Earth is entering a no-analogue state - and it's a bit scary

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An ice bridge cracks from the wall of the Perito Moreno Glacier located at Los Glaciares National Park. Photo / Getty

If you dig deep enough into the Earth's climate change archives, you hear about the Palaeocene-Eocene Thermal Maximum, or PETM. And then you get scared.

This is a time period, about 56 million years ago, when something mysterious happened - there are many ideas as to what - that suddenly caused concentrations of carbon dioxide in the atmosphere to spike, far higher than they are right now. The planet proceeded to warm rapidly, at least in geologic terms, and major die-offs of some marine organisms followed due to strong acidification of the oceans.

The cause of the PETM has been widely debated. Some think it was an explosion of carbon from thawing Arctic permafrost. Some think there was a huge release of subsea methane that somehow made its way to the atmosphere - and that the series of events might have been kickstarted by major volcanic eruptions.

In any case, the result was a hothouse world from pole to pole, some 5 degrees Celsius warmer overall.

But now, new research suggests, even the drama of the PETM falls short of our current period, in at least one key respect: We're putting carbon into the atmosphere at an even faster rate than happened back then.

Such is the result of a new study in Nature Geoscience, led by Richard Zeebe of the University of Hawaii at Manoa, and colleagues from the University of Bristol in the UK and the University of California-Riverside.

"If you look over the entire Cenozoic, the last 66 million years, the only event that we know of at the moment, that has a massive carbon release, and happens over a relatively short period of time, is the PETM," says Zeebe. "We actually have to go back to relatively old periods, because in the more recent past, we don't see anything comparable to what humans are currently doing."

That's why this time period is so crucial to study - as a possible window on our own.

There's no doubt that a lot of carbon - about as much as contained the fossil fuel reserves that humans have either already burned, or could still burn, combined - made its way into the atmosphere during the PETM. The result was a major warming event that lasted over 100,000 years. But precisely how rapidly the emissions occurred is another matter.

"If anthropogenic emissions rates have no analogue in Earth's recent history, then unforeseeable future responses of the climate system are possible," the authors write.

To examine what happened in the PETM, the researchers used a deep ocean core of sediment from off the coast of New Jersey. The goal was to determine the ratios between different isotopes, or slightly different elemental forms, of carbon and oxygen, in the sediments during the PETM.

The relationship between the two lets researchers determine how atmospheric carbon dioxide levels, as reflected in the ratio of carbon 12 to carbon 13, in turn influenced temperatures (which can be inferred based on oxygen isotopes in the ocean).

"In terms of these two systems, the first shows us when the carbon went into the system, and the second tells us when the climate responded," says Zeebe.

It turns out that there is a lag time between massive pulses of carbon in the atmosphere and subsequent warming, because the oceans have a large thermal inertia. Therefore, a large lag would indicate a greater carbon release, whereas the lack of one actually means that carbon dioxide came out more slowly.

The geologic evidence from the new core did not show a lag, the new study reports. That means, the authors estimate, that while a gigantic volume of carbon entered the atmosphere during the PETM - between 2,000 and 4,500 billion tons - it played out over some 4,000 years. So only about 1 billion tons of carbon were emitted per year. In contrast, humans are now emitting about 10 billion tons annually - changing the planet much more rapidly.

"The anthropogenic release outpaces carbon release during the most extreme global warming event of the past 66 million years, by at least an order of magnitude," writes Peter Stassen, an Earth and environmental scientist at KU Leuven, in Belgium, in an accompanying commentary on the new study.

The analogy between the PETM and the present, then, is less than perfect - and our own era may be worse in key ways. "The two main conclusions is that ocean acidification will be more severe, ecosystems may be hit harder because of the rate" of carbon release, says Zeebe.

And not only have we only begun to see the changes that will result from current warming, but there may be other changes that lack any ancient parallel, because of the current rate of change.

"Given that the current rate of carbon release is unprecedented throughout the Cenozoic, we have effectively entered an era of a no-analogue state, which represents a fundamental challenge to constraining future climate projections," the study concludes.

- Washington Post

Rate of carbon emissions put in context

By Jonathan Amos BBC Science Correspondent

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Image copyright JAMES ZACHOS
Image caption Deep-sea sediments from 55.5 million years ago. The red clay band marks the onset of the PETM
We are now putting carbon into the atmosphere at a rate unprecedented since at least the age of the dinosaurs, scientists say.

The researchers have examined ocean sediments laid down during the so-called Palaeocene-Eocene Thermal Maximum - a dramatic warming event some 56 million years ago.

They find the amount of CO_2 going into the air at its onset was four billion tonnes a year at most.

Today's figure is 10 times as big.

The work is published in the journal Nature Geoscience. http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2681.html

The PETM has been extensively studied by scientists because it is regarded as a possible "analogue" for what is happening on Earth now.

But the team argues that the scale of human-produced carbon emissions means that the lessons we could learn from the ancient event may actually have limited relevance.

"We have effectively entered an era of a no-analogue state, which represents a fundamental challenge to constraining future climate projections," they write in their paper.

Carbon pulse

The PETM was an extraordinary occurrence in Earth history.

Previous research has shown that ocean surface temperatures rose by about five degrees in a relatively short timescale, in the geological sense.

This phase of global warming drove a rapid turnover in species, both in the sea and on land.

CO_2 concentration in the atmosphere very probably went above 1,000 parts per million by volume, compared with the 400ppm it stands at today.

The big pulse in emissions has been attributed to a range of factors, including a comet impact and prodigious volcanism. Some scientists suspect buried methane stores on the ocean floor were also released, amplifying the warming.

In their paper, Richard Zeebe and colleagues do not concern themselves with the cause; what they wanted to pin down was simply the rate of emissions.

Catch-up

The team achieved this by studying the remains of tiny marine organisms from the PETM known as Foraminifera.

The different types, or isotopes, of carbon and oxygen atoms in these fossils can be used to reconstruct likely CO_2 levels and temperature 56 million years ago.

Analysis of this chemistry, together with some modelling work, suggests that temperature during the PETM rose in lock-step with carbon emissions.

Contrast this with the modern era where carbon emissions are rising so fast the "equilibrium temperature" lags behind.

Zeebe and colleagues calculate that it took at least 4,000 years for the PETM warming to take hold, with carbon going into the atmosphere at a rate of between 0.6 to 1.1 billion tonnes of carbon per annum.

At present, human emissions of CO_2 are approaching 40 billion tonnes a year.

Time to cope

"If you go back to the [impactor] that killed off the dinosaurs (66 million years ago) - that was obviously an incredibly quick climate change," observed co-author Andy Ridgwell from Bristol University, UK.

"It wasn't driven by carbon emissions per se, but it was still an incredibly quick climate change. And so there has been a lot of searching around for what was the next most rapid event, and people have latched on to the PETM because it has all the characteristics of current warming and anthropogenic emissions - except it turns out the emissions in the PETM were actually an order of magnitude slower than they are today," he told BBC News.

Just how fast the planet might warm over the next two centuries is a topic of live debate because this likely be a big factor in how well species are able to adapt to changing conditions.

"The rate of change is as important as the magnitude of an event for determining particularly terrestrial ecosystem disruptions," Prof Ridgwell said.

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