SCIENCE NOW

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ARTICLES

Children of the Tropics: El Ni�o and La Ni�a

For many years, coastal residents of Peru have noticed a strange feature of the eastern Pacific Ocean waters that border their home. This region of tropical yet relatively cool water is host to one of the world's most productive fisheries and a large bird population. In the first months of each year, a warm southward current usually modifies the cool waters.

But every few years, this warming starts early (in December), is far stronger, and lasts as long as a year or two. Torrential rains fall on the arid land; as one early observer put it, "the desert becomes a garden." Warm waters flowing south bring water snakes, bananas, and coconuts from equatorial rain forests. However, the same current shuts off the deeper, cooler waters that are crucial to sustaining the region’s marine life. Fisheries can be decimated and the economy suffers.

This is El Ni�o, "the Christ child," so named because of its frequent Christmas appearance. Once thought to affect only a narrow strip of water off Peru, it is now recognized as a large-scale oceanic warming that affects most of the tropical Pacific. The meteorological effects related to El Ni�o and its counterpart, La Ni�a (a cooling of the eastern tropical Pacific), extend throughout the Pacific Rim to eastern Africa and beyond.

El Ni�o is normally accompanied by a change in atmospheric circulation called the Southern Oscillation. Together, the ENSO (El Ni�o-Southern Oscillation) phenomenon is one of the main sources of year-to-year variability in weather and climate around the world. Since recognizing some 25 years ago that the oceanic and atmospheric parts of ENSO are strongly linked, scientists have moved steadily toward a deeper understanding of ENSO. Climate forecasters have taken the first steps toward predicting the onset of El Ni�o and La Ni�a events months in advance.

The tropical Pacific releases tremendous amounts of energy into the atmosphere as heat and moisture and impacts the global climate; two phenomena generated by the energy in the Pacific are El Ni�o and La Ni�a.
Photo by NCAR

The presence of El Ni�o has been correlated with a number of wide-ranging atmospheric events. Some of the best-established effects are enhanced rainfall over the central Pacific, Peru, Ecuador, and the southern United States and drought in Australia, southern Africa, and northeastern Brazil. ENSO events have also been associated with warm winters in the former Soviet Union, mild winters in western Canada, and cool summers in northeast China, and they have been blamed for contributing to the collapse of the Peruvian anchovy fishery, the rise of the Chilean sardine fishery, and changes in the salmon fishery off the coast of the U.S. Pacific Northwest.

If scientists can better predict ENSO events, countries that are affected by them can prepare for drought and subsequent economic and health impacts. Even countries that are not directly affected by El Ni�o events can benefit from accurate predictions. For example, Kenya would want to know how its competitors in the world coffee trade -- Brazil, Southeast Asia, and Ethiopia-have been affected by ENSO.

The Basics of ENSO

It was the atmospheric part of ENSO -- the Southern Oscillation, or SO -- that first attracted the attention of scientists. Sir Gilbert Walker documented and named the SO in the 1930s. Other persistent patterns of high and low pressure had been previously noted in the North Pacific and North Atlantic; thus, the "southern" in SO.

The clearest sign of the SO is the inverse relationship between surface air pressure at two sites: Darwin, Australia, and Tahiti in the South Pacific. The pattern reverses every few years. It represents a standing wave or "see-saw" -- a mass of air oscillating back and forth across the International Date Line in the tropics and subtropics.

This one-dimensional picture was extended vertically by renowned meteorologist Jacob Bjerknes in 1969. He noted that trade winds across the tropical Pacific flow from east to west. To complete the loop, he theorized, air must rise above the western Pacific, flow back east at high altitudes, then descend over the eastern Pacific. Bjerknes called this the Walker circulation (in honor of Sir Gilbert); he also was the first to recognize that it was intimately connected to the oceanic changes of El Ni�o and La Ni�a.

The persistent easterly trade winds that blow throughout the tropics are a key ingredient in the ENSO process. Such winds push water toward the western Pacific. The sea level in the Philippines is normally about 60 centimeters (24 inches) higher than the sea level on the southern coast of Panama. The trade winds also allow the westward-flowing water to remain near the surface and gradually heat. This gives the water's destination-the western Pacific-the warmest ocean surface on earth. Usually above 28� C (82� F), parts of this pool are sometimes as warm as 31.5� C (89� F). The persistent oceanic heat surrounding Indonesia and other western-Pacific islands leads to frequent thunderstorms and some of the heaviest rainfall on earth. During an El Ni�o, this cycle changes; the trade winds weaken, allowing the pool of warm water to flow eastward toward the coast of South America.

ENSO Variations

Data reveal that ENSO is a regular yet highly variable phenomenon. The strength of the events, as judged by the pressure anomaly (variation from normal), varies greatly from case to case. The strongest El Ni�o in the past century occurred in 1982-83. Its effects included torrential storms throughout the southwest United States and Australia's worst drought this century. Sometimes the warm waters generated by an El Ni�o flow all the way across the Pacific. The 1982-83 event increased surface water temperatures near Peru by up to 4� C (7� F).

Among the many global phenomena connected to

the El Ni�o-Southern Oscillation are Asian monsoons.
Photo by NCAR

In the much weaker event of 1986-87, the warm water flowed eastward only as far as the mid-Pacific (near 170� W) and raised the temperatures there a modest 1� C (2� F) or so. In still other cases, warm anomalies first appear offshore of Peru and then progress westward to meet the preexisting arm pool.

El Ni�o and La Ni�a events have a tendency to alternate about even two years, so the average time between El Ni�os is four years. However, the time from one event to the next can vary from two to ten years. Sometimes El Ni�o and La Ni�a events are separated not by their counterparts, but by rather normal conditions.

Some researchers are using computer models to attempt to reproduce the physics of the ocean and atmosphere as they evolve during ENSO events. In 1990, a milestone was reached when the El Ni�o beginning late that year was successfully predicted months in advance by a computer model at the Lamont-Doherty Earth Observatory of Columbia University. Soon afterward, in 1992, NCAR produced the first model to show the evolution of ENSO-like behavior in an atmosphere containing twice the carbon dioxide of the present (a state likely to be reached by the year 2050). The model indicates that the rainfall anomalies connected to El Ni�o and La Ni�a may become stronger in a global-warming scenario.

What are the remaining obstacles to predicting El Ni�o and La Ni�a? One is to better understand their quasi-cyclic yet variable beginnings and endings. The factors leading to the end of an El Ni�o event are not yet entirely clear, as evidenced by the recent failure of computer models to predict the end of the El Ni�o that began early in 1991. The Lamont-Doherty model called for the event to end in 1992. It continued until late 1993, making it the longest-running El Ni�o in half a century.

Improvements in tropical-ocean observation will help advance research on ENSO. Buoys that measure ocean temperature to a depth of up to 500 meters (1,650 feet) are now moored throughout the tropical Pacific. A giant field program was mounted in the western Pacific in late 1992 and early 1993, the Tropical Ocean and Global Atmosphere Program’s Coupled Ocean-Atmosphere Response Experiment. The wealth of data from that program and others like it, and from long-term moored instruments, will help scientists better understand the tropical Pacific waters.

These lines of research point toward the day when ENSO events can be reliably predicted months ahead of time. Such information could be of great benefit in planning for drought, flood, and temperature extremes and in mitigating the associated pain and damage. If we cannot hope to control the effects of ENSO, there is real hope that we can understand and forecast its on-off switch.

Bob Henson

Scientists Study Ocean-Atmosphere Link

Heat and humidity, mosquitoes, and malaria plagued the more than 700 scientists, students, and specialists studying ocean atmosphere interactions near Townsville, Australia in 1992 and 1993. Toilets didn't flush and showers wouldn't shower, but the dedicated people involved in the Tropical Ocean and Global Atmosphere Program's Coupled Ocean-Atmosphere Response Experiment (TOGA COARE) persevered.

Researchers from mow than 15 nations including the United States, Australia, France, Japan, China, and the United Kingdom, measured temperature, moisture, precipitation, and mixing in the atmosphere. They used satellites, weather balloons, and specially equipped airplanes, ships, and buoys to better understand the engine that drives the global climate.

Energy from the sun drives large-scale atmospheric motions that determine global and regional climate. Because solar radiation strikes the earth most directly near the equator, the equatorial oceans absorb most of this energy. The oceans release much of the energy to the atmosphere as heat or moisture. In the atmosphere, the upward movement of warm, moist air transports energy, releasing heat when water vapor condenses into cloud droplets and raindrops.

Computer models and historical data indicate that a particularly important region is the western Pacific warm pool northeast of Australia. This warm pool, which covers more of the earth's surface than the continental United States, is the largest expanse of warm water (consistently higher than 28� C (82� F)) on the planet. Up to a half-meter (200 inches) of rain falls on the region each year as part of an intense convective process that releases great amounts of heat to the upper atmosphere and produces clouds that block some incoming energy, but trap outgoing energy. Variations in this exchange of energy between the warm pool and the atmosphere appear to induce climate variations over the Pacific basin and beyond.

Researchers are using the enormous quantities of data they gathered last year to better understand processes in climate. Through projects like TOGA COARE, scientists hope to answer the following questions: How do the ocean and atmosphere interact in a global system to produce variations on time scales of seasons to years? Can we understand this coupled system well enough to predict regional climate variations such as droughts, flooding, or stormy periods months to years in advance? Once we understand climate variation, can we then assess long-term climate change?

Climate variations such as El Ni�o have serious impacts on human affairs, including loss of life, crop failures and fishery depletion. With analysis of data from projects like TOGA COARE, researchers will improve their ability to make more accurate predictions of such variations for the benefit of society.

ACTIVITY

Make a Model of El Ni�o

Using hot and cold water, cooking oil, and a blow dryer or fan, you can model the El Ni�o phenomenon in your classroom. The two modelling options included in this activity demonstrate the difficulty scientists face in modelling complex systems.

Materials:
* A blow dryer or fan
* cooking oil

* food coloring
* glass baking dish or clear plastic shoebox
* cold water in container
* hot water in a container
* funnel

Safety Warning to Teachers: Please stress to your students the importance of keeping an electrical appliance, such as a blow dryer, away from water. Electric shock can occur when the appliance is in contact with water even if the appliance is switched off. Always unplug the appliance after use. If the appliance falls into or is in contact with water, unplug it immediately. Do not reach into water to retrieve the appliance unless it is unplugged. To reduce risk of electric shock, provide close supervision for students, or demonstrate the El Ni�o model for the entire classroom.

Procedure:
Measure out three to five cups of very hot and very cold water in separate containers. Add different colors of food coloring to each container. (Red for hot water and blue for cold water works well.) Be sure the water in each container represents extremes of temperature. Tepid water will not work effectively. Pour the hot water into the dish. Carefully add the cold water to the bottom of the dish using the funnel. This two layer effect represents El Ni�o. The sun-warmed water prevents the cold, nutrient-rich water from welling up to the surface. Without that cold water, the fish die. This version of the model shows the temperature variation of the ocean, but it does not illustrate an accurate ratio of warm water to cold water. Fill another dish about 3/4 full of colored water (temperature does not matter) and pour a thin layer of oil over the surface. This version does not demonstrate the temperature gradient, but does show a more realistic layering effect as found in the Pacific.

To illustrate the normal condition of the Pacific, turn the blow dryer on to a no-heat setting or the fan on to an air setting and point the air flow across the length of each dish. This air represents the trade winds. As the winds blow across the surface of the water, the warm pool is pushed to one side and the cold, nutrient-rich water can come up to the surface, providing food for the fish populations. A cessation of the trade winds accompanies an El Ni�o in the real world. Experiment with different depths of water and oil and different wind speeds. Does the warm pool creep back over the surface if the winds only blow a short while? What does the circulation pattern look like with the oil?

RESOURCES

El Ni�o Phenomenon Examined in SIRS Print and CD-ROM

A wealth of information about El Ni�o can be found in SIRS print volumes and on SIRS CD-ROM databases.

Based on the premise that many outstanding articles are irretrievable soon after publication, SIRS research staff selects articles from national and international newspapers, magazines, government publications and journals, and structures them for reference use. SIRS articles are reproduced both in print volumes and CD-ROM formats for quick reference.

Many articles on El Ni�o are contained in the "Earth Science" volume from the five-volume SIRS Science Series and in the "World Affairs" volume from the four-volume SIRS Global Perspectives Series. Both of these series are contained on SIRS Researcher CD-ROM. The articles are from publications such as *Christian Science Monitor, Discover, Earthwatch, Mariners Weather Log, National Wildlife, Oceanus, Sea Frontiers, Weatherwise* and *Wildlife Conservation.*

A number of El Ni�o articles are also found in SIRS Government Reporter CD-ROM, which contains documents from selected federal departments, agencies and commissions. Those government publications include *Background Notes* (U.S. Department of State), *FDA Consumer* (U.S. Food and Drug Administration), *Farmline* (U.S. Department of Agriculture), *Geographic Notes* (U.S. Department of State) and *Logos* (U.S. Department of Energy).

Following are excerpts from full-text articles in SIRS resources:

- *El Ni �o might seem to be a climatic "bad guy" bringing destructive weather patterns. Yet research at Florida State University and at the University of Arizona and U.S. Geological Survey Office in Tucson shows that abnormal rains associated with El Ni �o reduce wildfires. El Ni �o also puts a lid on Atlantic tropical hurricanes. "When it suppresses forest fires and hurricanes, El Ni �o is actually a 'good guy,'" O'Brien observes.*

"The El Ni�o Climate Connection," by Robert C. Cowen. Christian Science Monitor, Jan. 29, 1992. From SIRS Print Science Series or SIRS Researcher CD-ROM.

- *The weather too can affect the delicate ecosystem of the Channel Islands. The recent El Ni �o caused the death of an unusually large number of seals, sea lions, pelicans, and other marine life. El Ni �o dramatically reduced sea bird nesting and the number and size of seal and sea lion pups was much smaller than normal. However, it produced a banner year for whale watching in the sanctuary. With the population explosion of Krill, small shrimp-like crustaceans, an unprecedented number of whales came to feed Mild winds moved warm surface water away and caused nutrient rich deep water to up ell and reinvigorate the food chain.*

"Channel Islands National Marine Sanctuary," by Justin Kenney. Mariners Weather Log, Spring 1993. From SIRS Government Reporter CD-ROM.

National Center for Atmospheric Research / Learning About Science Easily and Readily Series.

The cover story is a shortened version of a LASERS article by the same title: "Children of the Tropics: El Ni�o and La Ni�a." You can get a copy of it by writing to NCAR Outreach, P.O. Box 3000, Boulder, CO, 80307.

Much of the information in this newsletter was drawn from "General Characteristics of El Ni�o-Southern Oscillation," by Kevin Trenberth, in Teleconnections, *Linking Worldwide Climate Anomalies,* edited by Michael Glantz, Richard Katz, and Neville Nichols (Cambridge University Press, 1991).

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