Studies of ancient climates suggest Earth is now on a fast track to global warming

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Human activities are releasing greenhouse gases more than 30 times faster than the rate of emissions that triggered a period of extreme global warming in the Earth's past, according to an expert on ancient climates.

"The emissions that caused this past episode of global warming probably lasted 10,000 years. By burning fossil fuels, we are likely to emit the same amount over the next three centuries," said James Zachos, professor of Earth sciences at the University of California, Santa Cruz.

Zachos presented his findings this week at the annual meeting of the American Association for the Advancement of Science (AAAS) in St. Louis. He is a leading expert on the episode of global warming known as the Paleocene-Eocene Thermal Maximum (PETM), when global temperatures shot up by 5 degrees Celsius (9 degrees Fahrenheit). This abrupt shift in the Earth's climate took place 55 million years ago at the end of the Paleocene epoch as the result of a massive release of carbon into the atmosphere in the form of two greenhouse gases: methane and carbon dioxide.

Previous estimates put the amount of released carbon at 2 trillion tons, but Zachos showed that more than twice that amount--about 4.5 trillion tons--entered the atmosphere over a period of 10,000 years (Science, June 10, 2005). If present trends continue, this is the same amount of carbon that industries and automobiles will emit during the next 300 years, Zachos said.

Once the carbon is released into the atmosphere, it takes a long time for natural mechanisms, such as ocean absorption and rock weathering, to remove excess carbon from the air and store it in the soil and marine sediments. Weathering of land rocks removes carbon dioxide permanently from the air, but is a slow process requiring tens of thousands of years. The ocean absorbs carbon dioxide much more rapidly, but only to a point. The gas first dissolves in the thin surface layer of the ocean, but this surface layer quickly becomes saturated and its ability to absorb more carbon dioxide declines.

Only mixing with the deeper layers can help restore the ability of the surface water to absorb additional carbon dioxide from the atmosphere. But the natural processes that mix and circulate water between the ocean surface and deeper ocean layers work very slowly. A complete "mixing cycle" takes about 500 to 1,000 years, Zachos said.

The greenhouse emissions that triggered the PETM initially exceeded the ocean's absorption capacity, allowing carbon to accumulate in the atmosphere. Unfortunately, humans appear to be adding carbon dioxide to the air at a much faster rate: about the same amount of carbon (4.5 trillion tons), but within a few centuries instead of 10,000 years. What was emitted 55 million years ago over a period of about 20 ocean mixing cycles is now being emitted over a fraction of a cycle.

"The rate at which the ocean is absorbing carbon will soon decrease," Zachos said.

Compounding this concern is the possibility that higher temperatures could retard ocean mixing, further reducing the ocean's capacity to absorb carbon dioxide. This could have the kind of "positive feedback" effect that climate researchers worry about: reduced absorption, leaving more carbon dioxide in the air, causing more warming.

Higher ocean temperatures could also slowly release massive quantities of methane that now lie frozen in marine deposits. A greenhouse gas 20 times more potent than carbon dioxide, methane in the atmosphere would accelerate global warming even further.

Such positive feedback or "threshold" effects probably drove global warming during the PETM and a few other ancient climate extremes, Zachos said, and they could happen again. It is possible that we already are in the early stages of a similar climate shift, he said.

"Records of past climate change show that change starts slowly and then accelerates," he said. "The system crosses some kind of threshold."

Clues to what happened during the PETM lie buried deep inside the sediment at the bottom of the sea, which Zachos and his colleagues have probed during several cruises of the Ocean Drilling Program (ODP). Composed mainly of clay and the carbonate shells of microplankton, this sediment accumulates slowly, but steadily--up to 2 centimeters every millennium--and faithfully records changes in ocean chemistry. The layer of sediment deposited during the PETM, now buried hundreds of meters below the seafloor, tells a clear and compelling story of sudden change and slow recovery, he said.

During the PETM, unknown factors released vast quantities of methane that had been lying frozen in sediment deposits on the ocean floor. After release, most of the methane reacted with dissolved oxygen to form carbon dioxide, which made the seawater more acidic. Acidic seawater corrodes the carbonate shells of microplankton, dissolving them before they can reach the ocean floor and reducing the carbonate content of marine sediment.

Zachos led an international team of scientists that analyzed sediment cores recovered from several locations during an ODP cruise in the southeastern Atlantic. Collected at depths ranging from 2.5 to 4.8 kilometers (1.6 to 3.0 miles), each sediment core bore a telltale PETM imprint: a 10- to 30-centimeter layer of dark red carbonate-free clay sandwiched between bright white carbonate-rich layers.

By relating the thickness of the clay layer to the rate of accumulation of marine sediment, Zachos estimated that it took 100,000 years after the PETM for carbon dioxide levels in the air and water to return to normal. This finding is consistent with what geochemists have predicted using models of how the global carbon cycle will respond to carbon dioxide emissions from the burning of fossil fuels.

"We set out to test the hypotheses put forward by a small group of geochemists who model the global carbon cycle, and our findings support their predictions," Zachos said. "It will take tens of thousands of years before atmospheric carbon dioxide comes down to preindustrial levels. Even after humans stop burning fossil fuels, the effects will be long lasting."

Source: University of California, Santa Cruz

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