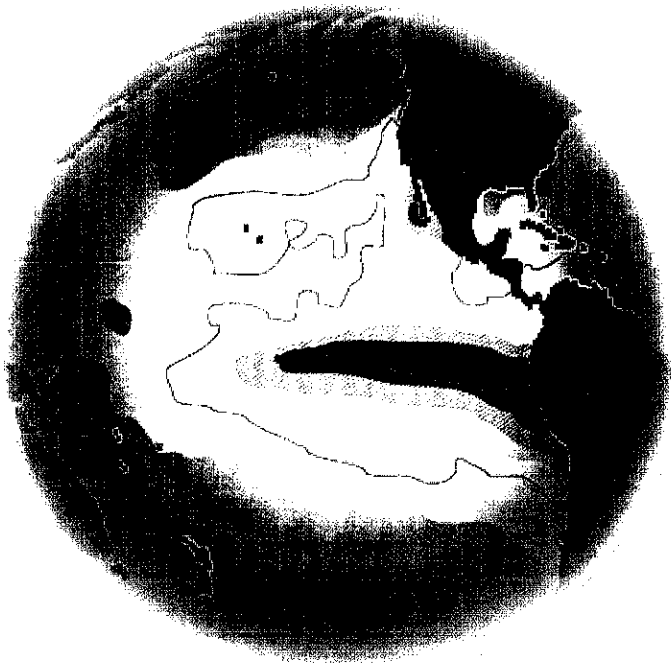


# EL NIÑO



*At a Glance*



*Working together in Weather, Water and Climate*

World Meteorological Organization

# *Rhythms of climate*

We are all accustomed to the regular rhythm of the sun-driven seasonal cycle that turns the weather throughout the year, for much of the planet at least, through its familiar cycles of warm to cold and wet to dry. Each location has its own particular variations on the general theme; some locations experience wide swings in the seasonal pendulum while others, especially in the tropics, have subtler shifts. However, there are other rhythms in the Earth's climate that are not so obvious at first, and not so regular. The largest of these is what has now become widely known as the El Niño phenomenon\*. El Niño is part of a complex interplay of processes in and between the atmosphere and ocean centred in the tropical Pacific Ocean. As the world's largest ocean basin, the Pacific is capable of generating variations in the global climate system whose impacts can be felt not only in the countries around its rim but further afield into many other regions of the world.

## *What is an El Niño event?*

An El Niño event occurs when the sea-surface temperature (SST) over a large area of the central and eastern equatorial Pacific becomes warmer than normal. At the same time, a number of concurrent changes occur in the normal pattern of winds blowing across the broader tropical regions of the Pacific. An El Niño event, however, is only one stage of a characteristic cycle of changes that occur in this region that also can be likened to a pendulum, in this case an irregular one. An El Niño event occurs when the pendulum has swung furthest in a particular direction.

Figure 1 shows the three main stages of an El Niño cycle: (1) the presence of an El Niño event; (2) normal or intermediate conditions; and (3) the presence of a La Niña event, which occurs when the pendulum has swung furthest away from El Niño conditions. One can see in these figures systematic patterns of change in both the atmosphere and ocean between the three stages. Perhaps the most important point to note is that the main centre of weather activity moves eastward or westward along the equator according to which stage is dominant at any time.

The changes observed in the atmosphere over many years were independently given the term Southern Oscillation since they were typically recorded by calculating the difference between the atmospheric pressures in Darwin, Australia and the Pacific island of Tahiti (both in the Southern Hemisphere). Around 20 years ago, when meteorologists and oceanographers gathered to examine and compare what was happening in their respective domains, they soon realized that what they had been observing independently was in fact an intimately connected set of processes. In a true spirit of cooperation, they then joined forces to study what has become known in scientific circles as the El Niño/Southern Oscillation phenomenon, or simply ENSO.

\* The term El Niño, the Spanish word for a boy child, derives from the observations by fisherman around the end of the year (i.e. Christmas) of the arrival of warmer-than-normal sea water off the tropical Pacific coasts of South America. This displacement of the typically cool waters of the region causes disruptions in the availability of the normally plentiful schools of fish.

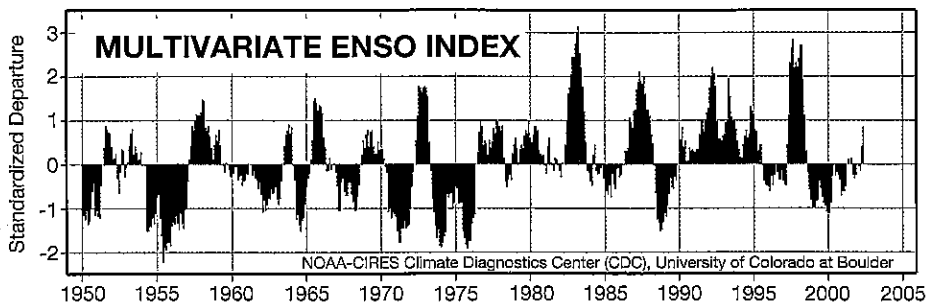


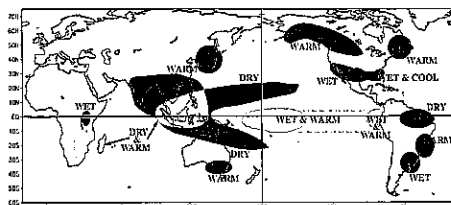
Figure 2. This graph represents the ENSO signal in the tropical Pacific since 1950. Major events are indicated when the signal is greater than +1 for El Niño events (red) and less than -1 for La Niña events (blue). Note the major El Niño events of 1982-83 and 1997-98, and the prolonged La Niña period from 1998 to 2001.

## What does ENSO do to the world's weather?

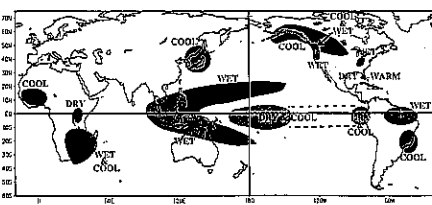
Since the tropical regions of the Earth act as the 'boiler-house' for the world's weather and climate, any process that significantly reorganizes the distribution of heat released into the tropical atmosphere is bound to have consequences on how weather is subsequently distributed around the globe. Hence, whenever El Niño or La Niña conditions prevail in the tropical Pacific, different but characteristic patterns of 'abnormal' rainfall and temperature are observed in many locations.

However, no two El Niño or La Niña events are identical. Some, such as the 1982-83 and 1997-98 El Niño events and the 1998-2000 La Niña event, are strong and forceful, leading to severe and widespread disruptions to weather patterns. Others are much weaker, in which case

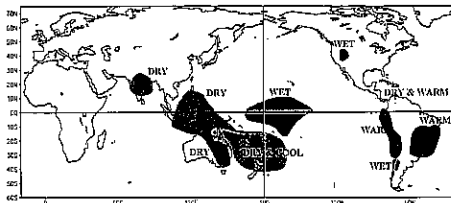
WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



WARM EPISODE RELATIONSHIPS JUNE - AUGUST



COLD EPISODE RELATIONSHIPS JUNE - AUGUST

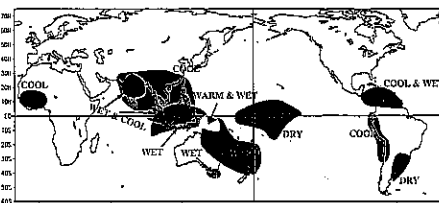


Figure 3. Some of the more typical seasonal weather patterns associated with El Niño or 'warm episode' events (left) and La Niña or 'cold episode' events (right) during the summer and winter months. (NOAA Climate Prediction Center)

it may be difficult to attribute any effects of the event to occurrences outside the immediate Pacific and Pacific Rim countries. In all cases, the effects of an El Niño or La Niña event will be mixed with other forces at work within the climate system. These may include the monsoons of Asia, Australia, Africa and the Americas, or fluctuations caused by abnormal patterns of SST in the tropical regions of the other major ocean basins — the Atlantic and Indian. This mixture of factors complicates the problem of deciding whether a particular flood, drought or storm can be blamed on an El Niño or its sibling La Niña. Despite the confusion of factors at play, there are several features of El Niño and La Niña events that are observed on most occasions. Some of the more common features are shown in the diagrams of Figure 3. The fact that these regional patterns tend to recur with each El Niño or La Niña event suggests that if we can predict a coming event, then we will be able to alert countries in the particular regions of an increased risk of anomalous seasonal conditions. This would not only enable decision makers in many sectors sensitive to weather and climate variations to take appropriate measures to mitigate possible adverse effects, but also to take advantage of any positive benefits that might come with these events.

## Can we now predict ENSO?

As noted above, scientists have made an enormous effort over the past 20 years to understand what drives ENSO. The research, based on data received from a vast array of observing instruments, some relatively simple statistics, and increasingly very powerful computers running very complex models of the climate system, is beginning to improve our understanding. For example, scientists are now able to detect and track patterns of sea water temperature moving eastward below the surface of the tropical Pacific. These include patterns of warmer water that eventually emerge at the ocean surface off the coast of South America and can be tied to disruptions to the local weather, e.g. in the form of the torrential downpours associated there with an El Niño event.

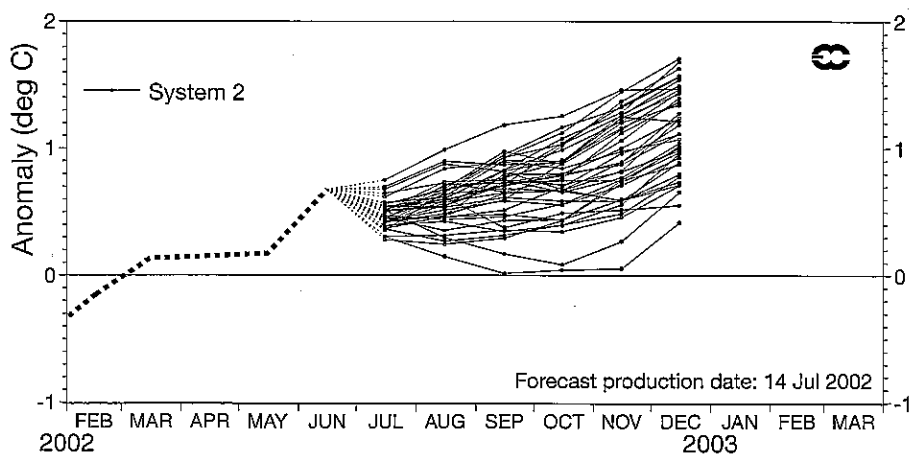


Figure 4. A group of computer forecasts of sea-surface temperature (SST) anomaly in the tropical eastern Pacific for July-December 2003. The blue line represents actual SSTs, the red lines represent forecast SSTs. Despite the spread in individual forecasts, all suggest that the SST will remain above normal. (European Centre for Medium-Range Weather Forecasts)

The real and exciting promise for climate (and in particular ENSO) prediction, however, lies in the use of the computer models. Using data on what is happening in the atmosphere and oceans, it is possible for computer models to simulate or forecast what might happen over the following weeks and months. With today's powerful computers, this can be done many times for the same period. For each simulation, slightly different starting conditions are used to represent our uncertainty of the 'true' state of the climate system. Due to this induced uncertainty, the forecasts begin to diverge after a time. The principle behind this approach is that despite the chaotic nature of the weather, if there are strong forces at work, such as an El Niño event in the Pacific, these will tend to dominate in the individual simulations. The extent to which the forecasts diverge can therefore be interpreted as a measure of the confidence in the forecast. The less the forecasts diverge, the higher the confidence and vice versa. Statistics can then be derived for risk assessment purposes from the group of possible weather outcomes to aid farmers, water and energy resource managers and the disaster preparedness community. This approach is depicted in Figure 4 for a forecast of SST in the eastern tropical Pacific.

Thus, the benefits to be gained from new-found expertise in seasonal forecasting will not come from being able to predict the likelihood of rain on a particular day several weeks or months in advance. Rather, they will come from assessments of the probability that a season's rainfall may or may not be adequate to meet the demands of a nation.

Despite the optimism, there are some important caveats. Apart from the seasonal cycle, ENSO provides the strongest recurring signal in the records of the Earth's climate on seasonal to inter-annual timescales. While the direct effects are strong in the tropics and especially the Pacific, they weaken the further one moves away from these regions. Across the higher latitudes of Europe, for example, the effects of ENSO are usually so swamped by other factors that it is generally of little significance in predicting the overall outcome of a particular season. This is true even if the presence of an ENSO event may have been a factor in the occurrence of some single weather event during the season, e.g. a major but short-lived wind storm.

Scientists are working to identify other recurring patterns or signals in the climate record that may show promise in improving predictive skill. If they can learn to understand them as they have ENSO, and ensure that their characteristic behaviours are faithfully reproduced in the computer models, then further progress in extending seasonal forecasting capabilities is clearly possible.

## *ENSO and Climate Change*

'What is the connection between El Niño and Global Warming?' is certainly an important question. As noted above, ENSO has been around for a long time — far longer than the period over which human activities have begun to show up in the climate record in the form of global warming. Consequently, increased amounts of greenhouse gases in the atmosphere from human activities are not 'causing' El Niño events to occur. Nevertheless, because these increases may cause more general global-scale changes in the climate system, it is possible that those changes will show up as changes in the ENSO cycle. A recent assessment by the Intergovernmental Panel on Climate Change (IPCC), for example, has cautiously suggested either little change or a small increase in the strength of ENSO events over the next 100 years.

# The 1997-98 El Niño

The major El Niño event of 1997-98 is ranked, along with that of 1982-83, as one of the strongest in history. Following are some of its consequences in a few of the affected countries:

## *Australia*

Dry conditions prevailed across large areas of Australia throughout the southern winter of 1997, but the wheat crop was saved by drought-breaking rains in September and October. It is likely that warm SSTs in the Indian Ocean during 1997 provided the right conditions to prevent a repeat of the 1982-83 El Niño event for Australia, which devastated much of its agriculture.

## *Indonesia and Papua New Guinea*

Low rainfall from May-June 1997 until about March 1998 led to drought accompanied by severe wildfires in areas of Indonesia, causing massive smoke pollution.

## *China*

The Asian summer monsoon of 1997 did not penetrate as far north as usual and there was significantly reduced rainfall over northern China. Heavier-than-normal snowfalls accumulated over the Tibetan Plateau and high rainfall totals at lower elevations contributed to record river heights and lake and water storage levels. Early snowmelt and average to above-average spring and summer rains after the El Niño event combined to cause record flooding, with many deaths and widespread infrastructure damage over large areas of southern China during the 1998 summer.

## *Peru*

Several regions of Peru received very heavy rainfall that resulted in significant destruction. Temperatures were also significantly warmer than normal.

## *Ecuador*

From December 1997 through April 1998, heavy rainfall continued over the coastal regions of Ecuador. Flooding, mudslides and damage accompanied the heavy rainfall.

## *Paraguay*

From October 1997 to May 1998 Paraguay, particularly the southern parts, received above-normal rainfall with extensive flooding.

## *Kenya and Ethiopia*

July to September 1997 was relatively dry over Ethiopia as the normal summer rains failed to materialize. Such conditions over sub-Saharan Africa are not uncommon during El Niño events. What was unusual in 1997 was the heavy rain with widespread flooding over much of East Africa from October 1997 to February 1998. The heavy rainfall was likely an outcome of the abnormally warm SSTs over the western equatorial Indian Ocean. Rainfall of such magnitude is rare for East Africa and may be partly attributed to the strength and timing of the 1997-98 El Niño event.

## *Atlantic Tropical Storm and Hurricanes*

There was a nearly complete shutdown of Atlantic tropical storm and hurricane activity after July 1997, and an expanded area of favorable conditions for hurricane activity over the eastern North Pacific. The rapid swing towards La Niña conditions after mid-1998 is likely to have been a factor in the unusual behavior of Hurricane Mitch that devastated Central America in 1998.

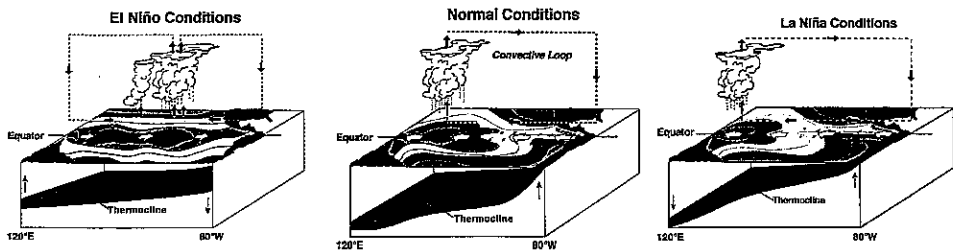


Figure 1. Three stages of a typical ENSO cycle. Shown are patterns of sea-surface temperatures (SSTs) across the tropical Pacific Ocean (red-warm to blue-cool), surface ocean currents along the equator (broad arrows), and wind circulation in the atmosphere (thin arrows). Also shown is how the centre of tropical convection shifts. Note too the change in slope of the thermocline (blue band below the ocean surface), which marks the boundary between water well mixed by wind blowing over the surface and the deeper, more stably stratified ocean.

(M.J. McPhaden, NOAA/Pacific Marine Environmental Laboratories)

## Is ENSO a new phenomenon?

No. Evidence suggests that El Niño and La Niña events have been occurring for a very long time. However, it is only in the past decade or so that an understanding of how they form and are maintained has been gained.

## What is the period of the ENSO pendulum?

A full cycle of the ENSO pendulum takes on average around three to six years to complete, but there are wide variations (Figure 2). There is evidence of periods in the distant past when the ENSO cycle disappeared for several decades. El Niño events are often referred to by scientists as 'warm' and La Niña as 'cold' events, which refer to SST anomalies observed in the central to eastern tropical Pacific at the two extremes of the pendulum's swing.

Since the ENSO cycle is not regular like the seasonal cycle, there has been a great deal of investment during the past two decades in monitoring and research to enhance the capacity to predict it. This applies especially to predicting the onset and intensity of El Niño and La Niña events, which are frequently associated with extreme weather events and persistent periods of drought in many parts of the world. The availability of high-speed computers has enabled scientists to put together a coherent picture of the complex atmosphere-ocean interactions from the massive amounts of data now available to study the phenomenon.

## Why does El Niño affect global weather patterns?

As shown in Figure 1, an El Niño event is characterized by warmer-than-normal water along the equator in the central and eastern Pacific. This concentration of excess heat, much further east than usual, forces changes in the atmosphere immediately above, which affect the wind flow in the upper atmosphere. The effects are then carried around the globe by the modified large-scale circulation of the atmosphere, resulting in changes in the normal weather patterns of many regions. The consequence of a major El Niño event is a climatic response that is global in scale.

## Where can I learn more about El Niño?

Information on El Niño can be obtained through the WMO Web site ([www.wmo.ch](http://www.wmo.ch)), which provides links to a number of the major climate prediction centres and to the Web servers of WMO Members. These sites give information about the climatological characteristics of ENSO, including the corresponding rainfall and temperature patterns; observed evolution of the SSTs over the Pacific; the outlook for the Pacific Ocean SSTs, rainfall and temperature during the coming months; and other related information. Inquiries concerning a specific country should be directed to the National Meteorological Service in that country, which will provide details and specific information on the local-scale manifestations of ENSO.

More scientific information on the global patterns of abnormal precipitation and temperature related to warm and cold episodes in the tropical Pacific and their impacts and consequences can be found in the following publications:

*Learning to Predict Climate Variations Associated with El Niño and the Southern Oscillation: Accomplishments and Legacies of the TOGA Program* (1996), U.S. National Research Council, Washington DC.

*The 1997-1998 El Niño Event: A Scientific and Technical Retrospective* (WMO-No. 905) (1999), World Meteorological Organization, Geneva.

*Once Burned, Twice Shy: Lessons Learned from the 1997-1998 El Niño* (2001), Glantz, M.H. (Ed.), United Nations University, Tokyo.

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