El Niño's Long Good-bye

As symptoms of the massive climate upset fade, the litany of familiar questions echoes on: How did it start? When will it happen again?

By CHERYL SIMON

Sea surface temperatures, while still higher than normal, are dropping over much of the central equatorial Pacific. Torrential rains no longer douse coastal Ecuador and Peru. The storms that chewed southern California's sandy beaches and carried them back to the sea have subsided, as have the floods in Louisiana and the record droughts in Indonesia and Australia. These events all were related to a dramatic warming of the Pacific and to changes in the winds—the massive climate upheaval called El Niño, an event that usually occurs every three to ten years.

The current El Niño, most scientists agree, is on the wane. They speak of it in guarded post-mortem tones, but none will call it dead. All signs point to its demise, but even now practiced eyes are scanning the most recent measurements of sea surface temperatures and winds in the Pacific to detect early signs that another warming may begin near Christmas, as El Niños usually do. A major warming in two consecutive years would be unprecedented, says Eugene Rasmusson of the National Weather Service's Climate Analysis Center in Washington, D.C. But he says, "It's not impossible, and we wouldn't want to miss it."

The El Niño of 1982-1983 will go down in history as both the greatest ocean-atmosphere disturbance ever recorded and as one of the most puzzling. Its peculiarities were several. It began in the western tropical Pacific, rather than off the Peruvian coast where warmer-than-normal waters usually define an El Niño's birth (SN: 2/26/83, p. 135). This time the classical coastal warming was not an early sign; it set in months after vast expanses of the central Pacific were considerably warmer than usual. The trade winds that blow steadily from east to west dropped off in May and June 1982, shirking their role of piling warm water in the western Pacific. Freed of the constraining trades, the warm water sloshed back toward South America, propelled by pulses of internal sea waves called Kelvin waves, and by the exceptionally strong winds from the west that persisted from late June through November 1982.

At the same time the thermocline, the boundary between warm surface waters and the cool deep waters, began to move. Usually it slopes from east to west so that the warm surface layer is thickest in the western Pacific. As the trade winds dropped off, the thermocline, like a teeter-totter in slow motion, began to shift. By September 1982 the thermocline in the west was 20 meters shallower than normal, and the surface layer was thickest in the central and eastern Pacific. By October the abnormally warm waters had piled up near Peru, preventing the cold nutrient-rich deep waters from welling up along the coast. The El Niño officially was underway.

Quirks notwithstanding, this El Niño has been a boon to scientific efforts to decipher the intricacies of the ocean-atmosphere system. In past El Niños, measurements of the atmosphere's response to the disturbance have been good. This time, Rasmusson says, researchers are combing abundant data from the sea as well, thanks to improved satellite observations and to ongoing projects to study the climate and ocean in the equatorial Pacific. Dozens of scientists worldwide tracked the chronology of this event, and because of the El Niño's stupendous magnitude, both in area affected and in size of the warming, it has had many unambiguous effects on weather around the world.

As the event continued, it engaged the public fancy and was linked to weather abnormalities that appear to be unrelated, or only marginally related, to the Pacific warming. For instance, opinions vary over whether the El Niño is linked to the current dry conditions in South Africa, or to the recent floods in Arizona. But researchers have pinpointed the El Niño as the cause of several extreme and unusual weather episodes such as the spring California coastal storms, the heavy snowfalls and subsequent spring floods in the west, and the severe droughts in South America.

Many meteorologists tie the El Niño to the warm, wet 1983 winter in the U.S. northeast, though this view is not unanimous. Jerome Namias, of the Climate Analysis Group at Scripps Institution of Oceanography in La Jolla, Calif., suggests it is more likely that the warm winter and the spring rains in the east were due partly to a high pressure system that started in the Atlantic late in fall 1982. This system, he says, diverted the storms northward, and also caused the spring rains that persisted for 38 straight days in London. He is tentative about ascribing to the El Niño last summer's drought in the eastern United States, though he says, "There

Major Impacts: El Niño/Southern

	Hurricanes/Storms			Flooding		
	Mountain & Pacific States	Hawaiian Is.	Tahiti	Gulf States	Cuba	Ecuador, N. Peru
Period	**9/82-6/83**	**11/82**	**4/83**	**12/82-5/83**	**1-3/83**	**12/82-6/83**
Public Impact	45 + dead	1 dead	1 dead	50 + dead	15 dead	600 dead
Property Impact	**$500M****	**$200M**	**$50M**	**$900M**	**$20M**	**$500M**
Agricultural Impact	$600M	$30M	—	> $200M potential	$150M	$150M
Total Impact	**$1,100M**	**$230M**	**$50M**	**$1,100M**	**$170M**	**$650M**

**Impacts that may have been influenced by the Southern Oscillation, Summer 1982 to July 1983*
**M = Million

Lesser Frigates used to abound on Christmas Island (left). By June 1983, countless adults and all of the chicks had died (right).

could be some very complex residual effects that we don't fully understand."

Other subtle and critical questions still elude definitive answers. What causes the trade winds to drop off? Why was this event so far out of phase with the classical timetable for El Niño genesis? How does one predict an El Niño?

George Philander of Princeton's Geophysical Fluid Dynamics Laboratory says the most important outcome of this event is that it provides the best evidence so far that the interaction between the ocean and atmosphere is the hub of the El Niño. He thinks this event belies the previous view that the ocean responds passively to a disturbance in the atmosphere. Rather, in a delicate feedback response, the ocean and atmosophere respond simultaneously. A small perturbation, such as a slightly warm pool of ocean surface water, can start things off by releasing some water vapor to the atmosphere. This warms the atmosphere and disrupts the winds, allowing the ocean to warm even more, causing it to release more heat to the atmosphere, and so on. After a few months, what began as a local upset takes on a life of its own, feeding on itself until the entire ocean is ensnared in the cycle. After a year or two, the ocean has released so much heat that the El Niño runs out of steam and typical seasonal movements of ocean and atmosphere regain the upper hand. However, minor ocean or atmosphere perturbations are frequent, and as yet no one can predict which will spawn an El Niño.

While conceding that this event certainly was unusual in some respects, Philander says it was only out of phase with the familiar El Niños, which typically begin in the eastern Pacific. These are linked to the east-west, or tropical, portion of a vast seesaw of atmospheric pressure, the other half of which hovers in the vicinity of Indonesia and Australia. The fluctuating pressure system is known as the Southern Oscillation, and it exerts a dominant force on global climate variations. The two areas are marked by heavy rainfall, and occur where surface winds converge and rise, carrying moist air into the atmosphere.

In a typical El Niño, the east-west convergence zone moves first, carrying heavy rains south toward the equator. Hence, the downpours in Peru. This latest El Niño, Philander believes, occurred when the convergence zone over Indonesia moved over an initial warm spot—a coincidence necessary for start-up of an El Niño. The convergence zone moved toward the east carrying the rains out to sea and leaving Australia and Indonesia to wither in a record drought. This time the rains in South America followed, instead of preceded, the effects in the western Pacific. He wrote in the March 24 NATURE that air moving downwind over the heated region can weaken the trade winds over the eastern tropical Pacific, and in some instances can cause eastward winds over the western Pacific.

There is always one more maddening step back in the endless sequence culminating in the El Niño, and 10 scientists may yield 11 opinions about when and how the disturbance begins. In light of Philander's scenario, the inevitable question is, "What causes the warm spot?" Namias believes the feedback concept is sound, but says that its stimulus may be far from the tropics. In the current case, he says, it was an extremely strong low pressure system south of the Aleutians that removed heat from the northern Pacific, causing a large pool of colder than normal water. When the low-pressure system arced

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Oscillation, Spring 1982 through July 1983

	Drought							
	Mexico & Central America	Mexico & Central America	S. India	Philippines	Indonesia	Australia	Peru (S) Bolivia (W)*	S. Brazil, N. Argentina E. Paraguay*
	6-8/82	3-5/83	9/82-6/83	11/82-6/83	2-11/82	4/82-3/83	11/82-5/83	12/82-7/83
	—	—	—	—	340 dead	71 dead 8,000 homeless	—	>600,000 evacuated 170 + dead
	—	—	—	—	—	**$500M**	—	**$1,500M**
	$500M	$50-100M potential	$150M	$450M	$500M	$2,000M	$240M	$1,500M
	$500M	**$100M**	**$150M**	**$450M**	**$500M**	**$2,500M**	**$240M**	**$3,000M**

Adopted from NOAA

Siegel and his colleagues made available to Asiatic and African elephants various concentrations of alcohol in calibrated buckets. Each elephant, according to Siegel, drank the equivalent of 20 beers at a time. "The highest concentration of alcohol they would accept was seven percent," he says, "although, with fruit juice disguising, some took up to 10 percent. Interestingly, seven percent is the exact percentage of alcohol in fermented fruit."

In each case, the alcohol — which the elephants would collect with their trunks and squirt into their mouths—would trigger the same behaviors: trunk-wrapping (suggesting the alcohol gave off a burning sensation), vocalization, ear flapping (this is how elephants ventilate, since they have no sweat glands), head shaking (usually only done to shake off insects), extreme lethargy, swaying and leaning (in some cases, falling down). In addition, there was a breakdown in group behavior — the elephants spent less than 45 percent of their time herded together while intoxicated, compared with 80 percent when sober.

Such alcohol-induced behaviors, researchers believe, have distinct implications for humans. In a recent issue of SCIENCE, for example, researchers from Harvard Medical School in Boston and the New England Primate Center in Southborough, Mass., described how female macaque monkeys, when given access to alcohol in the lab, became alcoholics. The subsequent reproductive system failure "following self-induced dependence on alcohol," the researchers write, "parallels the results of clinical studies of alcoholic women."

Attempting to discover the implications of his own work for human behavior, Siegel "increased the stress" on the elephants by restricting them to only two acres of land for one month. During this period, the researchers found the animals' alcohol consumption increased by three-fold; they fell down regularly and were aggressive toward experimenters. This behavior, Siegel notes, was similar to that observed among extremely dense herds in Kenya, where competition for food was severe.

"We've recorded increases in these intoxications in Africa over recent years, concommitant with increases in poaching, destruction of herds by drought and destruction of millions of acres of range forests by timber companies," Siegel says. "The few elephants that are left in Africa move about in herds so dense that stress is inevitable and severe.

"Taken together, these preliminary observations suggest that environmental stress may be an important variable in the self-administration of alcohol in these natural habitats," Siegel says. "Elephants drink, perhaps, to forget ... the anxiety produced by shrinking rangeland and the competition for food. And I think we can see a little bit of ourselves in this kind of behavior." □

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southward, it weakened the trades and initiated the warm spot in the ocean. "There's no end to this thing," Namias says. The basis for the dip in the band of westward winds, he says, is tied to the preceding general circulation of the atmosphere, and to underlying sea surface temperatures in the temperate latitudes.

The El Niño may be in decline, but residual effects abound. Surface temperatures in parts of the eastern Pacific still are several degrees above normal, so that an observer unaware of events in the last year or two would rush to sound an El Niño alert. The excess heat in the Pacific waters and the persistent eastward winds encourage formation of tropical storms and cyclones, which still persist at unusual strength and frequency. James Sadler and Bernard Kilonsky of the University of Hawaii in Honolulu report that "tropical cyclones in the South Pacific east of 180° in 1983 have no historical rival in terms of numbers, area of formations or prolonged season."

Sadler and Kilonsky have measured rainfall at several stations in the central Pacific. They find that during the El Niño, Christmas and Autuona islands each experienced rainfall two or three times above previous records. At Christmas Island the mean rainfall for January is 65 mm; this year 772 mm fell, up from a 1958 record of 575 mm. In February 1983, Autuona received 1,021 mm of rain, compared to a 90 mm mean and the February 1931 and 1942 records of 295 mm.

The combination of heavy rainfall and warm water was disastrous, in human terms, for Pacific populations of some fish, birds and marine mammals. These animals feed from waters on or near the surface. When upwelling of deeper water ceases, the surface warms and rapidly becomes depleted in nutrients. The single-celled plants important at the base of the food chain decline, providing less food for small fish that usually are prey for larger fish, birds, seals and sea lions. Ralph Schreiber, of the Natural History Museum of Los Angeles County, Calif., calls the El Niño phenomenon a "major evolutionary forcing factor for the whole of biological oceanography."

When faced with adversity, such as too little food, marine birds and mammals turn to a well-known survival tactic—they shut down their reproductive cycles and abandon their young. The biological reason is that babies are cheaper than adults, who by saving themselves, can return to breed again. In past El Niños many sea lion pups died and this event was no exception. In October 1982 near a research station in the Galapagos Islands, there were 90 pups. By mid-February only one pup remained. In both coastal Peru and the Galapagos, adult sea lions and fur seals died as well as pups.

Dominique Limberger of the Max Planck Institute in Seewiesen, West Germany and colleagues from Scripps and the University of Cambridge in England suggest in the October TROPICAL OCEAN-ATMOSPHERE NEWSLETTER that fur seals are especially vulnerable to an El Niño's effects. These animals prey on marine fish that normally migrate to the surface at night. Fish such as the Peruvian anchovy avoid the influx of warm water and stay beneath the thermocline, out of the fur seals' reach.

On Christmas Island, the fall 1982 breeding too was a total failure: All of the nestlings died. The adult birds fled the island in search of food and, Schreiber suspects, because the relentless rains had made the island such a soggy and unappealing roost. The adults took to the skies, but the survival ploy may not have worked. When Schreiber visited the island last June, some individuals of all species had returned, but in vastly diminished numbers. Of an estimated 17 million resident birds before the El Niño, only one percent had come home. He cannot say for sure what befell the missing millions but he thinks that they could not find enough to eat and starved while they soared over the sea, searching for food.

What birds there are have resumed breeding, but Schreiber thinks it will take the birds, many of which live 35 years and possibly as long as 50 years, a decade or more to re-establish their populations and breeding patterns. "In an evolutionary context," he says, "El Niños are the major factor that keeps bird populations at the levels we see them."

Smaller marine organisms may prove more resilient. This event is the first El Niño in which biologists have watched the recovery, says Richard Barber of Duke University in Beaufort, N.C. The lowest biological activity off coastal Peru occurred in May 1983, and remained sluggish through the first week of July. Then on July 7, he says, cool water surged up along the coast, and with it, productivity of marine microorganisms such as phytoplankton. In a band stretching 200 kilometers out to sea, productivity was 20 times greater, nutrients were 30 times as abundant, and biomass increased 20 times compared to conditions in May.

Barber has been working closely with officials in South America who must help their nations cope with the phenomenal repercussions of the climate upsets. In northern Peru and Ecuador alone, flooding between December 1982 and June 1983 claimed 600 lives and caused a total of $650 million damage to crops and property. In southern Peru and western Bolivia, drought losses totaled $240 million. Barber says that El Niños, which occur every three to ten years, "have a frequency that is just terrible for society. They are too far apart for people to plan on, and too frequent to ignore." For the nations of North and South America, the variations of El Niño need to be part of the agricultural and meteorological plan, he says, adding, "There is going to be another one." □