surge in carbon dioxide emissions, which in turn amplified the warming trend. Overall, scientists believe that more than 90 per cent of the post-glacial warming occurred after the rise in atmospheric carbon dioxide.

There is still a considerable debate about the causal connections between temperature and carbon dioxide and the role played by the Milankovitch Cycles. Issues concerning data reliability further complicate an already heated debate. Whatever the causes of climate change in the past, there is little doubt among the scientific community that the current high levels of carbon dioxide are the result of anthropogenic (human) factors and that this is causing the recent rise in global temperatures.



**Figure 4** Vostok ice core records for carbon dioxide concentration (blue) and temperature change (red)