June 9, 2021

Earth & Space

Message in a frozen bubble: Antarctic ice reveals abrupt rises in atmospheric CO_2 in the ancient past

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doi.org/10.25250/thescbr.brk549

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This Break was edited by Akira Ohkubo, Associate Editor - TheScienceBreaker

Rapidly rising atmospheric carbon dioxide (CO_2) levels are accelerating climate change. Climate knock-on effects in response to the human-induced rise in CO_2 in the Earth's atmosphere have yet not played out and remain hard to predict. Detailed insights from an ice core record of past atmospheric CO_2 substantiate the urgency to limit global warming to 1.5°C as agreed upon in Paris in 2015.

Tiny bubbles visible in a freshly drilled ice core archive the atmospheric composition of the ancient past. Image credits: Dr. Christoph Nehrbass-Ahles

Today's atmospheric carbon dioxide (CO_2) levels are higher than ever during at least the last 800'000 years. More importantly, the atmospheric levels of this greenhouse gas continue rising at a speed that is unparalleled in our planet's recent geological history. Intensifying extreme weather events and rising sea levels due to melting polar ice sheets are just a couple of the direct consequences of this rise. But what happens beyond this? What other knock on effects (so-called climate feedbacks) are triggered by this warming trend that may further amplify (or slightly diminish) global warming? In a new study, we investigated carbon cycle feedbacks during warm periods in the ancient past that may become relevant again in the future, which would, in turn, help us better adapt to unfolding future climate conditions that remain hard to predict.

The atmosphere is only one of the Earth's carbon pools, and carbon is constantly flowing between different reservoirs including the ocean, the land and all living things. Future climate feedbacks associated with the Earth's carbon cycle are challenging to understand as they do not immediately play out. Although there is no natural blueprint for today's carbon cycle perturbation in our recent geological history, we can look at the climate system response during previous warm periods – when the CO_2 rose abruptly without human meddling and the global average temperature was comparable to today's – to estimate the risk for such climate feedbacks.

The Antarctic ice sheet is a unique archive of the past climate, as it traps small amounts of the atmosphere in tiny bubbles from the time when the ice was formed. The EPICA Dome C ice core provides unique insights into the last 800'000 years of atmospheric history, covering a total of eight preceding warm periods that are interrupted by longer-lasting ice ages.

Our initial goal was to improve the existing records for the time period between 300'000–450'000 years ago using a 240 meter long section from this ice core. This ancient time window includes two warm periods that serve as great analogues to today's situation in terms of greenhouse gas background levels. We measured the CO_2 concentration in great detail using the Centrifugal Ice Microtome, a machine we built at the University of Bern in Switzerland. In a nutshell, the measurement goes like this: Firstly, place the ice sample in a cold vacuum chamber and pump out the air, to avoid contamination with modern air molecules; Secondly, extract the old air from the ice sample by mechanically shaving the ice; Thirdly, shine light through the extracted air to measure CO_2 levels because CO_2 adsorbs certain "colour" of infrared light. One of the major innovations of this machine is that it allows us to measure more samples per day as compared to similar systems, ensuring that we even detect short-lived climatic signals hidden in a few centimeters of ice representing only a couple of centuries – very short time in such kind of analysis.

When the first results came in, we saw the pattern that we excepted based on previous research; that is, that the CO_2 variability looks a lot like the Antarctic temperature record derived from the same ice core. We knew that CO_2 and temperature resemble each other's patterns but, zooming in to our detailed data, we could see small, but abrupt rises in CO_2 that left no imprint in the Antarctic temperature record – which got us very excited.

Unexpectedly, we found eight instances when the CO_2 was rising abruptly for about 200 years, evidently caused by a burst of CO_2 to the atmosphere. Even more unexpected was that such jumps were also found during warm periods when continued freshwater from melting ice sheets likely disturbed the ocean circulation in the North Atlantic. Sounds familiar? It is important to note, however, that these events are small compared to the human-induced rise in atmospheric CO_2. For comparison, the extent of the CO_2 rise associated with the largest "jump" in our record is about the same as the CO_2 rise over the last seven years.

Our data are the first of their kind revealing short-term CO_2 variability during previous warm periods, providing yet another line of evidence that ongoing climate change progresses faster than ever in our planet's recent geological history. These data provide a new target for climate models to further narrow the predicted temperature ranges for the future. Most importantly, our study suggests that continued melting of the polar ice sheets may trigger changes in the ocean circulation. This may provoke an additional release of CO_2 to the atmosphere (a carbon cycle feedback) on top of human emissions, which would further accelerate global warming. For the discussion on the ambiguous 1.5°C target defined in the Paris Agreement in 2015, such additional CO_2 rises become more and more relevant.