Spying on El Niño

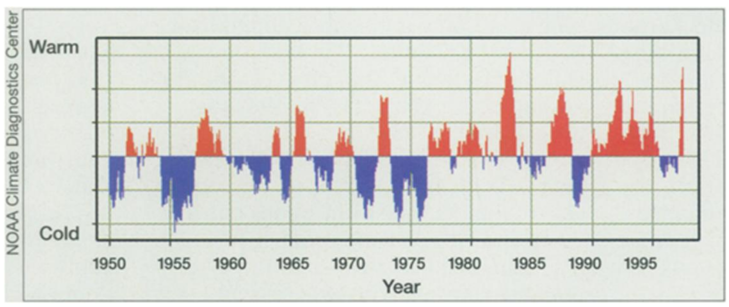
The struggle to predict the Pacific prankster

By RICHARD MONASTERSKY

In Indonesia and Malaysia, abnormally dry skies have spurred on epic wildfires, blanketing the region with a smoky haze. In California, homeowners are nailing down new roofs as emergency officials prepare for potentially torrential winter rains with accompanying floods and landslides. In the tropical Atlantic Ocean, waters have remained remarkably calm this summer, spawning far fewer hurricanes than normal.

Meanwhile, in the middle of the Pacific Ocean, the source of all this unusual weather grows stronger by the week.

The El Niño—the rogue warming of Pacific waters—has come roaring onto the scene this year and has already started turning conditions across the world topsy-turvy. First detected in April, it has gathered steam far faster than anticipated and has now spread to an area 1.5 times the size of the contiguous United States.



El Niño warmings (red) have hit more frequently than La Niña coolings (purple) since 1976. Climate scientists wonder whether the change is part of a natural cycle or linked to greenhouse warming.

The vast pool of warm water, up to 3.5°C above normal, is poised to surpass the greatest El Niño of the century, which wreaked havoc in 1982 and 1983. Although the damage from that event is impossible to quantify exactly, climate experts often quote a toll of $8 billion worldwide exacted by floods, storms, fires, and droughts.

Seventeen years ago, climate scientists had no reliable tools to provide advance warning of the El Niño. In fact, there were so few observational buoys in the Pacific that researchers had trouble recognizing the phenomenon even after it had started. That glaring gap in knowledge triggered a decade-long research effort called the Tropical Oceans and Global Atmosphere program, aimed at learning how to predict the Pacific's moods and their effects on weather outside the tropics.

Now, the world is reaping the fruits of that work. As early as the end of last year, sophisticated computer models started hinting that the Pacific would brew up an El Niño in 1997. Then, in the first 3 months of this year, satellite sensors and a network of buoys strung across the Pacific began to pick up signs of the warming. Forecasters with the National Oceanic and Atmospheric Administration (NOAA) issued an advisory in April, alerting the world to the possibility of a major El Niño.

These apparent successes, however, belie some major problems plaguing efforts to forecast El Niño. While several models correctly predicted that the Pacific would warm this year, all missed the magnitude and timing of the temperature increase. Some of them disagree on whether the El Niño will persist through next winter, a critical factor in determining how U.S. weather will fare. Perhaps most worrisome to researchers, the model with the longest track record failed miserably this year.

"This is the really scary part of the story because we don't know why that model failed," says Mojib Latif of the Max Planck Institute for Meteorology in Hamburg, Germany.

The earliest prediction schemes for El Niño, devised in the late 1970s and early 1980s, worked somewhat like the mind of a novice stock investor: They operated on the often flawed assumption that past performance guarantees future returns.

The early models did not seek to simulate the actual forces of nature that drive Pacific warmings. Instead, they were statistical models. They would take the temperatures and winds in the Pacific and then search past records to find comparable situations.

In the mid-1980s, climate scientists started trying to capture the physics of the El Niño process inside computer models. They devised cartoon versions of the ocean to predict how heat shuffles around the Pacific basin. These oceans-in-a-box have gradually gotten more complicated and are now coupled to computer models of the atmosphere. Simulated winds in the

The Atlantic's climate beast

In recent years, researchers have recognized that El Niño is only one of the goblins lurking in the climate system. For residents of Europe and the East Coast of the United States, a pattern called the North Atlantic Oscillation plays a bigger role in determining winter weather.

Under typical conditions in the North Atlantic, a high-pressure system sits over the Azores and a low-pressure one over Iceland. When that Icelandic pressure rises and the Azores' drops, Arctic air invades the northeastern United States. Storms that are normally bound for England head instead toward Spain. Northern Europe gets extremely cold, as it has been in the last two winters.

Although meteorologists have long known of the North Atlantic Oscillation, oceanographers are only now finding links between the air pressure and currents in the ocean, giving them the hope of one day being able to forecast the North Atlantic's moods. At present, however, climate scientists lack a firm understanding of what drives the weather pattern, making it impossible to predict how it will behave this winter, says Gerald D. Bell of NOAA's Climate Prediction Center. —*R.M.*

atmosphere stir up virtual ocean currents, which in turn alter the pressure patterns in the atmosphere that then feed back on the ocean, and so on.

The coupling of air and water is important because scientists have realized that El Niño ocean warmings are only one-half of a climatic marriage. The other partner, called the Southern Oscillation, is a see-saw variation in Pacific atmospheric pressure.

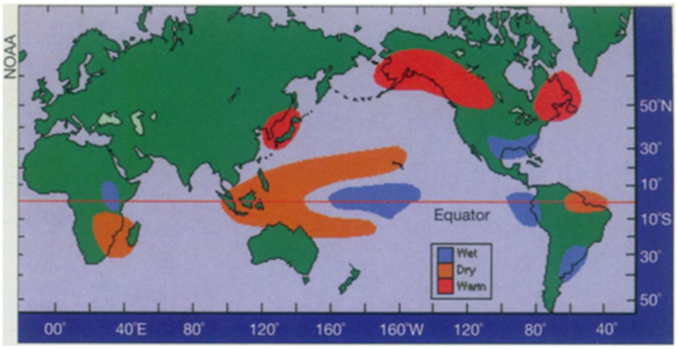
Under typical conditions, a high pressure system sits in the central Pacific near Tahiti and low pressure hangs over Indonesia, driving winds westward along the equator. These winds push surface waters to the west and pull up deep, nutrient-rich water that keeps the eastern Pacific cool and thriving with life. In the western Pacific, the same winds pile up warm water into a giant pool centered around Indonesia.

According to current theory, an El Niño develops when broad so-called Kelvin waves sweep toward the Americas and shut down the upwelling of cold water in the east. The sea surface warms in this region. The winds blowing westward weaken. The warmth normally contained near Indonesia spreads toward the center of the ocean, carrying with it the rain storms that would traditionally hit Australia and nations of the western Pacific, says Ants Leetmaa, who heads NOAA's Climate Prediction Center (CPC) in Camp Springs, Md.

As Kelvin waves and other types of waves slosh back and forth across the Pacific, they can trigger a chilly phenomenon called La Niña. In many ways the opposite of El Niño, La Niña can also disrupt weather: It was implicated in the devastating 1988 drought in the central United States and the forest fires in the Southwest.

The El Niño–Southern Oscillation (ENSO), as the ocean-atmosphere pattern is called, constantly cycles from warm to normal to a cold La Niña and back, although the variation is highly erratic. The job of forecasters is to predict when the Pacific see-saw will shift and how far it will tip toward the extremes. On average, El Niño comes once every 4 years. Sometimes, though, the ocean can go 7 years without a warm phase. At other times, the Pacific can pull out of an El Niño, skip a cold phase, and fall right back into another warm episode the following year, as happened twice in the 1990s.

Currently, a dozen forecasting teams around the world are employing various types of models to keep tabs on the many moods of the Pacific. For most of them, the 1997 El Niño could be regarded as a coming of age.



Expected effects of a typical El Niño.

The CPC ocean-atmosphere model, the most complex model currently in routine operation, fared particularly well this year, says Leetmaa. It started portending a 1997 El Niño as early as November 1996.

A much simpler model, built by researchers from the Scripps Institution of Oceanography in La Jolla, Calif., and the Max Planck Institute, also started picking up signs early on, says Latif. Unlike the CPC model, Latif's has a purely statistical atmosphere that relies on past weather patterns rather than simulating the underlying physics of jet streams and pressure patterns in the air.

Most surprising to the community of ENSO researchers, the longest-running and one of the most successful models went belly-up this year. Operated at Lamont-Doherty Earth Observatory in Palisades, N.Y., this computer program is a cartoon version of the ocean, but its simplicity and speed have brought good results in the last decade, says Lamont-Doherty's Mark Cane. The model accurately called for warmings in 1986 and 1992, and it picked up the 1988 La Niña.

Cane and others are struggling to make sense of why his model forecast a cold Pacific this year. The current whopper of a warming should have advertised itself more than most. "It's not obvious to me what went wrong," says Cane.

At a detailed level, even the best models face problems that threaten their accuracy, especially for predictions more than 6 months ahead. No model called for such an intense 1997 El Niño or one that developed so early in the year.

Looking into the future, there is uncertainty about how the El Niño will behave over the winter. "Models disagree on when it will peak and when it will go away. The impact that it will have on weather depends critically on having this event continue in winter and into the spring. Some models have it peak in the fall, in which case its impact will be less," says Leetmaa.

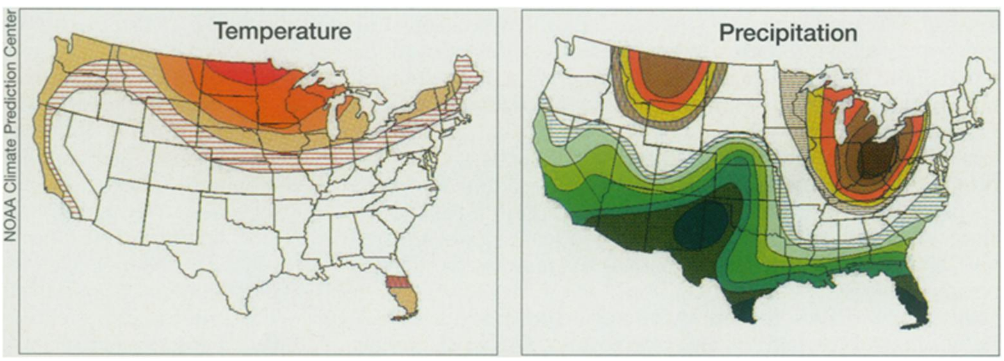
Part of the problem is that the models are still under development and are notoriously poor at predicting major transitions, such as when El Niño will die off, says Gerald D. Bell, a CPC forecaster. "Obviously, there's room for improvement. These models are in their infancy compared to where they will be in 10 to 15 years."

For Bell and his colleagues, climate forecasting is still an art that requires evaluating many different sources of information, only one of which is model predictions. The meteorologists rely heavily on actual measurements of the winds, pressure patterns, storm positions, and water temperatures in the Pacific. These facts, combined with a knowledge of past events, help the forecasters decide when to trust the models and when to regard them with suspicion.

For now, forecasters will not go out on a limb with only a model for support. "You can't put out an El Niño advisory based on just a model forecast because they're just not that reliable. You wait until there are at least El Niño–type conditions developing out there in the ocean to put the advisory out," says Bell.

For instance, when the CPC model began calling for a 1997 El Niño last November, forecasters had some doubts. In 1996, the model ran warmer than the actual Pacific Ocean, which stayed slightly cooler than normal. Bell and his coworkers began to trust the model only after they saw temperatures in the equatorial ocean warming markedly in the first quarter of 1997.

Even with substantial improvements,



U.S. forecasts for January through March 1998. The temperature map shows warmer-than-average conditions in red shades. In the precipitation map, orange and brown depict below-average precipitation, whereas green and blue denote wet conditions.

though, models will never make perfect climate forecasts. A heavy dose of chaos infects the streams of air and water coursing around the planet, explains Latif.

"There was an enthusiasm that went through the community a few years ago when we initially realized that we can predict El Niño. People overdid it a bit and were too optimistic. I think the claims that were made that ENSO may be predictable a few years in advance are probably not correct," he says. He estimates that unstable fluctuations of the ocean and atmosphere limit the predictability of ENSO to about 1 year.

For meteorologists, forecasting El Niño is only half the battle. Once they predict how the ocean will behave a half year hence, they must look into how something in the middle of the Pacific will affect the weather thousands of kilometers away, where more people live.

El Niño has such a long reach because it coaxes thunderstorms from the vicinity of Indonesia out into the middle of the Pacific. Like giant boulders in a river, these towering clouds redirect the atmospheric jet streams, shifting the normal track of storms over North and South America.

In the tropics, El Niño has an obvious influence. It tends to bring droughts to Indonesia, Australia, and northeast Brazil, as it inundates coastal Peru and Ecuador.

Meteorologists are now gaining insight into how the equatorial waters of the Pacific skew weather outside the tropics. Robert E. Livezey of the CPC has combed through 102 years' worth of U.S. temperature and precipitation records to document long-distance links between Pacific warmth and the weather in regions of each U.S. state.

The knowledge of these links, coupled with the record El Niño, has boosted CPC meteorologists' confidence in their ability to predict U.S. weather for this winter. "These factors have led us to make stronger forecast statements than we've ever done before," says Livezey.

The certainty shows up in CPC's map predicting U.S. precipitation for January through March 1998. The center has had to add a new hue to its maps to reflect the extremely high odds of dry conditions in the Ohio River Valley and of enhanced precipitation in parts of Texas and South Florida. The prediction also calls for a wet Southwest and Gulf Coast. The northern states will bask in unusual warmth, say the forecasts.

In the past, the weird weather spawned by strong El Niños has taken a heavy toll on people around the globe. Aside from direct effects, such as desiccated crops and flooded cities, the extreme conditions have also indirectly fostered the spread of diseases. Researchers have linked past occurrences of El Niño to outbreaks of cholera in Peru, malaria in Colombia, and hantavirus in the U.S. Southwest.

This year, however, the timely forecasts have provided advance warning of many of the upcoming disruptions. Last month, Antonio D. Moura of the newly created International Research Institute for Climate Prediction at Lamont-Doherty spent 2 hours briefing the president of Brazil on how El Niño and Atlantic Ocean temperatures could spur a drought in the northeast part of that nation. At the same time, U.S. meteorologists met with representatives of southern African nations in Zimbabwe to discuss the potential problems associated with El Niño. This month and next, researchers will carry their message to Peru and Uruguay.

More than in the past, politicians and emergency planners seem to be listening. "I can see that in many regions, governments are starting to worry about this," says Moura. "They are beginning to believe the forecasts and explore what is their best strategy for decreasing the negative impacts." □

Chemistry

Understanding how proteins fold

Scientists long to figure out the rules for how protein strands curl into their particular three-dimensional shapes. Understanding these principles could provide insight into biological processes and enable scientists to make proteins for specific uses.

Two recent studies move researchers closer to those goals. One boosts the basic knowledge of how proteins fold; the other offers a practical way of putting such knowledge to use.

Many scientists think that the formation of weak bonds between hydrogen and other elements, especially nitrogen and oxygen, helps proteins lock into their final shapes. To test this idea, Jeffrey S. Moore and Peter G. Wolynes of the University of Illinois at Urbana-Champaign and their colleagues synthesized short chains of phenylacetylene molecules, which don't contain elements that form hydrogen bonds, and dissolved them in a liquid.

The researchers found that the chains folded into spiral structures resembling alpha helices in proteins, suggesting that hydrogen bonds are not central to the folding of alpha helices. The chains wrap around themselves in order to minimize contact with solvent molecules, the researchers argue in the Sept. 19 SCIENCE.

In the second study, Bassil I. Dahiyat and Stephen L. Mayo of the California Institute of Technology in Pasadena reversed the usual strategy, which is to predict a protein's three-dimensional structure from its amino acid sequence. Instead, they developed a way to find the best string of amino acids to make a chosen shape.

As a target, the researchers chose a structure called a zinc finger, which helps certain proteins bind to DNA. This small module of 28 amino acids folds into a well-defined shape that contains many of the features found in larger proteins. Using a supercomputer, Dahiyat and Mayo sorted through the many possible combinations that could make up a 28-amino-acid segment. They combined available theoretical models and empirical results to predict each sequence's three-dimensional structure.

After finding the closest match to the target shape, the researchers synthesized that sequence in the lab and determined that its structure was nearly identical to that of the actual protein. "By combining theory, computation, and experiment," the researchers say, "[the method] has improved our understanding of the physical chemistry governing protein design." They report their findings in the Oct. 3 SCIENCE. —C. W.

Fuel chemistry advance wins prize

The National Academy of Engineering has awarded the 1997 Charles Stark Draper Prize to Vladimir Haensel, a chemical engineer at the University of Massachusetts at Amherst. The biennial award, engineering's highest honor, was given to Haensel for his development of a widely used method of producing high-octane fuels that burn cleanly and efficiently.

Until the 1940s, the only practical way to fragment the long hydrocarbon molecules in unrefined petroleum used heat and clay catalysts. The resulting fuel burned inefficiently, however, so gasoline companies added lead to improve its quality.

In 1947, while at Universal Oil Products in Des Plaines, Ill., Haensel developed much better, platinum-based catalysts, eliminating the need for leaded gasoline. The reusable catalysts produce more gasoline from the same amount of petroleum, while removing sulfur and many other contaminants. The result was cheaper, cleaner-burning fuel, which sparked an explosion of the transportation industry.

The process also yields large quantities of aromatic hydrocarbons, the raw materials for many plastics. Now, more than 4 million barrels of petroleum per day and 200 billion pounds of aromatic hydrocarbons per year are produced with Haensel's catalysts. —C. W.