CLIMATE

Chilly Ice-Age Tropics Could Signal Climate Sensitivity

During the past 3 million years, most of the world has alternated between the deep freeze of ice ages and the momentary balminess of warm interglacial periods. But the tropics seemed different. Some sort of thermostat apparently buffered the climate swings so evident to the north and the south and kept the tropics, well, tropical. Or so paleoceanographers have thought, ever since a classic 1976 study called CLIMAP indicated that the tropical ocean cooled less than 2°C during the worst of the last ice age while the rest of the world experienced a 5°C chill. Although more recent studies have hinted that the tropics did share in the glacial cooling (*Science*, 14 January 1994, p. 173), CLIMAP has remained the touchstone for researchers seeking to understand how Earth's climate system worked during the ice ages.

At the December meeting of the American Geophysical Union, however, CLIMAP came under renewed attack, and this assault seems to be hitting home. Even CLIMAP researchers say the new record, which Martin Stute of Columbia University's Lamont-Doherty Earth Observatory and his colleagues extracted from ice-age ground water trapped beneath northeast Brazil, is the strongest evidence yet that the tropics cooled along with the rest of the world during the ice age. CLIMAP "is on the defensive," concedes Theodore Moore of the University of Michigan, a researcher on the original project.

Some other researchers go further. "I don't believe the CLIMAP numbers in the tropics," says Scott Lehman of the Woods Hole Oceanographic Institution, adding that it's time to start thinking about what cool glacial tropics mean for the workings of Earth's climate system. He and his colleagues are now considering mechanisms, probably involving ocean currents, that might have tied the tropics more tightly to the rest of global climate during the ice age—and could shape the course of future greenhouse warming.

The original evidence that the tropics stayed warm during the ice age came from microscopic plankton that lived near the sea surface. CLIMAP researchers picked the microfossil remains of the plankton from seafloor sediments, then did a census of warmth- and cold-loving species. The species characteristic of warm tropical oceans were abundant even at the height of the last glaciation, and so the researchers reasoned that the tropical sea surface must have remained warm. Other paleothermometers—records of changing pollen species, coral chemistry, and snow-line altitudes on mountains—have since pointed to colder tropics, but CLIMAP researchers have argued that they didn't reflect tropical surface temperatures or were somehow flawed.

Climate researchers agree that there's less room for error in the Brazilian temperatures.

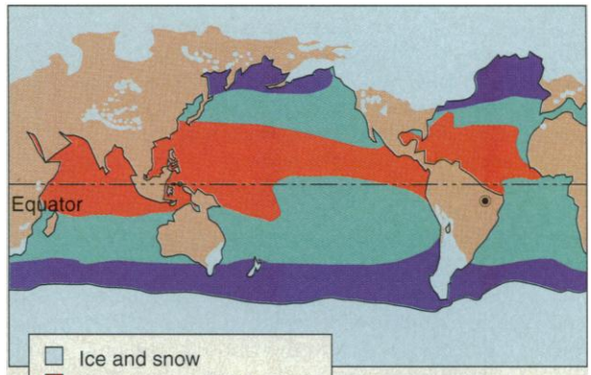

ILLUSTRATION: C. FABER SMITH
SOURCE: CLIMAP

Not so hot. The CLIMAP data shown here suggested that during the last ice age the tropical oceans were less than 2°C cooler than today, but a new measurement in Brazil points to cooler tropics.

That record is based on the amount of noble gas dissolved in water that seeped into the ground just 7° south of the equator during the ice age. There's no biology to complicate the interpretation, and the physics is pretty straightforward: The colder the water, the more neon, argon, krypton, and xenon dissolve in it before it sinks out of contact with the atmosphere. The concentrations Stute and his colleagues measured imply that water entering the aquifer 18,000 years ago or more was 5°C cooler than in recent millennia.

Some paleoceanographers argue that the contradiction between one tropical groundwater record and the CLIMAP temperatures doesn't mean CLIMAP is wrong. "There's a lot of reasons [land temperatures] might be more variable" than ocean temperatures, says Warren Prell of Brown University, another ex-CLIMAP researcher. For example, land temperatures, especially at high altitudes in the mountains, might drop more than ocean surface temperatures during an ice age. But Anthony Broccoli of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, has simulated ice-age climate in a computer model, and he says he "would be surprised by temperature changes over land that are much different than those over the ocean."

In that case, something could have led CLIMAP astray. Lehman and others wonder whether CLIMAP's plankton might be lying; maybe they aren't all that fond of warmth after all. "Perhaps they are really adapted to cooler conditions," says Lehman, "but they suffer through interglacial warmth because there's no reason for them to leave."

If so, and the ice-age tropics really were chilly, the picture of how the ocean circulated in the ice age may also need revision. Researchers have evidence that a key mechanism for carrying heat from the tropics to the far northern latitudes—the so-called "conveyor belt" of currents looping through the shallow and deep sea—wasn't working well in glacial times. The slowing of the conveyor seemed to explain the warm tropics revealed by CLIMAP. But if the tropics cooled despite the failure of the conveyor belt, some other heat drain could have been operating, says Lehman.

To see how big a heat drain would have been needed to cool the tropics a full 5°C, Robert Webb of the National Oceanic and Atmospheric Administration in Boulder, Colorado, David Rind of the Goddard Institute for Space Studies in New York City, and Lehman ran computer climate simulations of the glacial world with varying amounts of poleward heat transport in the ocean. The model's tropics cooled by 6°C, they reported at the meeting, with about two-thirds of present ocean heat transport. But if the deep-running conveyor wasn't carrying the heat, what was?

Lehman is considering the possibility that currents confined to a shallow layer of the ocean could have done the job. Chemical signs in sediments hint that shallow waters of the North Atlantic were circulating rapidly in glacial times, even though deeper waters were sluggish. And in a simple geochemical model of glacial oceans, Lehman found that a shallow circulation operating at the speed needed to cool the tropical oceans by 5°C also circulates enough water through shallow depths to account for the geochemical signs.

The evidence of climate sensitivity in the tropics raises new questions about their fate over the next century, when global climate may warm because of rising carbon dioxide levels. Paleoclimatologist Thomas Crowley of Texas A&M University has noted that CLIMAP implied that the tropics—some 40% of Earth's surface—might be spared the brunt of any warming. But if paleothermometers like Brazilian ground waters are accurate, he says, the most alarming projections of greenhouse warming may be the right ones.

–Richard A. Kerr