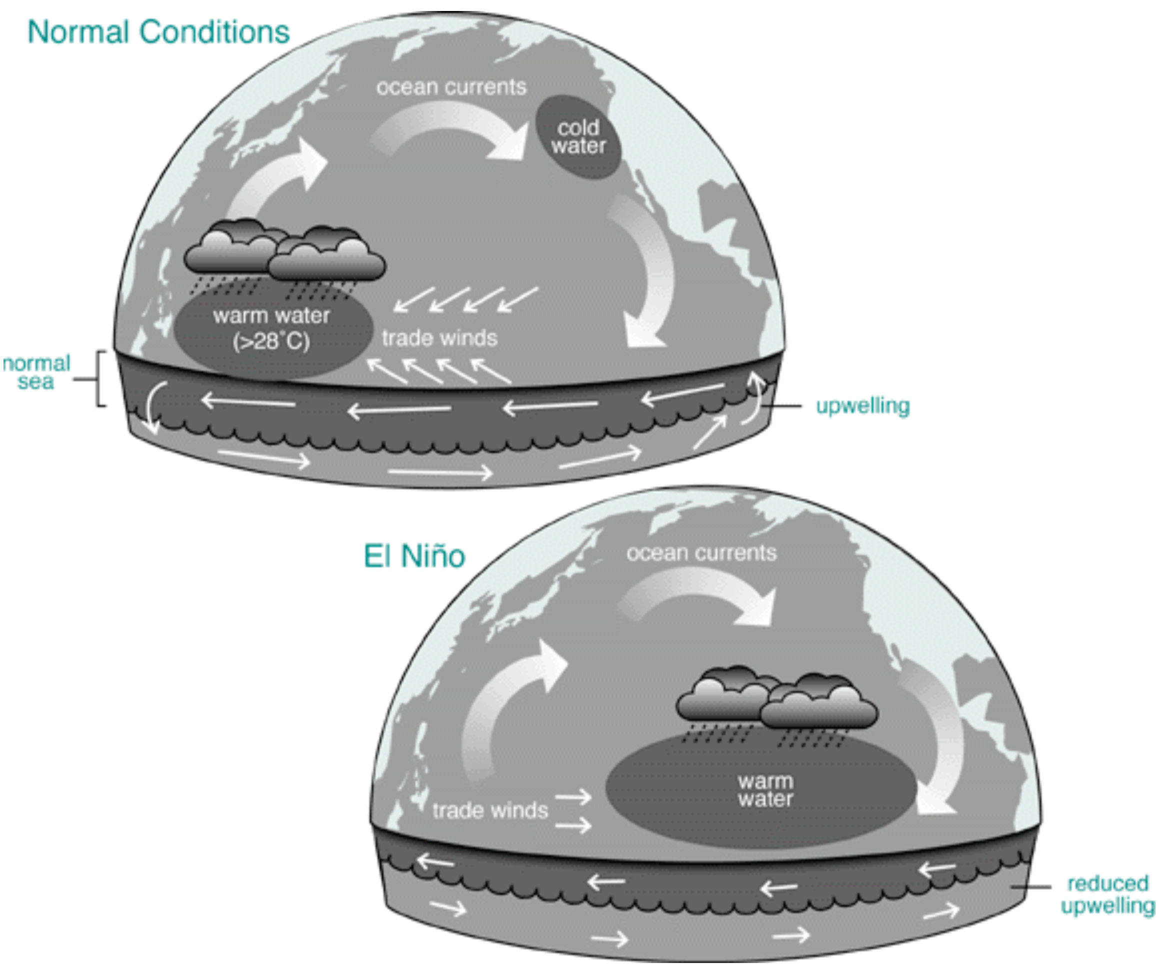
Quarterly
Winter 1997

El Niño and global warming: What's the connection?

As a record El Niño event changes temperature and precipitation patterns over a large part of the globe, it's natural to ask whether these changes have anything to do with the warming air and changing precipitation caused by human beings. According to Kevin Trenberth (NCAR Climate and Global Dynamics Division, or CGD), the answer is a likely yes--with emphasis on the "likely." But the link is quite complicated, and some questions remain unanswered.

Temperature and rainfall change naturally from season to season, but they also change on longer time scales--over the course of several years or decades. El Niño is a naturally occurring, longer-cycle mode of variability or change (see sidebar). When scientists look at the records of climate, the natural variability makes it hard to pick out any changes that may have come from human activities. Even harder is discerning how this natural variability itself could have changed.



The Pacific Basin under normal conditions and during an El Niño event. During El Niño, the

trade winds falter, and a pool of warm water moves eastward across the ocean. Normally, warm water extends to a greater depth in the western Pacific than in the east; during El Niño, this gradient evens out with the reduced upwelling off the coast of South America.

El Niño: Cooling power for the tropics?

Throughout history, the Pacific Ocean has moved back and forth between El Niño and La Niña, with periods of normalcy often coming in between. But like a big kid on a seesaw, El Niño has dominated the action lately. In the last 20 years, there have been seven El Niños and only three La Niñas, whereas historically the two have occurred in about equal numbers. The strongest event on record was in 1982-83, but the current event is a challenger for this title. The same 20-year period included an odd three-in-one El Niño lasting from 1990 to 1995, with three warming periods but no real recovery between them.

Trenberth theorizes that an El Niño event serves a specific role in the global heat budget, which he and De-Zheng Sun (a former NCAR postdoctoral student who is now at NOAA) have described in a paper submitted to *Nature*. "Our view is that El Niño is a fundamental way in which the tropics get rid of heat. If you continue to pour heat into the tropics--which is what the sun is always doing--the weather systems and the ocean currents, under their normal variations within the annual cycle, are not sufficient to get rid of all the heat. Something has to happen to get the heat out of the tropics, and the something which happens is El Niño." The authors support their theory with analyses of global oceanic and atmospheric heat budgets during an El Niño and a La Niña event in the late 1980s. If El Niño does serve as a release valve for tropical heat, then overall global warming could lead to more frequent events, as we have seen in the last two decades.

Another area of intersection between the phenomenon and global warming is precipitation. ENSO is associated with drought and flooding in many parts of the globe. Human-induced warming is accelerating the hydrological cycle; in a warmer atmosphere, surface moisture evaporates more quickly. Atmospheric moisture around the globe has risen about 10% since the early 1970s. Because this moisture is available to weather systems, precipitation rates rise, leading to an increased chance of flooding in areas where it is raining or snowing. If the humid air that El Niño pushes out of the tropics meets air that is already unusually moist, the resulting rain- or snowstorms would be even larger.

ENSO's northern relative

ENSO has a companion on the opposite side of the globe: the North Atlantic Oscillation. The NAO has two phases--like El Niño and La Niña. One phase of the NAO brings warm winters to Europe and well into Asia and cold winters to the few inhabitants of Greenland and the northwest Atlantic; the other phase does the reverse. Like ENSO, the NAO is changing in frequency, for reasons that are not yet understood.

At the beginning of this century, the NAO changed phase about every two years. For most of the century, it had about a 10- to 12-year period. However, starting in the 1970s, the phase did not change for about 20 years. This gave Europeans two decades of unusually warm winters, turning them into "some of the world's strongest believers in global warming," Trenberth jokes. "But they did have a wakeup call the winter before last, because the North Atlantic Oscillation did turn around, and they had a very cold winter as a result." (Last winter's NAO was neutral.)

As a result of the changes in the NAO and ENSO, says Trenberth, land in the Northern Hemisphere "has generally warmed up, while the main cold northerly outbreaks occur preferentially over the oceans, so that the North Atlantic has cooled and parts of the North Pacific have cooled, especially in winter. This has an influence on how the Northern Hemisphere temperature record looks." James Hurrell, also in NCAR's CGD, has calculated that 47% of the variance in the December-to-March Northern

Hemisphere temperatures can be accounted for by the combination of the NAO, ENSO, and the Pacific-North American teleconnection, as scientists call the influence of the Pacific Ocean on North American weather patterns.

Global warming's role is even less defined in the Atlantic than it is in the Pacific. "But it's intriguing that most of the warming has occurred over the land, which is what the models suggested that it should do--but for the wrong reasons." The models showed the land warming more quickly simply because it takes less heat to warm land than water.

Finding the connection

How can scientists untangle the knotted relationships among ENSO, NAO, and global warming? "We would normally use models to pin down what the effects would be," says Trenberth. However, "the models we have are not really good enough to answer our questions at the moment." Global general circulation models (GCMs) and models that couple the ocean and atmosphere are able to simulate El Niño events, but the modeled events have only about half the amplitude of those in the real world. Similarly, models do produce an NAO, but in most cases this simulated oscillation "hasn't been scrutinized carefully enough to see how realistic it is." The ones that have been examined don't have the range of intensity and variability that Mother Nature's do.

The speeded-up hydrological cycle that has resulted from global warming may lead to heavier rainstorms in El Niño years. (NCAR file photo by Curt Zukosky.)

One characteristic that makes El Niño hard to represent is that it involves the movement of heat around the ocean. To reproduce it correctly, models must be able to simulate globally both what's happening at the ocean's surface and the so-called conveyor-belt circulation, in which water moves slowly from the surface through the thermocline (the region with the strongest temperature gradients) to the deep ocean and vice versa. "One has to be able to get the large-scale circulation within the ocean and have the resolution to [simulate] these temperature gradients properly within the models in order to do it right," says Trenberth. "You can understand, perhaps, why it's such a difficult task."

But even though we can't trace the link between the changes in ENSO and NAO and global warming, Trenberth believes, "There's got to be a connection. The very unusual nature of what's happening now is an indication of that. The ambiguity arises because we can't quite sort out which is the natural part and which is the global warming part. If we continue to do this experiment with our climate for the next 20 to 30 years--which we will--presumably the global warming signal will be the thing that we will continue to see."

A primer on oscillations

An El Niño event changes the wind and water currents over the Pacific Ocean. The trade winds usually blow from east to west around the equator. In the Pacific, they blow surface waters clear across the Pacific Basin, warming them as they go. As a result, the western Pacific is home to a pool of the warmest water on earth, whereas the eastern Pacific is relatively cool for the tropics--as much as 8 degrees C cooler. The warm, western water makes for humid air and thus rainfall at that end of the ocean. During an El Niño event, this pattern breaks down. The trade winds falter, and the warm water begins to work its way back east. Rainfall follows the warm water, leading to droughts in Australia, Indonesia, and their neighbors and heavy storms on the west coast of South America. Ocean currents and the atmosphere's circulation spread the effects around the globe like ripples in a pond.

The opposite phase of El Niño is known as La Niña (the little girl). In this phase, the Pacific waters gain heat. Water in the eastern Pacific is more than usually cold, and rainfall is extra-scarce on South America's west coast while Australia is blessed with above-average precipitation.

El Niño is usually accompanied by a change in the atmospheric circulation known as the Southern Oscillation (SO), measured by the difference in air pressure between the island of Tahiti and Darwin, Australia (the Southern Oscillation Index). Tahiti has a higher air pressure than Darwin; during an El Niño event, the air pressure is higher than usual over Darwin, and unusually low over Tahiti. El Niño and the Southern Oscillation are so closely linked that scientists coined the term ENSO to describe the complete pattern.

Like the SO, the North Atlantic Oscillation is a variation in atmospheric circulation over the Atlantic, but from north to south: between the subtropical high (centered on the Azores) and the Icelandic low. The variation represents changes in the westerly winds across the North Atlantic Ocean. When pressure is lower than usual in the north, winters tend to be cold in Greenland and Labrador, and Europe gets warmer maritime air; in the opposite conditions, Europe gets direct blasts of arctic air. Although the NAO has a distinct effect on the ocean, with impacts on fisheries, it's not clear how the Atlantic Ocean in turn affects the atmosphere above it.

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Last revised: Tue Apr 4 14:43:58 MDT 2000