Increasing temperature *precedes* increasing atmospheric CO_2 levels in palaeoclimate and modern climate records

Net zero is doomed to failure and will only empower Xi Jinping and Vlad Putin

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Both palaeoclimatic and modern-day climate data demonstrate that temperatures increased *prior* to atmospheric CO_2 levels increasing. I shall quickly deal with the palaeoclimatic data, and then demonstrate evidence from the modern-day climate record.

Multiple palaeoclimatic studies clearly demonstrate that increased temperature *preceded* increased atmospheric CO_2 levels. For example:

Fischer and colleagues (Science 1999) used the fact that air contained in bubbles in ice cores provide an archive for the reconstruction of the relation between greenhouse gas concentrations and palaeoclimate and suggested that the major increase in CO_2 concentration *tends to lag temperature increases*, reaching a maximum CO_2 concentration around 600 years after the peak in temperature. Similarly, Ahn et al. (J. of Geophysical Research 2004) state "We have measured the CO_2 concentration of air occluded during the last 40,000 years in the deep Siple Dome A … ice core, Antarctica. The general trend of CO_2 concentration from Siple Dome ice *follows the temperature* inferred from the isotopic composition of the ice and is mostly in agreement with other Antarctic ice core CO_2 records". They suggest an approximately 210-year lag of changes in CO_2 concentration *behind* changes in temperature. Similarly, Joos and Prentice (2004) state that:

"Detailed comparison of temperature proxies and CO_2 during the last glacial-interglacial transition, however, suggests that Antarctic temperature started to rise before atmospheric CO_2. This finding is consistent with the view that natural CO_2 variations constitute a feedback in the glacial-interglacial cycle rather than a primary cause (Shackleton 2000)."

Finally, Petit and colleagues (Nature, 1999) examined lags between atmospheric CO_2 concentrations and surface temperatures over the past 420,000 years by sampling ice cores drilled in Antarctica and demonstrated a 20,000-, 40,000- and 100,000-year periodicity in the climate data and demonstrated that declines in atmospheric CO_2 concentration *lagged behind* declines in surface temperature by several thousand years. These periodicities are the hallmark of well-known Milankovitch cycles. These cycles describe the effect of changes in the axial tilt (the angle of Earth's N-S axis), precession (the wobble of the N-S axis) and eccentricity (a measure of the degree to which Earth's orbit around the Sun is circular of elliptical) on Earth's climate. Changes in these three cycles have predictable effects on Earth's climate because of their impacts on the amount and distribution of energy received from the Sun at the Earth's surface (so-called orbital forcing: changes in Earth's orbit force changes in Earth's climate). Importantly, Pettit and colleagues concluded that changes in atmospheric CO_2 concentration amplify the **initial** effects of orbital forcings and changes in atmospheric CO_2 concentrations can follow, not cause, changes in temperature.

Unfortunately, these paleoclimatic studies **do not** explain modern-era climate change because the time-scale of Milankovitch cycles is far too long (tens of thousands of years). However, *they do* *demonstrate three important principles.* First, *changes in temperature can precede changes in CO_2 concentration.* Second, small changes in temperature can be *amplified* into larger changes in temperature by subsequent changes in atmospheric CO_2 concentration. Third, CO_2 concentrations and temperature are *linked in a feedback loop*, whereby changes in either variable (concentration or temperature) affect the other variable.

So, let's look at the modern era.

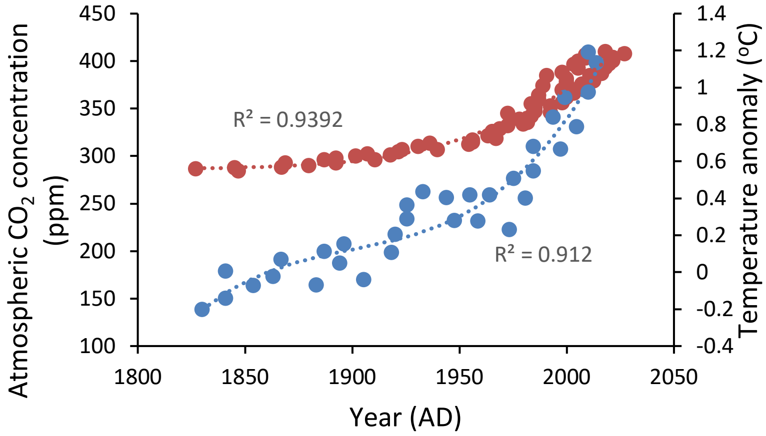

Figure 1: Changes in atmospheric concentration were very small from 1760 to 1900 (the first 65 y are omitted for clarity). In contrast, surface temperature anomalies (the difference between global mean surface temperature in any given year and the average surface temperature of a given reference period) were increasing from the early 19th century. Data from https://www.climate-lab-book.ac.uk/2020/2019-years/ and the CSIRO CO_2 data source. The temperature reference period is 1850 – 1900.

These data seem conclusive to me. Throughout the 19th century, atmospheric concentrations of CO_2 were pretty much static. But it is clear that temperature anomalies were increasing throughout the 19th century (and are continuing to do so).

What of more recent times?

A paper with the snappy title "Atmospheric temperature and CO_2: hen-or-egg causality?" (Kootsoyiannis and Kundzewicz, Sci, 2020) explicitly examined the possibility of increased surface temperatures causing increases in atmospheric CO_2 concentrations. These researchers used reliable instrumental temperature data and CO_2 concentration for the period 1980 – 2019 and concluded the following key points (Fig. 2):

- While it is certainly true that increasing atmospheric CO_2 concentrations can result in increased surface temperatures, the results demonstrate that the dominant direction of causality [during the period 1980 – 2019] was the reverse of the dominant paradigm, which claims that increased CO_2 concentrations cause increased temperature.

• Between 1980 – 2019, changes in atmospheric CO_2 concentrations followed changes in surface temperature. Figure 2 demonstrates this well (redrawn from Kootsoyiannis and Kundzewicz, 2020).

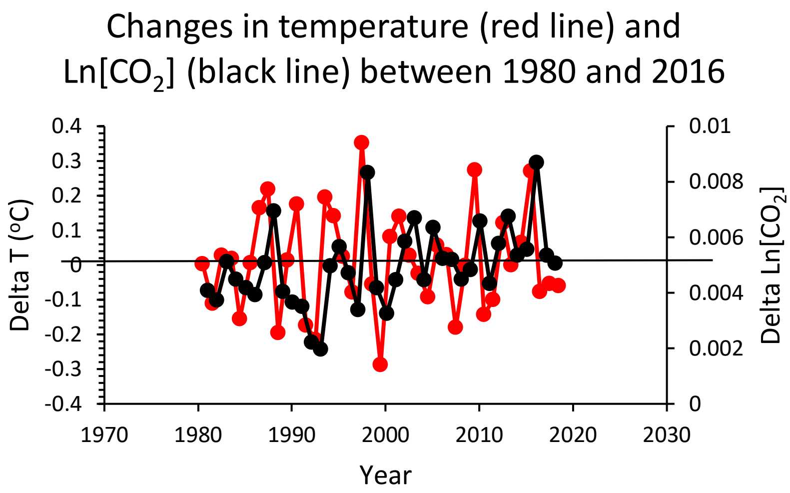

Figure 2: Changes in temperature (Delta T; red line) between 1980 and 2020 precede changes in atmospheric CO_2 concentrations (black line) by 6 to 18 months. Redrawn from Kootsoyiannis and Kundzewicz, Sci, 2020. Ln means natural log (or $\log_e$) rather than log to base 10.

Is there a plausible mechanism for the reverse paradigm?

A plausible mechanism for the hypothesis that increased surface temperature causes increased atmospheric CO_2 concentrations proposes that increased surface temperatures cause soil respiration to increase, resulting in a large loss of CO_2 from soil to the atmosphere. Importantly, soil respiration produces about 100 Gt C y^{-1}, compared to annual global anthropogenic emissions of about 10 Gt C y^{-1}. *Small increases in soil respiration are therefore able to significantly increase the rate of CO_2 accumulation in the atmosphere*.

Having a plausible mechanistic explanation for reversal of the presumed chicken-and-egg relationship lends considerable support to subversion of this dominant (exclusive?) paradigm. The judicious next question is: is there any evidence to support the hypothesis that increased surface temperature results in increased soil respiration? The answer is a resounding yes, as demonstrated in multiple laboratory, modelling and field studies. Three conclusions from three large meta-analyses of global data will suffice. The first is from Chen and colleagues (2013), who concluded the following:

"Annual global rates of soil respiration increased from 1970 to 2008 (the period of the study) and this increase was correlated directly with global temperature anomalies, suggesting that interannual variation in temperature was responsible for inter annual variations in predicted soil respiration."

Similarly, Yan and colleagues published a review of global data on soil carbon efflux (J. Soils and Sediments, 2019) and concluded the following:

“Across all terrestrial ecosystems, warming reduced soil organic carbon content by 4.96 %, stimulated soil microbial biomass C, soil respiration, and heterotrophic respiration by 6.30, 14.56, and 8.42 %, respectively.”

These results indicate that warming induces accelerated transition of soils from C sink to C source. Furthermore, they show the potential for global warming effects to exacerbate the positive feedback loop in terrestrial ecosystems.

Finally, Lei and colleagues published (Nature Communications, 2021) a modelling study that used data from 693 studies and stated:

“Our analysis directly addresses the long-held concern about the positive land C-climate feedback that could accelerate planetary warming in the 21st century, which is critical for ecological forecasting and climate policy-making. Given the huge impacts of warming on large soil C storage in cold regions, the stronger increase of soil respiration in high latitudes warrants more efforts…”

The positive land C-climate feedback loop they are referring to is that warmer temperatures lead to more soil respiration, which increases soil respiration, which increases atmospheric CO_2 concentrations, which leads to….etc.

Looks like the mechanistic interpretation of Koutsoyiannis and Kundzewicz might have legs…..

If we accept, for now, that increased temperatures can precede increased atmospheric CO_2 concentrations, we must ask, what might have kick-started the rise in temperature apparent in Figure 1? The answer could be an unfortunate sequence of megadroughts across large parts of the world. A megadrought is a prolonged period of drought extending across very large areas. For example, in 1780 – 1810 there was a long sequence of droughts and famines across much of India, causing more than 11 million deaths, and possibly the deindustrialization of India. Other examples include the Strange Parallels Drought (1756 – 1768) which affected most of India, Thailand, Laos, Vietnam, Cambodia and western Russia, while the East India drought (1790, 1792-1796) affected north and eastern India, Burma, Malaysia, Japan and much of China. Most of eastern China was affected by drought between 1770 and 1790. Europe did not escape untouched, with the megadrought of 1770 – 1840, with the driest period occurring 1770 – 1820. Coincident megadroughts were recorded in the south west of northern America and the southwest of southern America in the late 18th century.

The thing about megadroughts is that they cause surface temperatures to increase across vast areas of the globe, for many years. Interestingly, continental USA is in the grip of a pan-continental megadrought (2000 – present?). However, before we rush to ascribe climate change as the cause of this particular megadrought we should note that pan-continental droughts have occurred across the USA in 12 % of all years since the 10th century, and multi-decadal pan-continental droughts occurred across the USA in the 12th and 13th centuries, well before the industrial revolution.

If you find it hard to believe that a sequence of unpredictable events such as a series of megadroughts could alter global temperatures, consider that fact that the Little Ice Age (*circa* late 14^{th} to early 19^{th} century), which followed the Medieval Warm Period, is likely to have been triggered and sustained by a series of volcanic eruptions in 1257, 1268, 1275, 1284, 1452/3, 1580, 1600, 1660, 1783 and 1815 (the eruption of Mt. Tambora, the largest eruption in recorded human history). Miller and colleagues 2012, (Geophs. Res. Letters) conclude that vast quantities of ejecta, especially ash and SO_2 (which form particulates in the upper atmosphere) reflect sufficient incoming solar radiation to cool Earth for many years and this was a major contributor to the Little Ice Age (LIA). Numerical climate modelling has also suggested that volcanic activity was the largest driver of lower temperatures in the LIA (Owens et al 2017). Additional factors contributing to the initiation of the LIA include global depopulation arising from the Black Death and for many decades following (mid-14^{th} to mid-14^{th} centuries) and the formation of the Mongol Empire (13^{th} and 14^{th} centuries). Both events led to a massive depopulation of large parts of Europe and Asia. Consequently, large area of previously farmed landscapes returned to forest cover and this sucked large quantities of CO_2 from the atmosphere, resulting in large-scale cooling.

Why do we care about the cause-and-effect relationship?

If surface temperatures are the initial *cause* of increased atmospheric CO_2 concentrations, we are currently treating a symptom, not the cause. Just as Panadol treats a symptom of a viral or bacterial infection, namely a fever, without addressing the cause of the fever, it makes us feel better, but doesn't treat the infection. Western governments are mistakenly treating a symptom (increased CO_2 concentrations) through decarbonising our economies, they are not treating the cause of the symptom.

A short biography

I am Emeritus Professor at the University of Technology Sydney, Australia. I have researched plant ecophysiology and tree responses to increased atmospheric CO_2 concentration and increased temperature, experimentally and through modelling. I have published more than 250 research manuscripts, been cited more than 28,000 by researchers globally, and awarded two University Research Medals, for Research Excellence and Research Leadership. I have received many millions of dollars in research grants from the Australian Research Council, the Australian National Greenhouse Office, Environment Australia, the Commonwealth Scientific and Industrial Research Organisation, and Land and Water Australia. I have published two academic textbooks, and a popular science book 'Curiosity Unleashed: Questions and Answers About the Natural World' (Dec 2024) (available through Booktopia, Amazon and Kindle). This essay is an edited extract of chapter 11 of this book.