From Greenhouse to Icehouse

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The findings of this research indicate that even as the poles started to cool during the late Eocene, the sea surface temperatures in the tropical regions remained fairly stable. Credit: NASA

A new study that reconstructed ocean temperatures from millions of years ago could provide new insight into how the Earth responds to climate change.

It is often said that the past is the key to the future. For climate scientists, understanding how the Earth's climate changed and evolved millions of years ago could help predict future climate change.

In a study published in the journal *Nature*, scientists reconstructed ocean temperatures during a time when the Earth transitioned from a greenhouse world to an icehouse world.

"In the early Eocene, between 53 and 49 million years ago, the Earth experienced the warmest climates of the past 100 million years," says lead author Peter Bijl of Utrecht University. "After this super-greenhouse, global climates started a gradual cooling trend. This cooling persisted in the late Eocene."

The scientists found that during that time, as sea surface temperatures (SSTs) in the higher latitudes cooled, temperatures in the mid-latitudes or the tropical regions stayed fairly stable. Theoretically, the authors say, the tropics should have cooled as well. This finding brings into question the role that a decrease in concentrations of atmospheric greenhouse gases, such as carbon dioxide, had on cooling the poles.

"There must be a mechanism that we don't know up to now that is able to increase the temperatures at high latitudes without increasing the CO2 forcings at low latitudes," says Bijl.

Earth on the Rocks

Towards the end of the Eocene, the Earth had started to cool, and the first Antarctic ice sheets started to form during the early Oligocene, approximately 33 million years ago. Scientists, however, know very little about this climate transition. Their knowledge of what occurred in the lower latitudes is especially lacking because there are fewer ways to reconstruct past temperatures in that part of the globe.

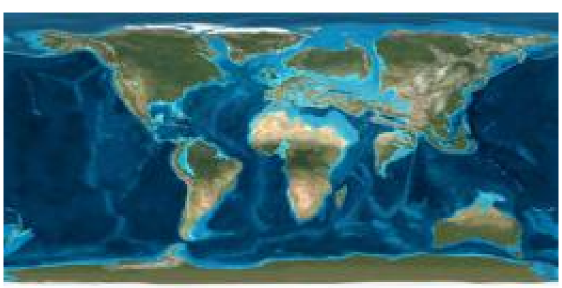
Speaking about the cooling that the world experienced during the end of the Eocene, Bijl says, "We don't know much about why it cooled down that much, how or how fast."

The warm conditions that existed throughout much of the Eocene allowed land mammals to flourish, and the first primates evolved during this time. By the end of the Eocene, most modern-day mammals had evolved. The transition from the greenhouse Eocene to the ice-house Oligocene represents one of the most dramatic climate change events in recent geologic history.

“We know the climate has changed much more radically in the past,” says Gavin Schmidt, climate modeler at NASA’s Goddard Institute for Space Studies. “Where we're expecting climate to go in the future is outside the range for what we have data for.”

That is where studies like Bijl’s could play a role. Studying climate change during the transition from a greenhouse world to an icehouse world could help climate scientists grappling with present-day climate change understand how the Earth responds to major climate events.

“To test our theories, to understand the impact of change to the ecosystem, it’s vitally important that we maintain research into past climates, precisely because we don’t know where we’re going in the future,” says Schmidt.



Position of the continents during the Eocene (55.8 to 33.9 Ma). Credit: Bristol University

Taking Temperature over Time

Studying such ancient events is by no means easy. Scientists need access to temperature data, and that presents one of the main problems of studying climate change that occurred millions of years ago. Thermometers were invented around 400 years ago, and most instrumental records of temperature only date back to the nineteenth century. To study the Earth's climate farther back in time, scientists use proxy data, or data collected from natural recorders of climate change. Some examples of proxy data include tree rings, ice cores, fossil pollen and ocean sediment, among others.

Bijl and the research team used two organic proxies to reconstruct SSTs. The TEX86 proxy, developed by the NIOZ Royal Dutch Institute for Sea Research, is an index based on lipids produced by microbes that dwell near the sea surface. This lipid index was devised to determine SST from marine sediments. The Uk,37 proxy is another paleothermometer based on a highly resistant organic compound produced by marine organisms such as algae. The researchers obtained ocean sediment samples from the East Tasman Plateau in the Southwest Pacific. The sediment cores were obtained by the Integrated Ocean Drilling Program in 2000.

The data obtained by Bijl's team show that SSTs in the southwest Pacific rose to about 35 degrees Celsius during the early Eocene and gradually dropped to approximately 21 degrees Celsius towards the late Eocene, while SSTs in the tropical regions stayed relatively constant throughout. The question is why the temperatures in the tropics changed very little during the Eocene even as the rest of the world was undergoing a more drastic cooling.

The common belief is that high atmospheric greenhouse gases such as carbon dioxide brought about the warm temperatures during the early Eocene. Similarly, the global cooling that took place during the mid to late Eocene, scientists believe, was a result of the decline in carbon dioxide levels in the atmosphere. But if lower levels of CO2 didn't lead to cooler temperatures in the tropics, then some additional positive feedbacks must have increased the cooling effect in the poles. Scientists are looking to climate models for a solution.

Mix and Match Models

There's just one problem with using climate models to figure out what happened in the past: the models don't always reflect reality. In fact, Bilj says that climate models for polar ocean temperatures during the Eocene don't match their data from the southern oceans.

"What they get out of their models is a much higher SST gradient than we find in our data," he explains. "That means there are some mechanisms that are missing in the models."

Given this mismatch, Bijl says it's frightening that scientists rely so heavily on computer models to predict future climate patterns. He says that is why it's crucial to make sure the models are as accurate as they can be, and he hopes that the collaboration that's currently taking place between climate modelers and other scientists will help to fill the gaps in existing models.

Schmidt notes that in such collaborations, modelers work closely with scientists in many different fields to determine what might be missing and to identify processes that were previously neglected.

"The kinds of models we're using today are more sophisticated than 10 years ago," Schmidt says. "We're hopeful they might provide answers that were elusive in the past. But they haven't provided (those answers) yet."

Whatever happens to the climate in the future, based on the past history of our planet, some change is inevitable. During its approximately

4.5-billion-year history, the Earth has undergone numerous natural shifts in climate change, and Bijl says the current climate crisis is another one of those events. Though he admits present-day climate change is occurring at a much faster pace, Bijl says it is not a new experience for the Earth.

"Whatever scary things everyone says about climate change, the world has experienced much worse," he says. "Many life forms may go extinct, but the world will keep spinning, and new life will evolve."

Source: Astrobio.net, by Anuradha K. Herath

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