But other experiments have begun to muddy this pretty picture and suggest that fixed stripes may not always be superconductivity killers. In work recently submitted to *Physical Review B*, a team of Japanese and U.S. researchers looked at a lanthanum-copper-oxide crystal with excess oxygen added as the dopant, a material that has the highest superconducting temperature of any lanthanum-based compound. The team's neutron scattering results clearly showed the presence of static stripes. The inescapable conclusion, says team member and MIT physicist Robert Birgeneau, is that "superconductivity and static magnetic order [fixed stripes] can coexist."

Now comes Imai's latest result, which underscores that puzzle. Because neutrons are strongly sensitive to the magnetic spins on the copper atoms, most neutron scattering work had revealed just the arrangement of magnetic spins in superconductors, leaving investigators to infer the charge stripes. Imai, however, has traced the charges themselves in the high-temperature superconductor lanthanum-strontium-copper-oxide. In a technique called nuclear quadrupole resonance, the team pulsed radiofrequency waves at the material and tracked the magnetic response, which indicated the spins of the copper nuclei. But nearby electrical charges also affect the magnetic signature, which allowed the researchers to piece together the location of the charges as well. Imai says the results, which have been submitted to *Physical Review Letters*, support the presence of "quasi static" stripes, largely fixed in place. "I didn't expect we'd see this phenomenon," says Imai. "So I was very surprised."

So how can fixed stripes and superconductivity be present in the same hunks of ceramic? One possibility, says Princeton theorist Philip Anderson, is that any seemingly fixed stripes and superconductivity may be confined to separate regions of the material. Emery suggests another: The stripes aren't completely fixed after all, but meander about an average position. His reading of the recent data suggests that "there is some movement there," he says.

Whatever the answer, it appears that stripes are here to stay. They may be either a key to superconductivity or a false lead devised by nature to throw theorists off the track. To find out, says Pines, researchers now need to show that stripes not only coexist with superconductivity in the same region of material, but that they somehow improve its superconducting behavior. Until someone figures out how to pull off that experiment, the charge stripes will remain a disquieting mystery.

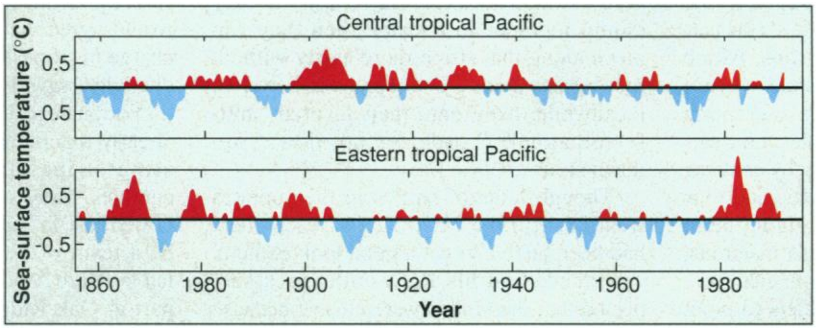
—**ROBERT F. SERVICE**

CLIMATE CHANGE

Big El Niños Ride the Back Of Slower Climate Change

After two "El Niños of the Century" in 15 years, climate researchers are finding explanations in long-term climate change

Climate modelers were patting themselves on the back last year after successfully anticipating the arrival of El Niño in 1997. In the spring of that year, dutifully following predictions of a modest event, the tropical Pacific warmed sharply (*Science*, 24 April 1998, p. 522). But then the Pacific asserted its independence, confounding the models by soaring to record-breaking warmth in one of the most severe events of this kind on record—worse than the devastating "El Niño of the century" that struck in 1982–83. By the time it was over in 1998, El Niño–related weather extremes had caused 23,000 deaths and $33 billion in damages around the world. Now, by deconstructing the symphony of longer-term climatic cycles that play out in the Pacific Ocean, researchers have found clues to why these events were so severe.



Synergy. Two of the tropical Pacific's climate cycles turned warm simultaneously in the early 1980s, fueling the 1982–83 El Niño.

SOURCE: ENFIELDS AND MESTAS-NUÑEZ

In two papers soon to appear in the *Journal of Climate*, researchers show that these other, slower cycles of ocean warming and cooling have tended to be at or near their peaks—in some cases unusually high peaks—since the 1970s. By preheating the Pacific, they boosted the intensity of the El Niños.

No one knows what drives these cycles, although some researchers suspect that the past century's global warming may have helped push some of them to the warm side simultaneously. But identifying the cycles at work in a given year could be a first step toward forecasting how powerful a predicted El Niño will be—and ultimately how it will affect weather patterns around the world (see sidebar). "If we are to extract every ounce of predictability from the [climate] system," says oceanographer David Enfield of the National Oceanic and Atmospheric Administration (NOAA), "we must try to understand how the other components work and how they interact with [El Niño] in modifying our climate."

Untangling climate to understand its workings and future behavior takes a record long enough to include repeat performances of a given climate oscillation. Enfield, of NOAA's Atlantic Oceanographic and Meteorological Laboratory in Miami, Florida, and oceanographer Alberto Mestas-Nuñez of the University of Miami found theirs in a 136-year record of sea-surface temperature measured by ships around the globe, just compiled by oceanographer Alexey Kaplan and his colleagues at Lamont-Doherty Earth Observatory in Palisades, New York.

The Miami researchers parsed the complex climatic symphony of the Kaplan temperature record into its component parts. First, they removed the so-called El Niño–Southern Oscillation or ENSO variations themselves, the high-pitched drone of tropical warmings and coolings that return every 2 to 7 years. Next, they removed the bass crescendo of global warming—a trend of nearly half a degree Celsius per century, which may be driven by human activity. Finally, they used a sophisticated statistical technique to separate the remaining melody of the temperature record into several oscillations—a decade or two long and a half degree or more in amplitude—that were being played out in different parts of the ocean.

What they found was more of a cacophony of discordant cycles than a harmo-

In North American Climate, A More Local Control

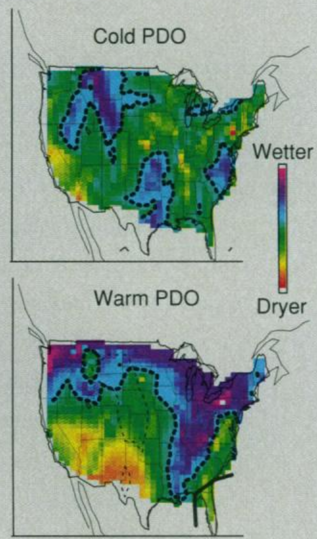
El Niño doesn't reign alone. Other cycles of ocean temperature sometimes intensify this warming of the tropical Pacific Ocean (see main text). And it now seems that at least one other ocean cycle wields influence over some of El Niño's worldwide effects: a decades-long temperature seesaw in the North Pacific.

El Niño, for example, often gives Minnesotans a break from their normally brutal winter cold. But not always, climate researchers Alexander Gershunov and Tim Barnett of Scripps Institution of Oceanography in La Jolla, California, have found. If the climatic mood of the North Pacific isn't right, Minnesotans may not get their usual respite, although other areas may be spared El Niño–related weather extremes. "They're onto something interesting and useful," says meteorologist Nathan Mantua of the University of Washington, Seattle. "It should improve the skill" of long-range winter weather predictions.

In the classic El Niño winter pattern, tropical warmth displaces storm tracks in midlatitudes, leaving the northern contiguous United States warmer and drier and the south wetter and colder. But Gershunov and Barnett found that it's not that simple when they sorted a 61-year record of U.S. winters by the condition of the North Pacific. Every few decades or so, this basin swings from being unusually cold in its western and central parts and warm in the east to the opposite pattern, a cycle called the Pacific Decadal Oscillation, or PDO (*Science*, 10 July 1998, p. 157).

The researchers report in the 19 January issue of *Eos* that when the central North Pacific was cold, the El Niño pattern was stronger and more consistent. When the PDO was in its opposite phase, the El Niño winter pattern weakened. In the winter of 1997–98, for example, a powerful El Niño was felt even more keenly in North America because the PDO was in its cold phase, suggest Gershunov and Barnett.

They also found that the PDO interacted even more strongly with El Niño's opposite number, La Niña, a cooling of the tropical Pacific that currently holds sway. A cold North Pacific disrupted the La Niña pattern of a dry Southwest and wet northern states, and a warm North Pacific strengthened it (see graph). Because the PDO switched phases from cold to warm late last summer, Gershunov says, it should now be reinforcing the current La Niña, bringing chill and snow back to Minnesota.



Pacific power. A cold northwestern Pacific disrupts the usual La Niña pattern of precipitation (*top*), while a warm Pacific enhances the pattern (*above*).

SOURCE: GERSHUNOV, BARNETT, AND CAYEN

That seems to be happening, with the Southwest being especially dry, although it's too early in the winter to be sure. Indeed, meteorologist Martin Hoerling of the University of Colorado, Boulder, cautions that Gershunov and Barnett's record is relatively short given the PDO's decades-long swings, so the correlation may only be chance. Minnesotans should still check the thermometer, rather than the PDO, before venturing out. –R.A.K.

nious melody. In the eastern tropical Pacific, the researchers found that temperature swings slowly from warm to cold and back over 10 to 20 years. This oscillation, called an "interdecadal ENSO" because it is also located in the eastern tropical Pacific, began a sharp swing to the warm side in the late 1970s and reached a peak in the early 1980s, helping to drive the 1982–83 El Niño into record territory. When this shift was first recognized, some researchers suggested it was driven by greenhouse warming (*Science*, 28 October 1994, p. 544). But the Miami analysis shows that the interdecadal ENSO has been waxing and waning through the whole record—although its last comparable peak was in the 1860s.

Another cycle, unnamed, throbs to its own decadal beat in a large westward-pointing wedge of the central tropical Pacific. This cycle reached its greatest warmth in the early part of this century, but it, too, took a sharp turn toward the warm side in the late 1970s. And in the North Pacific, two distinct climate seesaws, each following its own rhythm, raise the temperature of the central part of the basin while lowering that of the rest of the ocean and vice versa. The more rapid of the two, which Enfield and Mestas-Nuñez equate with a well-known climate variation called the Pacific Decadal Oscillation, also showed tropical warming in the late 1970s. When El Niño struck in the early 1980s, all these cycles added up to trouble. "What's really spiking the '82–'83 event is the decadal-multidecadal variability," says Enfield.

That seems to be what happened in 1997, too. In an independent analysis of a shorter sea-surface temperature record from 1955 through 1997, meteorologists William Lau of NASA's Goddard Space Flight Center in Greenbelt, Maryland, and Hengyi Weng of SAIC/General Sciences Corporation in Laurel, Maryland, found a similar combination of long-term global warming and decadal variations that "adds up to a huge [temperature] increase in '97," says Lau. Their work is also in press in the *Journal of Climate*. And in their most recent analysis, Enfield and Mestas-Nuñez also see a convergence of decadal variations pushing the latest El Niño to its peak. "We can confirm what Lau is saying," says Enfield.

All this is good news for those who'd like a bit of warning before a giant El Niño strikes. Because the oceans change slowly and these are longer-term cycles, forecasters can assume that the state of the oceans won't change too much in a year, so they can hope to warn of big El Niños 6 months to a year in advance, says Enfield. For even longer-term predictions, however, researchers will need to better understand what's driving the decadal fluctuations—and those answers may be a long time coming.

Although researchers have a variety of theories, no one really knows for sure what pushes the Pacific into these oscillations. It may be a feedback loop among winds, currents, and temperature. Occasionally, such loops could produce simultaneous warming in several cycles, according to recent work by modeler Gerald Meehl and his colleagues at the National Center for Atmospheric Research in Boulder, Colorado. But Lau and others say that global warming could be enhancing all the natural decadal cycles at once. "We've been looking at these phenomena as being separate," says oceanographer Michael McPhaden of NOAA's Pacific Marine Environmental Laboratory in Seattle, Washington, "but we're beginning to realize there are these connections."

These uncertainties mean that forecasting the likelihood of big El Niños 10 years out probably isn't in the cards, says Enfield. But by analyzing decadal climate variations, he and others are at least beginning to learn to follow the Pacific's tune. –RICHARD A. KERR