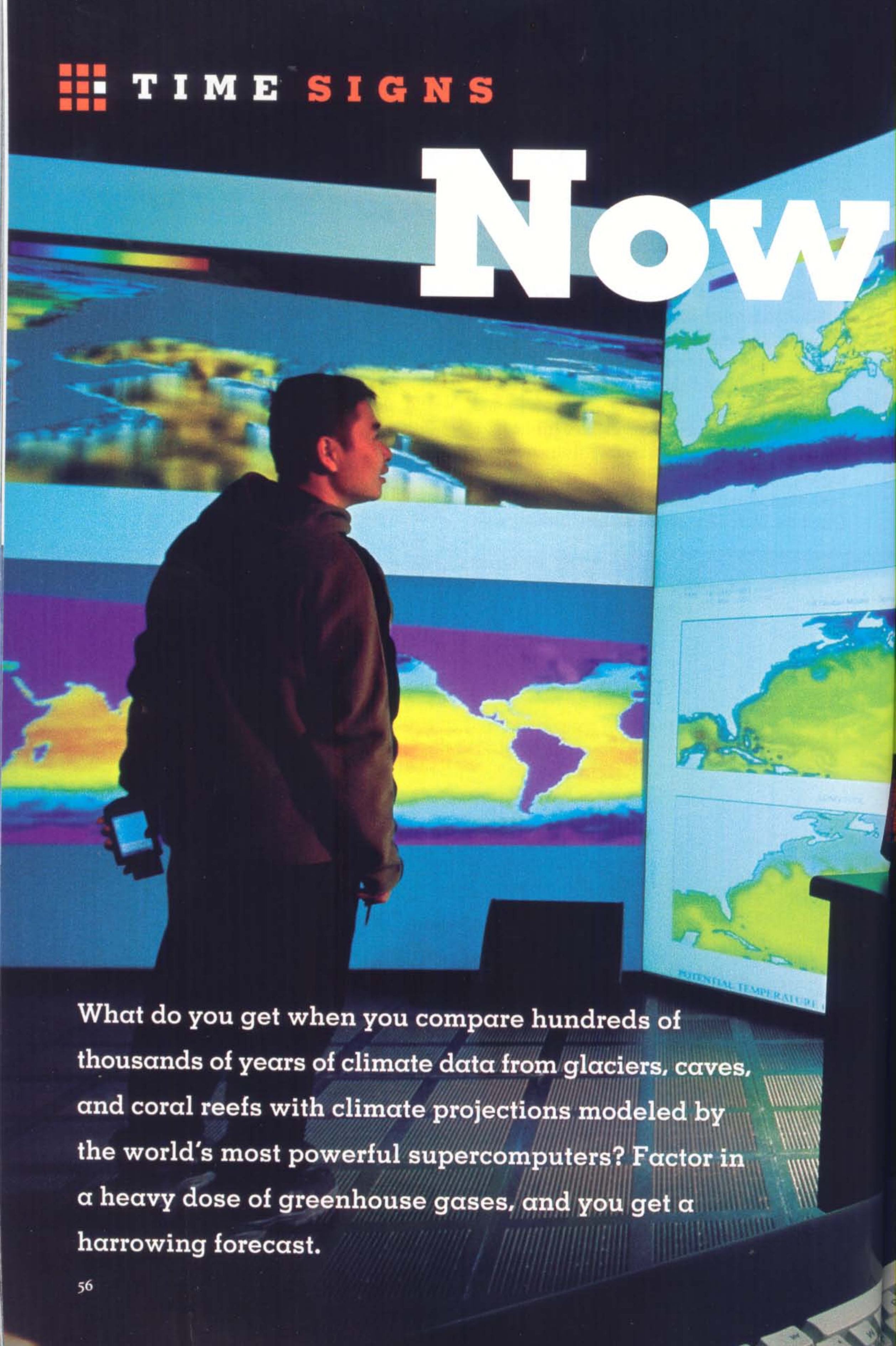
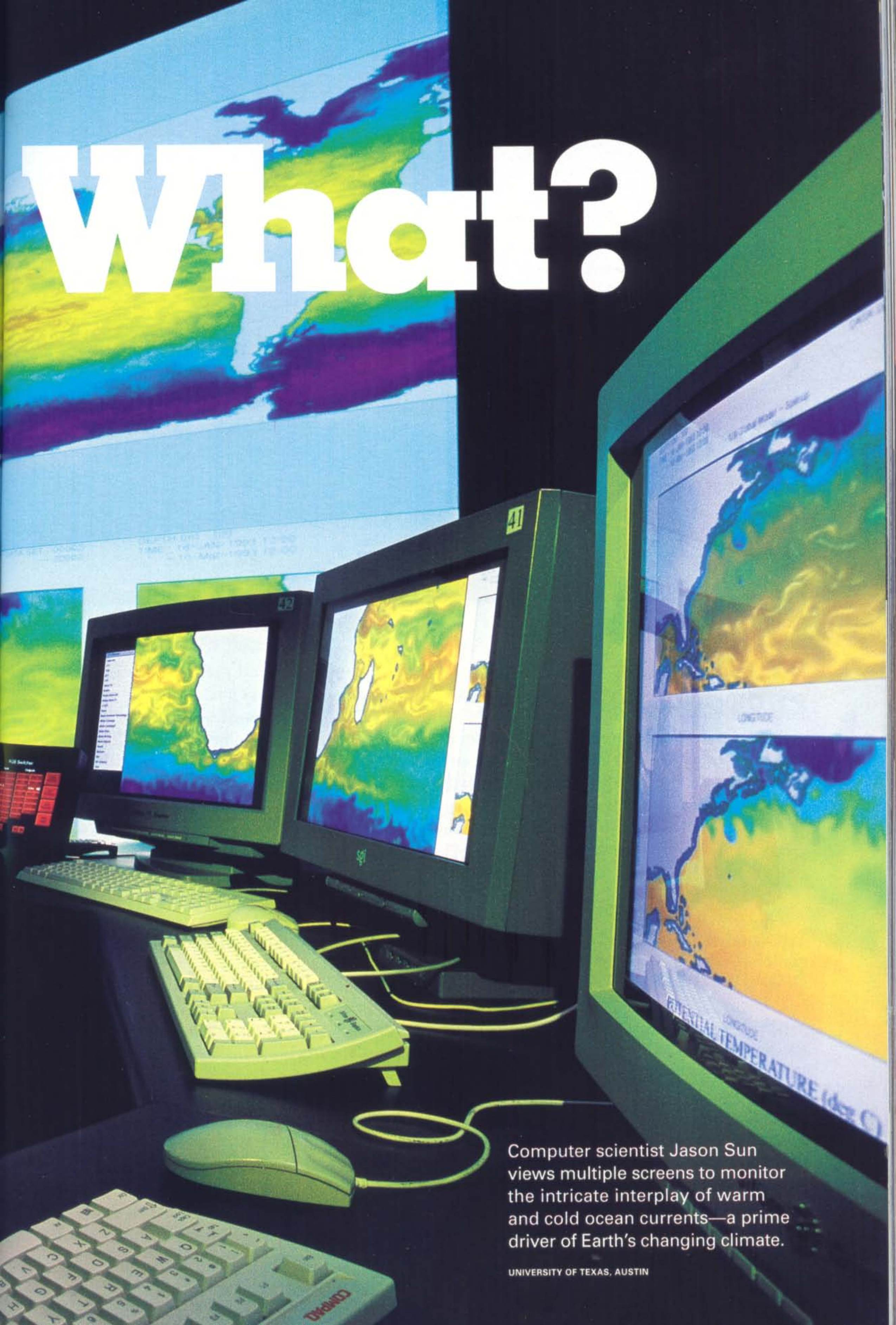
TIME SIGNS

Now



What do you get when you compare hundreds of thousands of years of climate data from glaciers, caves, and coral reefs with climate projections modeled by the world's most powerful supercomputers? Factor in a heavy dose of greenhouse gases, and you get a harrowing forecast.



What?

Computer scientist Jason Sun views multiple screens to monitor the intricate interplay of warm and cold ocean currents—a prime driver of Earth's changing climate.

UNIVERSITY OF TEXAS, AUSTIN

SAN PEDRO VALLEY, ARIZONA

BY VIRGINIA MORELL
PHOTOGRAPHS BY PETER ESSICK

"One. Two. Three. Lift!" barks Cathy Whitlock, a fossil pollen expert and paleoclimatologist at the University of Oregon. She and the three of us—two of her students and I—tighten our grips on the cold metal tube of a lake-bed drilling rig and heave. "Again," she commands. Slowly, inch by inch and groan by groan, the coring barrel that Whitlock and her students had manhandled into the marshy shore of Little Lake, a blue jewel of water in Oregon's central Coast Range, emerges from the mud.

"Once more," orders Whitlock. We bend to the task and at last free the barrel from the muck. Whitlock has extracted a couple hundred similar cores from the deep sediments of this lake, but she beams like a kid getting her first bike as she slides her latest sample of old mud, five centimeters thick and a meter long, out of the barrel.

"Oh, that's a lovely core," she says. To me it looks about as interesting as a Tootsie Roll. But to Whitlock's trained eye even the chocolate hue of the mud holds a story. "That rich brown color tells you it's full of organic matter—especially pollen," she says, slicing the core in half lengthwise with her pocketknife. "You can't see the pollen without a microscope, but it's there."

EVERGLADES, FLORIDA

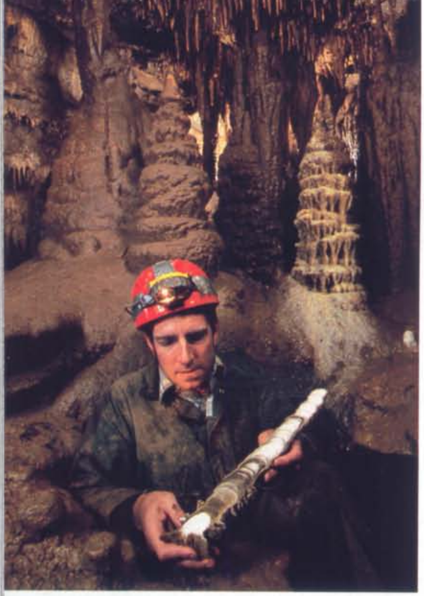
And in that pollen lie clues to one of the greatest puzzles facing researchers like Whitlock: What has caused—and will cause again—the sudden climate changes that our Earth periodically undergoes? Not the 100,000-year fluctuations between a glaciated and a warmer Earth that have occurred for the past million years or so, but the more rapid shifts that scientists have recently identified when the Earth switched suddenly from frozen ice age to picnic-warm and back again. How often and how quickly have such dramatic changes happened? Perhaps most important, what do these past abrupt reversals tell us about the direction of Earth's climate today and in the future?

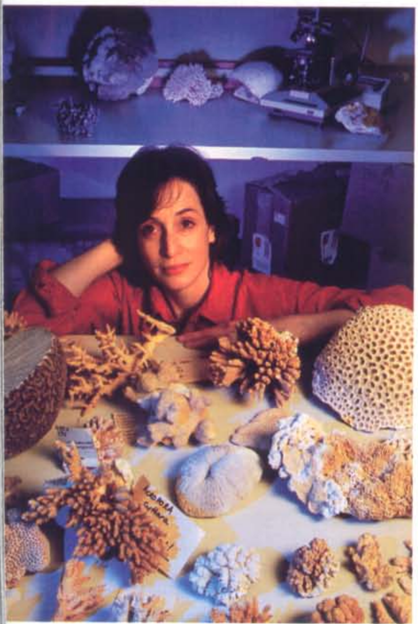
To answer such questions, scientists are busy unearthing signs of ancient climate in a surprising array of sources: glacial ice and moraines, stalagmites from caverns, tree rings and corals, dust and sand dunes, and the microscopic shells of organisms buried in deep-ocean sediments. Others, hoping to piece together the climate of the more recent past, turn to human records, using archaeological inscriptions, vintner and gardening diaries, and ship captains' logs. "We need both human and natural records," explains Ohio State University glaciologist Lonnie Thompson, who specializes in retrieving ice cores from the dwindling glaciers on tropical mountains. "We want to understand how the climate worked before and after people appeared. That's the only way we'll figure out what impact people have on climate, how much we're responsible for the way it's changing now."

Just how swiftly climate changes can occur is clear from Whitlock's study of her Little Lake cores. Those like the ones we drilled are stored at her university lab. Each meter of mud contains about 2,300 years of pollen grains from trees, grasses, and flowering plants. To find the

Wetlands Then and Now

A black line of decayed plants atop a white layer of carbonate and fossil shells (opposite) is all that's left of marshes that dominated the San Pedro Valley during the last ice age. The Everglades' vast mangrove forests (above) won't last as long. A dramatic rise in sea level—nine inches since 1930 in South Florida—could put the mangroves underwater this century.





Cutting to the Core

Stalagmites provide a trove of past climate data for University of Iowa geologist Jeff Dorale (top), holding a sample from Crevice Cave in southeastern Missouri. By measuring isotopes of uranium, as well as mud embedded in the slow-growing stalagmites, Dorale and colleagues believe they can link El Niño events to flooding in the cave and higher rainfall over the past 10,000 years.

Pack Rats have been hoarding seeds, leaves, and twigs in the arid Southwest for more than 30,000 years. Preserved in crystallized urine, such middens give geologist Camille Holmgren (middle) a snapshot of an evolving landscape in Arizona's Peloncillo Mountains. During the last ice age the area was cooler, wetter, and covered with piñon pines and junipers.

Corals produce annual rings like trees. The density of a ring depends on sea surface temperature, which, according to Woods Hole researcher Anne Cohen (bottom), has risen dramatically off Bermuda in 50 years. "Those temperatures were pretty steady from 1850 to 1950," says Cohen. "Then boom! They just shot up. You can see global warming right there."

Tree Rings like those in a hemlock log buried for a millennium and uncovered by Alaska's retreating Columbia Glacier, give geologist Greg Wiles (right) an annual regional temperature record from A.D. 585 to the present. "Living trees seem to be experiencing stresses they haven't seen in the past thousand years," Wiles says.

SOUTHEAST ALASKA. OPPOSITE: PERRYVILLE, MISSOURI (TOP); SAN SIMON, ARIZONA (MIDDLE); WOODS HOLE, MASSACHUSETTS (BOTTOM) pollen in the mud, Whitlock takes smudges from every core at set intervals, then puts the mud in a chemical bath that eats away everything but the thousands of previously invisible pollen grains. She places a droplet of the pollen residue on a slide and then "reads" about 300 grains, identifying the species of each one—a process that allows her to trace how the vegetation in the Coast Range changed during the climatic variations of the past.

"You hit bedrock at the lake at about 18.25 meters," Whitlock says, placing a sample slide beneath her microscope. "The pollen at that level dates to about 42,000 years ago."

Very few mountain lakes have such a continuous record, she adds, since they are often formed when glaciers retreat. But a landslide that blocked a small stream before the last ice age made Little Lake. The pollen in its muddy sediments "tells us what the coastal Oregon environment was like before and at the height of that ice age and how it changed as the climate warmed about 13,000 years ago," says Whitlock.

"It was a big change," she continues. "Here's what the forest looked like 21,000 years ago at the height of the last ice age. And, oh man, was it a different world."

I take her place at the scope, and she guides me from grain to grain. It's a surprisingly easy tour, since there are really only two types of pollen on this slide: the large, kidney-shaped grains of Engelmann spruce trees, and the smaller grains of mountain hemlock, which look like ovals with two small ears.

"Now think about this," Whitlock says. "Engelmann spruce doesn't grow in the Coast Range today. Instead, you find Douglas fir; that's the dominant conifer. But there isn't any Doug fir pollen on that slide. Doug fir doesn't show up until close to the end of the last ice age, and then—suddenly boom!—it's there and the spruce forest is gone. And that happens in 200 to 500 years: A whole forest vanishes and another one takes its place."

Whitlock pauses. "So we want to know how that happened and why. What caused the forest and the climate to change so dramatically and abruptly? And what happens if the climate shifts in the other direction, toward an ice age again or toward even warmer conditions? How are we—people—going to respond?"

Ice cores from Greenland, first obtained and analyzed in the 1960s, gave scientists early clues to rapid climate change. Because the ice there has accumulated undisturbed for over 100,000 years, it holds some of the best records for such things as past temperatures, amount of precipitation, and atmospheric conditions.

The Greenland cores, combined with even older ice cores from Antarctica's Vostok Station, showed the expected long periods of gradually increasing cold followed by shorter warm periods. But the Greenland ice also revealed that within the long, cold stretches there were short periods of warming and cooling. These shorter changes came in bursts, causing the climate to jump from cold to hot to cold again, sometimes in mere decades. The past climate had behaved like "an impish three-year-old" flicking a light switch, as Richard B. Alley, one of the scientists on the early 1990s Greenland drilling project,

Frozen History

Lonnie Thompson of Ohio State University holds an ice core from Peru's Quelccaya ice cap, which is retreating 40 times faster today than in the 1960s. Thompson's freezer may soon contain the sole remains of tropical glaciers from around the world, including the famed snows of Mount Kilimanjaro, which could vanish in 15 years. "What glaciers are telling us," says Thompson, "is that it's warmer now than it has been in the last 2,000 years over vast areas of the planet."

wrote in his book *The Two-Mile Time Machine.* And that raised a new question, one that remains unsolved: What caused—and may cause again—all those flickerings?

Sudden climate flips occurred throughout the last ice age—from about 70,000 to 11,500 years ago. At the height of this glaciation, vast ice sheets blanketed much of North America, Europe, parts of Russia, and Antarctica. Periodically the ice melted, then advanced again, until the final melting—an event that marks the beginning of the modern warm (and more climatically stable) epoch known as the Holocene.

But getting to the Holocene was a start-stop affair. It began with an abrupt warming—probably the cause of Whitlock's suddenly altered forest. Then there was another switch, back to cold times, and yet another warming at 11,500 years. In that jump, Greenland's surface temperature increased by 15°F in a single decade. England warmed suddenly too, becoming a haven for certain beetles that can only live in balmier climes. And on both sides of the North Atlantic, the sudden warmth melted terrestrial glaciers thousands of years old in just a few hundred years.

"Some of the ice we have here is already gone from the mountains."

"All those events happened essentially

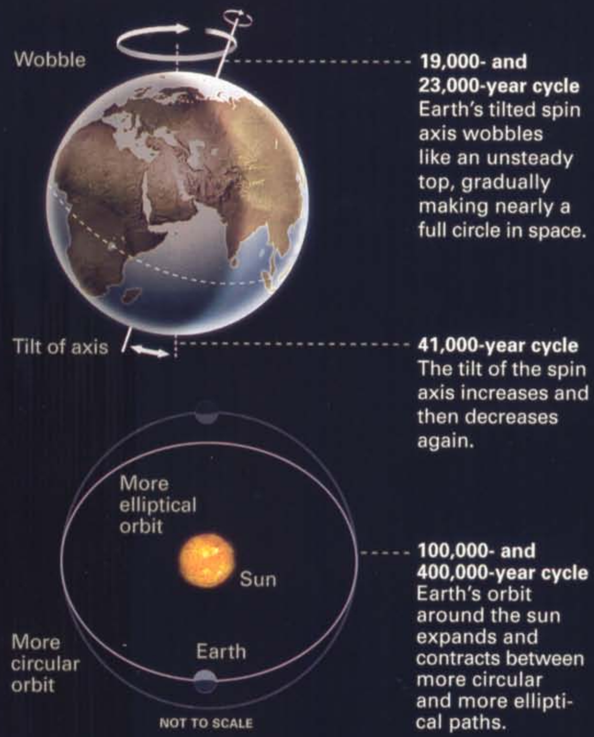
OHIO STATE UNIVERSITY, COLUMBUS

T I M E S I G N

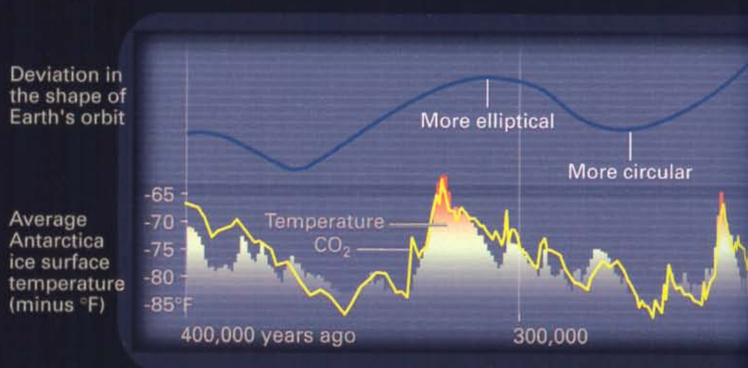
An ancient cycle ending?

Astronomical rhythms that affect climate >>>>>

■ **Earth in space**
Earth's orbit around the sun and its orientation in space change regularly. Together these rhythms are thought to help set the timing of ice ages by affecting the distribution of sunlight over the Earth's surface. For most of the past 2.5 million years, Earth was moving through cool and warm cycles every 41,000 years. Then, about a million years ago, the climate cycles became about 100,000 years long.



■ A 400,000-year ice-core record from Vostok Station, Antarctica, suggests a link between ice ages and astronomical rhythms. During ice ages CO_2 levels drop.



Past Change

Ice cycles For the past 2.5 million years Earth's climate has cycled through ice ages. In the most recent episodes, ice grew over tens of thousands of years until it formed large continental ice sheets. It then retreated quickly, and the Earth entered a warm interglacial period. Scientists believe this timing is partly determined by astronomical factors that affect the length of seasons and allow ice to build from one winter to the next.

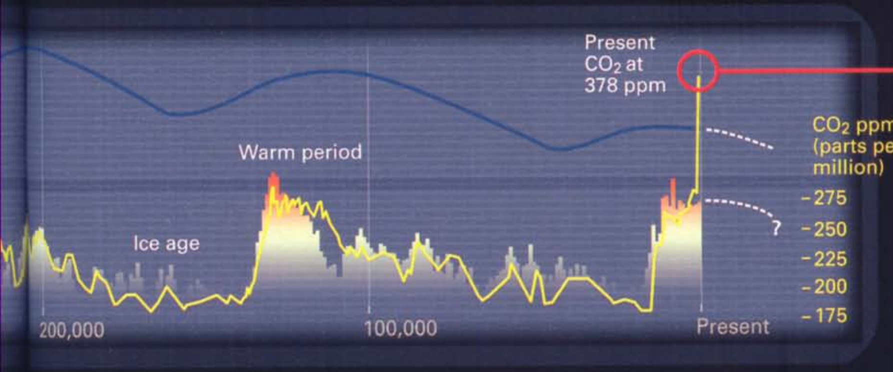
Fossils as clues to past climate change >>>>

Ancient sea life
Fossilized shells of microscopic marine organisms called foraminifera contain a chemical signature of water temperature. In foraminifera from seafloor sediments, researchers can trace climate back for millions of years.

Ancient plant life
Fossil pollen grains record ancient vegetation—another climate indicator. This is a 20,000-year-old spruce grain from Oregon.

FORAMINIFERA
256 TIMES ACTUAL SIZE

POLLEN
305 TIMES ACTUAL SIZE



Astronomical patterns, historical data, and computer models suggest the Earth could be in an extended interglacial period. Increased atmospheric CO_2 could warm the planet further.

ART BY 5W INFOGRAPHIC, JUAN VELASCO. ASTRONOMICAL CYCLES: JAMES ZACHOS, UNIVERSITY OF CALIFORNIA, SANTA CRUZ, AND ANDRÉ BERGER, UNIVERSITÉ CATHOLIQUE DE LOUVAIN, LOUVAIN-LA-NEUVE, BELGIUM. FORAMINIFERA: BRIAN T. HUBER, SMITHSONIAN INSTITUTION. POLLEN: CHRISTY BRILES, UNIVERSITY OF OREGON. VOSTOK ICE-CORE DATA: PETIT ET AL., *NATURE*, 3 JUNE 1999. PRESENT CO_2 DATA: C. D. KEELING, SCRIPPS INSTITUTION OF OCEANOGRAPHY

Following climate's ups and downs

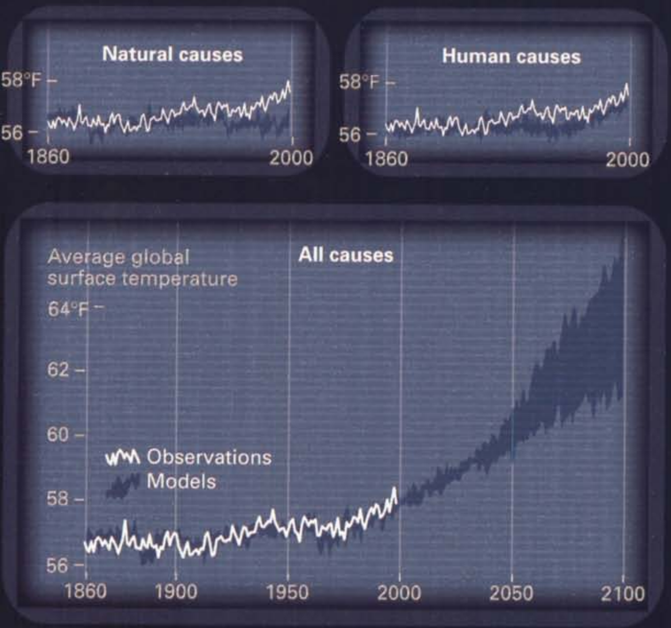
With no temperature records from ancient times, scientists turn to clues left in ice or in sediments from the oceans and lakes. Past air temperatures affected the chemical makeup of the snow that fell to form today's ice sheets. Ocean temperatures are recorded in certain marine organisms. And ancient fossil pollen reveals vegetation type, another indicator of climate.

What's ahead for the planet?

Climate models vs. observed temperature >>>

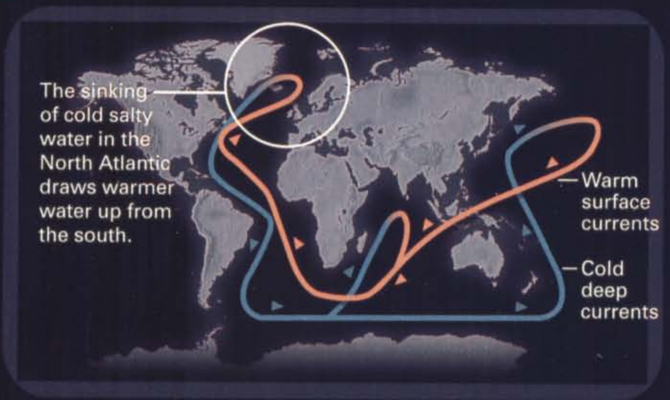
Not the whole story Computer models that include only natural (left) or human (right) influences on climate can't match the planet's observed warming.

A persuasive match A model that includes both natural influences and human ones like greenhouse gas emissions closely tracks the observed warming —and projects that it will continue.



Global ocean circulation system >>>>>>

Climate paradox Fresh water flowing from melting Arctic ice into the North Atlantic could disrupt the global system of ocean currents. Although Europe would warm with the rest of the world, its winters might cool.



Future Change

ART BY 5W INFOGRAPHIC, JUAN VELASCO. CLIMATE MODELS: HADLEY CENTRE FOR CLIMATE PREDICTION AND RESEARCH, U.K. OCEAN CIRCULATION SYSTEM: JAYNE DOUCETTE, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Climate crystal ball Most scientists agree that human activity—the burning of fossil fuels and the clearing of forests—is a major cause of the global warming observed so far. They predict that the warming trend will continue as greenhouse gases increase. But no one knows whether the climate change will be gradual or swift, occurring in years instead of decades. One reason is that ocean currents play a key part in global climate,

LIVENGOOD, ALASKA

MISSISSIPPI RIVER AT QUINCY, ILLINOIS; JIM RICHARDSON

FARSON, WYOMING

carrying heat from the tropics around the planet. Computer models project that continued warming could trigger a rearrangement of currents, perhaps leading to abrupt climate changes in parts of the world.

overnight," says Oregon State University's Peter Clark, who is tracking climate changes in Ireland's glacial geology. "We'd like to understand why the sudden retreats happened—what triggered them and if something like that could happen today," says Clark. "But to get those answers, we first need to know as precisely as possible when the ice melted."

In an effort to answer that question, Clark and fellow geologist Marshall McCabe from Ireland's University of Ulster don their rain gear and knee-high rubber boots, grab shovels and plastic bags, and make their way to a muddy cliff in a farmer's pasture above Ireland's Atlantic coast. Along the way, McCabe points his shovel at a small palm tree planted outside the farmer's house. "You know, we're at the same latitude here as southern Alaska. And that palm shows that our friend, the North Atlantic Ocean conveyor, is working," he says, referring to the ocean currents that pull warm water from the tropics to the Irish coast, keeping its temperature mild. "Otherwise, the palm would be dead."

From their studies of coral reefs and marine sediments, paleoclimatologists have shown just how important this ocean circulation system—the North Atlantic conveyor—is to the climate of the entire planet. During the ice ages it weakened and even occasionally stopped, triggering a cascade of events that ultimately led to warmer temperatures in the Southern Hemisphere and colder temperatures in the north.

"That conveyor sits right offshore," McCabe adds, this time aiming his shovel toward the sea. "So Ireland is particularly sensitive to any big changes in what it's doing; they're felt here immediately."

In the last ice age, with the conveyor slowed down, Ireland was much more like Alaska. Glaciers covered its mountains and pushed across the land and into the sea. But whenever the climate switch was flipped and the deep freeze momentarily ended, Ireland's glaciers began to retreat—rapidly. Meltwater coursed over the land, cutting deep river-size channels and pouring a slurry of mud into the sea. "These were high-energy events," says McCabe.

As the mud settled, tiny organisms called zooplankton were buried in the sediments. Today, with relative sea level far lower than in the past because the land is no longer weighted with ice, those muddy deposits are up to several hundred feet above the ocean, and a geologist who knows where to look can find in them the fossils of the shell-covered zooplankton called foraminifera (forams for short). Forams are an integral part of paleoclimatological research because their calcareous shells can be dated. And that's why McCabe and Clark have come to this pasture: to dig about 50 pounds of foram-filled mud for dating. With precise dates for the rapid retreat of the ice in hand, the two will be able to link Ireland's glacial history with that of North America and Scandinavia.

By dating forams from mud on the Irish Sea coast, McCabe and Clark found evidence for a rapid 35-foot rise in global sea level about 19,000 years ago. "That was a Northern Hemisphere melting, a pulling back of the entire ice margin," says Clark. "It wasn't just a little local event. We figure that the equivalent of two ice sheets the size of Greenland's today must have melted within a few hundred years."

What could have triggered such a large-scale event? McCabe and Clark argue that it could have been the weight of the ice itself. As the ice sheets grew, their increasing weight pushed down on the underlying land. Where the glaciers sank far enough to reach sea level, the ice began to float, breaking up into icebergs. "That would have added more fresh water to the ocean, changing its salinity and deepwater currents," says Clark.

ATLANTA, GEORGIA

"What happens if the climate shifts in the other direction, toward an ice age again or toward even warmer conditions?"

More fresh water in the North Atlantic would have slowed the conveyor and decreased the amount of warm water pulled from the tropics, changing ocean circulation dynamics and temperatures as far south as Antarctica. Computer models that simulate the Earth's climate show that what happens in the North Atlantic very quickly affects the rest of the planet. "As the water gets cooler here, the ocean gets warmer in the Southern Hemisphere," says Clark. "It's a seesaw effect. That warming could have caused an ice sheet in Antarctica to melt."

Heat Wave
Kids cool down in Atlanta's Centennial Olympic Park on a 90°F day. Using global climate models, scientists say temperatures in Georgia could rise one to nine degrees Fahrenheit over the next century. Higher temperatures and more frequent heat waves could double the number of heat-related deaths in Atlanta by 2050.

And that additional cold fresh water from Antarctica would, in turn, have caused the tropical warm currents to flow back toward the north, starting up the North Atlantic conveyor. Once again the Northern Hemisphere ice sheets would have begun to melt.

"You essentially would have ended up with ice sheets melting at both ends of the Earth at slightly different times," says Clark. "Today we have two big ice sheets: Greenland and Antarctica. And the climate is changing because of the high amount of carbon dioxide we've put in the atmosphere. How will it affect those ice sheets? If they melt, how will that affect us?"

Not everyone is convinced that the North Atlantic Ocean conveyor is the only switch for the Earth's sudden climate changes. "Maybe that's true for the higher latitudes, but it's not for the tropics," says Lonnie Thompson, whom many credit with retrieving the best paleoclimate records from the torrid zone—the latitudes between the Tropic of Cancer and Tropic of Capricorn. Indeed, until research by Thompson and others showed something different, most scientists regarded the tropics as a place where little climate change had ever taken place—not even during the ice ages.

"There's a bias in our view of climate change that sees events in the Northern Hemisphere as the most important," Thompson explains as we gear up to enter his ice-core storage room in the basement of Scott Hall on the Ohio State University campus. "But it's a data-collecting bias: That's where we have the most records from."

Behind a nondescript, beige door marked 089-B lie 6,000 meters of ice cores that give Thompson the data to challenge that interpretation. The cores come from glaciers crowning summits in the Andes, the Himalaya, and

Troubled Slopes

Skiers glide on man-made powder at a resort in central Wisconsin that cannot depend on natural snowfall. The skiing industry would be hit hard by a warmer world, with ski areas contracting to higher elevations, resorts enduring shorter seasons, and operators forced to make more snow. In nearby southern Ontario the length of the ski season could be cut in half by 2080.

CASCADE MOUNTAIN, WISCONSIN

Alaska, and from Mount Kilimanjaro. I'm glad for the down-filled parka, gloves, and snow boots when the first blast of arctic-cold air from Thompson's ice room hits my face.

The cores are kept in silvery, cardboard cylinders and lie in stacks on frost-covered shelves. A temperature gauge reads minus 30°C (minus 22°F), and I shiver in spite of the down. But the numbing cold is necessary to preserve what has or will soon disappear: the climatic history of the tropics. "The sources for these records—the glaciers on the highest mountains—are melting because of the increasing greenhouse gases in the atmosphere," Thompson says. "Some of the ice we've collected and have here is already gone from the mountains."

Greenhouse gases, such as carbon dioxide and methane, are released by a variety of human activities. Over the past 150 years, the amount of these gases has increased enormously in the Earth's atmosphere, trapping more heat and causing temperatures to rise—and glaciers worldwide to melt. And as the ice melts away so do the records that Thompson and other scientists deem vital to a better understanding of Earth's climate.

Thompson pulls down one of the cardboard containers and carries it to a table, handling it as carefully as if it were a tome from a library's rare-book room. "We forget that the Earth is a globe and that 50 percent of the surface of the planet is in the tropics. That's a major heat source, and I think it has a much bigger role in driving climate change than we've realized."

Thompson opens the cylinder and pulls out a meter-long ice core that's wrapped in plastic.

"This is a core we drilled on Sajama mountain in Bolivia," he says. It is dense and white, yet as Thompson points out, it also has slight variations, the faintest ringlike bands, indicating the annual accumulations of snowfall. By counting the bands, he can estimate the age of a core. And this one, Sajama's final core, the last one Thompson pulled from the mountain's ice before hitting rock, dates to 25,000 years ago, making it the oldest core Thompson has found in his high-altitude work in the tropics.

"This core shows that there actually were climate shifts in the tropics of the same magnitude that Greenland experienced during the ice ages," he says. Near the Equator, Earth's climate had switched rapidly back and forth from cold to warm just as it had in Greenland. And that makes Thompson think that the North Atlantic isn't the only driving mechanism for these abrupt changes. There may be a second driver in the Pacific Ocean.

Projections for the 21st century:
- **Higher minimum temperatures, fewer cold and frost days over nearly all the planet's land areas.**
- **Fastest climate warming in the past 10,000 years.**

Other anomalies in this high-mountain ice suggest that the past 10,000 years, which is often characterized as a stable climate period, was in fact also given to climate swings. Thompson opens another cylinder and produces a core from the ancient snows of Mount Kilimanjaro. Like the Sajama core, it is dense and white—except for a two-centimeter-thick band, which is black.

"That's dust," says Thompson. "It dates to 4,200 years ago when there was a terrible 200-year drought in North and East Africa. The upper atmosphere must have been full of sand, dirt, and dust, all of which mixed with the snow as it fell on Kilimanjaro."

Hieroglyphic inscriptions from the period describe how the annual Nile flood failed for about 50 years. The Egyptians suffered in a drought, and people died from famine. At about this time Egypt's Old Kingdom ended, and a period of social and political upheaval began. Thompson believes that the dry spell contributed to the collapse of the Old Kingdom. Some archaeologists also think that the drought extended north into the eastern Mediterranean and contributed to the decline of the Akkadian empire in Mesopotamia.

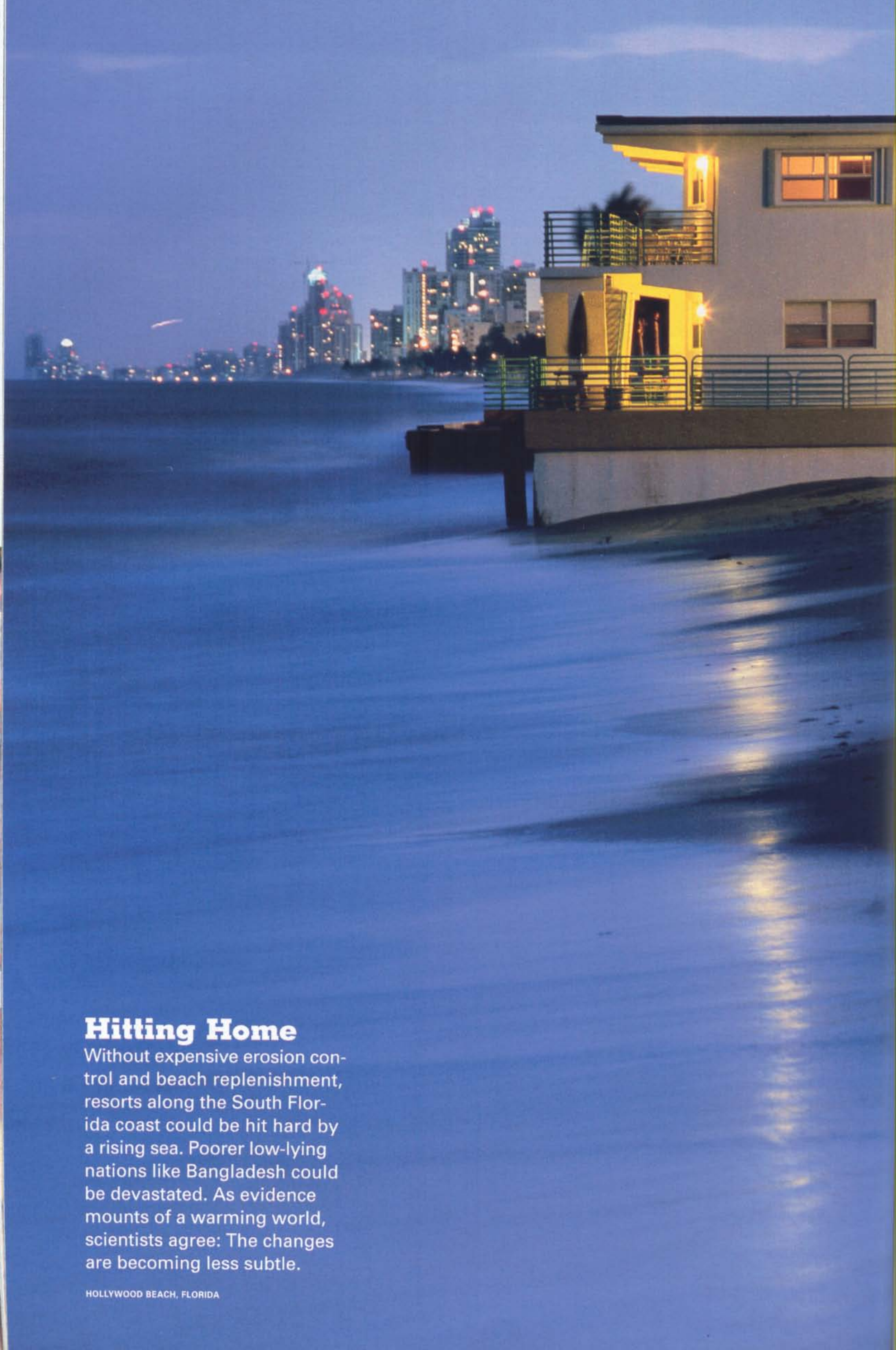
"It shows what climate change can do," says Thompson. "That was an abrupt, but natural, occurrence, when there were only 250 million people on the planet. Now there are 6.3 billion of us, and we're changing the climate."

Every paleoclimatologist I'd spoken to had said much the same thing. Some were certain that we had already succeeded in flipping one of Earth's climate switches and had triggered a new abrupt change. Others were more cautious, saying only that given the steady emission of carbon dioxide and other gases, the climate was bound to be different. All were alarmed by our collective refusal to slow down our use of fossil fuels. One wryly summed up our behavior as a

Contrasting Impacts

A warming world will harm some—and benefit others. Home heating costs will likely fall in New England, while power bills in Florida will rise as demand for air-conditioning grows—giving Miami appliance salesman Elbris Paz (above) reason to smile. The prospects are grim for drought-plagued Ethiopian children (below), who could see rainfall decline by 10 percent over the next 50 years. Widespread poverty and dependence on subsistence agriculture make Africans the most vulnerable to climate change.

MIAMI, FLORIDA (ABOVE); GEMETO, ETHIOPIA (BELOW)



Hitting Home

Without expensive erosion control and beach replenishment, resorts along the South Florida coast could be hit hard by a rising sea. Poorer low-lying nations like Bangladesh could be devastated. As evidence mounts of a warming world, scientists agree: The changes are becoming less subtle.

HOLLYWOOD BEACH, FLORIDA

"remarkable experiment," a quip I pass on to Thompson as we leave his ice-core room.

"He forgot one word," Thompson says, ready as ever to add to the record what is missing. "It's a remarkable, *uncontrolled* experiment."

"The climate of the past is our anchor for looking at the future," Cathy Whitlock told me when explaining the importance of her fossil pollen studies. "If we can understand the past linkages between the ocean, atmosphere, and biosphere, and determine which parts were the really big players in past sudden change, then maybe we can better deal with future surprises."

That's the dream, the goal of paleoclimatology. And although all the connections among the disparate parts of the Earth's climate have yet to be fully untangled, computer modelers have made big steps in predicting what the weather will be in the near future. One of the best models runs on a supercomputer at the United Kingdom's Hadley Centre for Climate Prediction and Research. Simon Tett, a Hadley Centre climate specialist, sets up his laptop at my London hotel and calls up a map of the world. Superimposed on it are swirls and colors representing ocean and atmospheric currents—essentially a model of Earth's climate. Plug in different factors, like a big spike in CO_2 and methane levels, and you can sit back and watch the weather change.

"Right. So here is what the world's climate could be in 2080," Tett says. A red hue settles over most of North America and Europe, indicating higher temperatures, while the Arctic turns from white to blue as the summer ice cap melts.

"People don't realize how dramatic these changes will be," says Tett. "But we expect to see a two- to five-degree [Celsius] warming over the next hundred years. It will be higher over land, but the oceans will also warm."

The warming doesn't mean that every place will suddenly become like Miami. Some areas, like the interior of the United States, are likely to grow hotter and drier. Others, like China, Southeast Asia, and the western U.S., may get more precipitation but less snowfall, jeopardizing the drinking water of people in cities like Los Angeles. Sea levels around the world are projected to rise as the last of the glaciers melt and the warmer oceans expand. Intense hurricanes may occur more frequently, and storm surges coupled with the higher sea level could severely damage cities like New York. Heat waves, like the one Europe experienced in the summer of last year, may become the summer norm.

Can we do anything to stop the change?

"No," says Tett. "We'd need to get to zero emissions to stabilize the CO_2 that's already in the atmosphere. And that's not the path we, as societies, have chosen. Even if we were to stop CO_2 emissions now, we are committed to warming.

"Ultimately there will be an effect on the ocean's thermohaline circulation—the conveyor belt," he continues. "Climate models show that circulation will slow, but it's possible that it could collapse. One result of that would be cooler winter temperatures in Europe."

> **"We'll have a better idea of the actual changes in 30 years. But it's going to be a very different world."**

Tett turns off his laptop. "We'll have a better idea of the actual changes in 30 years, because some of us will have lived through them. But it's going to be a very different world."

Outside, the light of a cold winter sun spills over the London streets. It's a week before Christmas and shoppers bustle by. There's the whoosh and honking of traffic, and the smell of diesel and gasoline fumes rising in the air. I hail a cab and set off for the airport.

"The weather's going to change," the cabbie tells me. "It's fine now, but that's the end of it; it's turning rough tomorrow."

I nod in agreement. He is more right than he knows. □

PREDICTING EARTH'S FUTURE What do tree rings, pack rats, and stalagmites have in common? Test your climate knowledge with an interactive quiz. Then read field notes and find related resources at **nationalgeographic.com/magazine/0409.**