Team studies Earth's recovery from prehistoric global warming

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(PhysOrg.com) -- The Earth may be able to recover from rising carbon dioxide emissions faster than previously thought, according to evidence from a prehistoric event analyzed by a Purdue University-led team.

When faced with high levels of atmospheric carbon dioxide and rising temperatures 56 million years ago, the Earth increased its ability to pull carbon from the air. This led to a recovery that was quicker than anticipated by many models of the carbon cycle - though still on the order of tens of thousands of years, said Gabriel Bowen, the associate professor of earth and atmospheric sciences who led the study.

"We found that more than half of the added carbon dioxide was pulled from the atmosphere within 30,000 to 40,000 years, which is one-third of the time span previously thought," said Bowen, who also is a member of the Purdue Climate Change Research Center. "We still don't know exactly where this carbon went, but the evidence suggests it was a much more dynamic response than traditional models represent."

Bowen worked with James Zachos, a professor of earth and planetary sciences at the University of California, Santa Cruz, to study the end of the Palaeocene-Eocene Thermal Maximum, an approximately 170,000-year-long period of global warming that has many features in common with the world's current situation, he said.

"During this prehistoric event billions of tons of carbon was released into the ocean, atmosphere and biosphere, causing warming of about 5 degrees Celsius," Bowen said. "This is a good analog for the carbon being released from fossil fuels today."

Scientists have known of this prehistoric event for 20 years, but how the system recovered and returned to normal atmospheric levels has remained a mystery.

Bowen and Zachos examined samples of marine and terrestrial sediments deposited throughout the event. The team measured the levels of two different types of carbon atoms, the isotopes carbon-12 and carbon-13. The ratio of these isotopes changes as carbon dioxide is drawn from or added to the atmosphere during the growth or decay of organic matter.

Plants prefer carbon-12 during photosynthesis, and when they accelerate their uptake of carbon dioxide it shifts the carbon isotope ratio in the atmosphere. This shift is then reflected in the carbon isotopes present in rock minerals formed by reactions involving atmospheric carbon dioxide, Bowen said.

"The rate of the carbon isotope change in rock minerals tells us how rapidly the carbon dioxide was pulled from the atmosphere," he said. "We can see the fluxes of carbon dioxide in to and out of the atmosphere. At the beginning of the event we see a shift indicating that a lot of organic-derived carbon dioxide had been added to the atmosphere, and at the end of the event we see a shift indicating that a lot of carbon dioxide was taken up as organic carbon and thus removed from the atmosphere."

A paper detailing the team's National Science Foundation-funded work was published in Nature Geoscience.

It had been thought that a slow and fairly constant recovery began soon after excess carbon entered the atmosphere and that the weathering of rocks, called silicate weathering, dictated the timing of the response.

Atmospheric carbon dioxide that reacts with silicon-based minerals in rocks is pulled from the air and captured in the end product of the reaction. This mechanism has a fairly direct correlation with the amount of carbon dioxide in the atmosphere and occurs relatively slowly, Bowen said.

The changes Bowen and Zachos found during the Palaeocene-Eocene Thermal Maximum went beyond the effects expected from silicate weathering, he said.

"It seems there was actually a long period of higher levels of atmospheric carbon dioxide followed by a short and rapid recovery to normal levels," he said. "During the recovery, the rate at which carbon was pulled from the atmosphere was an order of magnitude greater than the slow drawdown of carbon expected from silicate weathering alone."

A rapid growth of the biosphere, with a spread of forests, plants and carbon-rich soils to take in the excess carbon dioxide, could explain the quick recovery, Bowen said.

"Expansion of the biosphere is one plausible mechanism for the rapid recovery, but in order to take up this much carbon in forests and soils there must have first been a massive depletion of these carbon stocks," he said. "We don't currently know where all the carbon that caused this event came from, and our results suggest the troubling possibility that widespread decay or burning of large parts of the continental biosphere may have been involved."

Release from a different source, such as volcanoes or sea floor sediments, may have started the event, he said.

"The release of carbon from the biosphere may have occurred as a positive feedback to the warming," Bowen said. "The forests may have dried out, which can lead to die off and forest fires. If we take the Earth's future climate to a place where that feedback starts to happen we could see accelerated rates of climate change."

The team continues to work on new models of the carbon cycle and is also investigating changes in the water cycle during the Palaeocene-Eocene Thermal Maximum.

"We need to figure out where the carbon went all those years ago to know where it could go in the future," he said. "These findings show that the Earth's response is much more dynamic than we thought and highlight the importance of feedback loops in the carbon cycle."

More information: Rapid Carbon Sequestration at the Termination of the Palaeocene-Eocene Thermal Maximum, by Gabriel J. Bowen and James C. Zachos

Abstract
The Palaeocene-Eocene Thermal Maximum (PETM), an approximately 170,000-year-long period of global warming about 56 million years ago, has been attributed to the release of thousands of petagrams of reduced carbon into the ocean, atmosphere and biosphere. However, the fate of this excess carbon at the end of the event is poorly constrained: drawdown of atmospheric carbon dioxide has been attributed to an increase in the weathering of silicates or to increased rates of organic carbon burial. Here we develop constraints on the rate of carbon drawdown based on rates of carbon isotope change in well-dated marine and terrestrial sediments spanning the event. We find that the rate of recovery is an order of magnitude more rapid than that expected for carbon drawdown by silicate weathering alone. Unless existing estimates of carbon stocks and cycling during this time are widely inaccurate, our

results imply that more than 2,000 Pg of carbon were sequestered as organic carbon over the 30,000-40,000 years at the end of the PETM. We suggest that the accelerated sequestration of organic carbon could reflect the regrowth of carbon stocks in the biosphere or shallow lithosphere that were released at the onset of the event.

Provided by Purdue University

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