New climate record challenges ideas about recent glaciations

Predicting how a changing climate and rising sea levels might impact humans in the future requires an understanding of how Earth has changed in the past. So scientists are continually seeking more and better data to help illuminate earlier conditions.

Using a novel method for converting oxygen isotopic data preserved in Mediterranean Sea sediments to past sea levels, a team of researchers has now produced one of the longest continuous logs of Earth's climate. The record dates from the present back to the Early Pliocene 5.3 million years ago. The technique separates contributions from ocean temperatures and glacial ice that are usually entangled in such data — a conundrum in previous climate reconstructions. It also offers an independent check of previous efforts, along with new insights about Pleistocene glaciations, the scientists say.

Much of what we know about climate in the last several million years comes from oxygen isotopes in sediment cores pulled from the deep ocean. When single-celled, deep-dwelling critters called benthic foraminifera (forams) die, their calcium carbonate shells preserve a record of the ratio of different oxygen isotopes in deep ocean water at that time. Because light oxygen-16 — the most abundant form — evaporates preferentially compared to heavy oxygen-18, the lighter isotope becomes concentrated in precipitation-fed glacial ice sheets and depleted in seawater at times when Earth's atmosphere and oceans are cold enough to maintain ice sheets. At the same time, oxygen-18 remaining in the seawater is progressively enriched as the climate cools and ice sheets grow.

Analyzing the oxygen isotopic ratio in foram shells from layer upon layer of old ocean sediments gives scientists a global overview of changes over time in deep-ocean temperatures and glacial ice volume — the latter reflected in global sea levels. However, although ocean temperatures and ice volume typically follow similar long-term trends, they don't necessarily change in lock-step. And each contributes separately to the isotopic ratios ultimately preserved in forams, making it difficult to resolve exactly how these individual factors changed through time.

That's where the new record, published in a study in Nature, comes in. Rather than analyzing benthic forams, researchers considered isotopic data dating back 5.3 million years that had been gathered previously from sea-surface-dwelling, or planktonic, foraminifera that were preserved in Mediterranean sediments. The planktonic forams record the oxygen isotopic ratio in the Mediterranean's surface waters, a ratio that is sensitive to the exchange of water between the sea and the Atlantic Ocean.

This exchange is constrained by the Strait of Gibraltar, a rocky underwater sill that acts as an aperture, opening or closing and allowing more or less water to flow back and forth, respectively, as sea levels have gone up or down over geologic time.

"Because [the Mediterranean] is a highly evaporative basin," says Eelco Rohling, a marine geologist at the Australian National University in Canberra and lead author of the new study, "the salinities and the oxygen isotope ratio of the water [in the basin] go up as a function of sea level in the Strait of Gibraltar." The higher the sea level, in other words, the more ocean water can flood into the sea and replenish oxygen-16 lost to evaporation.

Measuring the ratios in the planktonic forams thus "gives us a direct measure of the sea level in the Strait of Gibraltar," Rohling says. He and his coworkers used this information in a hydraulic control model describing flow through the strait and isotopic changes in the Mediterranean over the past 5.3 million years to derive estimates of global sea level and, hence, ice volume on the planet. By subtracting those values from previous deep-sea oxygen isotope records, the team then separated out the contribution of ocean temperatures in records.

Fossilized foraminifera from sediments at sites such as this one at Punta Maiata, Sicily, contributed to a new sea-level and deep-ocean temperature record dating back more than 5 million years.
Credit: Eelco Rohling

"We're de-convolving the signal that is in the deep-sea isotope records," Rohling says. "Because we can separate it now, we can start looking at the relative timing of these two controlling processes."

Based on established deep-sea oxygen isotope records, for example, a conventional assumption has been that the first substantial growth of continental ice sheets and drop in global sea levels happened about 2.5 million years ago during the Quaternary. But the new record challenges that notion, suggesting that there was first a rapid cooling about 2.7 million years ago and that the first major glaciation actually followed that cooling by about half a million years. Rohling says the observation makes sense, noting that "the primary expectation should not be that [cooling and glaciation] work perfectly in synchrony," but instead that they broadly follow the same trend "in their own rhythm."

The conclusion "receives a lot of support from other studies of regional paleoclimatic trends" during the period, suggested Ralph Schneider, a paleoclimatologist at the University of Kiel in Germany, in a commentary on the study also published in Nature. In Schneider's estimation, the new record bears a "striking similarity" to previous records covering the last 1.5 million years, he wrote, which "strongly suggests that the researchers' conclusions for older periods are correct."

Rohling's team also suggested that the peak of the most recent large-scale glaciation — the so-called Last Glacial Maximum, which ended about 20,000 years ago — was more extensive than those that preceded it. Although obscured in earlier isotopic records, it's an observation that appears when ocean-temperature and ice-volume contributions are separated, the researchers noted. "This contradicts continental evidence for the extension of ice sheets over North America and Eurasia," Schneider wrote, "but, if correct, will serve as a crucial benchmark for improved modeling of glacial ice-sheet volumes and heights."

Not everyone is convinced by the new approach, however. "There are a couple of things that don't make empirical sense," says Ken Miller, a paleoclimatologist at Rutgers University who has led past attempts to reconstruct sea-level and climate records.

Miller says the new record agrees well with previous reconstructions back to about 1 million years ago, but he is "skeptical that this is a correct sea-level record for much of the interval between 2 million and 5 million years ago" because it suggests "much higher" sea levels than previously thought. For example, he says, "I think it's quite implausible that in the Early Pliocene [roughly 5 million years ago], sea level was 50 meters above present. And that's what their record says."

How well the various reconstructions agree may be a matter of perspective, as Rohling notes that his team's sea-level projections for the Mid-Pliocene, about 3 million years ago, are in line with the consensus best estimate of between 12 and 32 meters above present. He agrees that the farther back in time their record goes, the more it appears to stray from other reconstructions. It's possible, his team suggested in the study, that the bathymetry of the Strait of Gibraltar has shifted gradually under the influence of tectonic forces not factored into their model, which could systematically shift their sea-level estimates and account for discrepancies. But, equally possible, Rohling says, is that earlier reconstructions may contain unrecognized systematic errors as well. Sorting out potential sources of error is ground for future work, he says.

The new method "has several limitations that require further study and improvement," Schneider wrote, but, he noted, it should still "provide much-needed information that should help to predict future rates of sea-level rise."

Timothy Oleson

Twinkle, twinkle new little star

What's red, sparkly and far from home? Not Dorothy's shoes, but a Thorne-Zytkow object (TZO), a type of hybrid star theorized since 1975 to exist but not observed until now.

TZOs are hybrid stars thought to form as a red supergiant star swallows a neutron star. Although the newly seen TZO glows the color of Betelgeuse, a red supergiant, its interior composition is different. Using a 6.5-meter Magellan Clay telescope in Chile, the researchers observed the TZO in the Small Magellanic Cloud, a nearby galaxy about 210,000 light-years away. The researchers noted in the light spectra from the galaxy's red supergiants that one had a distinct chemical signature: Although the TZO's temperature is typical of a red supergiant, it has excess rubidium, lithium and molybdenum — not characteristic of these big stars.

The TZO's chemistry doesn't perfectly match the theoretical model, however, the researchers pointed out in their study published in the Monthly Notices of the Royal Astronomical Society Letters. "The theoretical predictions are quite old, and there have been a lot of improvements in the theory since then," said Philip Massey, a co-author and an astronomer at the Lowell Observatory in Flagstaff, Ariz., in a statement. "Hopefully our discovery will spur additional work on the theoretical side now."

Allison Mills

A new hybrid star, called a Thorne-Zytkow object, was observed in the Small Magellanic Cloud, one of the closest and brightest galaxies near the Milky Way.
Credit: NASA/CXC/JPL-Caltech/STScI