SACRED BUBBLES IN ICE CORES

HOT TAKES

1 To prove climate change is man-made requires a demonstrated link between CO_2 concentrations and temperature changes.

2 However air bubbles in ice cores show that historically temperature changes have led CO_2.

3 The common assumption that ancient air bubbles trapped in ice provide precise and reliable evidence of man-made climate change is challenged by issues of measurement and also data from other proxies for historic CO_2 concentration.

Central to proving man-made climate change is establishing a cause-and-effect link between the levels of carbon dioxide (CO_2) in the atmosphere and Earth's temperature. Data from ice cores seemed to present the opportunity to prove that link. The concept is simple enough: by measuring the CO_2 concentration in air bubbles trapped in ancient ice, and by using stable isotopes as proxies to estimate temperatures at the time, it could be shown CO_2 and temperature moved together. As the early reports were published the world was captivated by the unnerving parallelism of temperature and CO_2 shifting together through the eons. It made great news[1]. The 'science was in' – or was it? In fact, temperature rises before carbon, as we shall see.

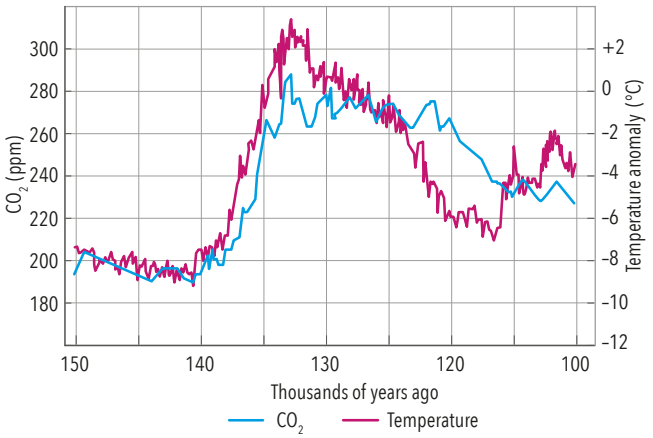
Ancient CO_2 Versus Temperature: Cause or Effect?

In the hunt for evidence, there has been nothing more compelling than ice-core bubbles. There is no other dataset like it. Nothing else shows CO_2 and temperature moving 'in lock step', moving up and down, in parallel. But, as with all things more complicated than they initially look, the devil is in the detail. The relationship was not as straight-forward as initially believed.

The first Intergovernmental Panel on Climate Change (IPCC) report in 1990 revealed scientists could not tell cause versus effect for the observed CO_2 – temperature relationship. The IPCC admitted it wasn't sure whether CO_2 led the temperature, or temperature led CO_2. The early ice-core measurements were not detailed enough to tell.

It would take another ten years after that first report before scientists realised it was temperature that rose first, not CO_2. Between 1999 and 2003, thanks to better time-resolved measurements, it was discovered (quietly) that temperature was driving CO_2 levels, and not the other way around. Cause and effect were back to front and thereafter were barely spoken of again. In the end, it was just high school chemistry; the oceans cover 71% of the Earth's surface and contain more than 50 times the amount of CO_2 as all the air in the sky. As the oceans warmed between the 'ice age' global glaciation cycles, they degassed and released CO_2 into the air. But this took time to happen, so there was a delay (see Figure 1).

Figure 1: Temperature and CO_2 in the Vostok ice core[2]



By 2003 it was obvious that temperature led CO_2 levels by hundreds of years. CO_2 followed temperatures up and, with a longer delay, back down again.

Whatever drove temperature, by default, indirectly drove CO_2. For example, peer-reviewed papers detailing the lag have been published in prestigious journals such as *Science*[3] and *Nature*[4].

That ought to have been a major blow to the theory of a man-made catastrophe, but paleoclimatologists (and many others) were implacably convinced that CO_2 controlled the climate. They argued that even though temperature initiated the rise in CO_2, after that, CO_2 amplified the warming. And perhaps it does to some small extent, but it's not large enough to directly measure. Teams of researchers have hunted for the link ever since, but with little success.

Not So Sacred Bubbles

The ice cores were sold as time capsules from the past, inferring that not only is the air trapped at the same instant the enclosing snow falls, but that its composition stays perfectly preserved despite the fact the air can be trapped for hundreds of thousands of years at extreme pressures beneath a few kilometres of constantly moving ice. Considering that CO_2 is a chemically 'reactive' trace gas, the claims made that the trapped CO_2 can faithfully reproduce the original amount of CO_2 in the atmosphere should be treated with some caution.

For a start, the air bubbles can take anything from 10 to 2,000 years to completely seal off. The snow eventually compacts into ice but it means the CO_2 in the trapped bubbles becomes a smoothed average. Any spikes or dips in CO_2 will be flattened out. This means it should not be possible for a scientist to use long-term ice-core graphs to claim CO_2 levels have never risen as fast as they have over the last century (and yet they did so). If it had risen so quickly in the past the ice core data would not reflect that, because of this smoothing effect. In addition, most of the measurement points in the Vostok core shown above are between 200 and 2,000 years apart.

Furthermore, there are many ways the bubbles of air could be gradually changed, even once sealed within the vaults of ice. When kilometres of ice press down from above, the pressures can become so immense that gas bubbles undergo a kind of solid state high-pressure interaction with the ice surrounding the air bubble – CO_2 in the trapped air can enter the surrounding ice and become trapped as a CO_2 'clathrate'[5]. The question is whether all of the CO_2 involved in this process is being released again when the air from the depressurised ice is recovered. If not, it could lead to a systematic underestimation of CO_2 in the ancient atmosphere.

It is also well known that, deep within an ice sheet, the extreme high pressure allows veins of liquid water to percolate, even at temperatures that would be well below freezing at the surface[6]. Intergranular percolation of this water promotes the growth and recrystallization of ice crystals. As this happens the water could also chemically interact with any trapped ancient air bubbles and alter the concentration of the CO_2 they contain.

Then there is the well known issue of the explosive release of the compressed air trapped in the bubbles as the ice cores are extracted, and the confining pressure is released. If the air in the bubbles escapes, the ancient CO_2 is lost.

There is also the issue of the cores becoming contaminated with modern air during collection, handling, storage and transportation.

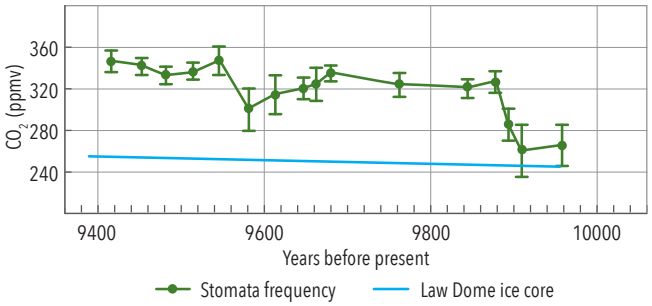
Plant Stomata as an Alternate Proxy for CO_2 in Ancient Air

Stomata are the pores that exist beneath the leaves of nearly every plant. Their job is to capture CO_2. They also make sensitive CO_2 meters. When CO_2 is scarce, plants produce more stomata in a race to catch more. Each species has its own stomata response curve. Scientists can use living plants to calibrate the way their fossil equivalents reacted.

Stomata records suggest natural CO_2 variation is common and much larger than recorded in ice cores over the same period, as shown in Figure 2. Stomata frequencies suggest CO_2 levels were often higher than ice cores, which were close to 250 parts per million at Law Dome 10,000 years ago.

In response some researchers have dismissed this disagreement as evidence the stomata results are less reliable than the ice core data, but it is unclear why this should be the case.

Figure 2: Stomatal frequency counts and ice-core measurements[7]



In summary, the common assumption that ice core data unequivocally support the hypothesis that rising CO_2 levels cause global warming is not borne out by the evidence, and the precision of the ice core CO_2 data is greatly overstated.

SEE ALSO

FACT SHEET #2: Climate Change in the Polar Regions

FACT SHEET #6: Monitoring Temperatures and Sea Ice with Satellites

Information in this fact sheet has been drawn from *Climate Change: The Facts 2020* (IPA 2020), Chapter 5, by Jo Nova. Fact Sheet series general editor: Dr Arthur Day

1. See for example: https://www.newscientist.com/article/mg12216694-400-the-end-of-the-ice-ages/
2. Source: Data from the CO_2 Information Analysis Center: http://cdiac.ornl.gov/ftp/trends/temp/vostok/vostok.1999.temp.dat; http://cdiac.ornl.gov/ftp/trends/co2/vostok.icecore.co2. Graph by Jo Nova 2008, from http://joannenova.com.au/global-warming-2/ice-core-graph.
3. Caillon et al. 2009, 'Timing of Atmospheric CO_2 and Antarctic Temperature Changes Across Termination III', Science, vol. 299, pp. 1728-1731.
4. Landais et al. 2013, 'Two-phase change in CO_2, Antarctic temperature and global climate during Termination II', *Nature Geoscience*, vol. 6, pp. 1062–1065.
5. In a 'clathrate', a molecule of one substance, such as CO_2, becomes completely enclosed within the crystal structure of another substance, such as ice.
6. Ice is unusual because it melts under pressure.
7. Source: Wagner et al. 1999, 'Century-Scale Shifts in Early Holocene Atmospheric CO_2 Concentration', *Science*, vol. 284, no. 5422, pp. 1971–1973.

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