NASA Facts

National Aeronautics and
Space Administration

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The Earth Science Enterprise Series

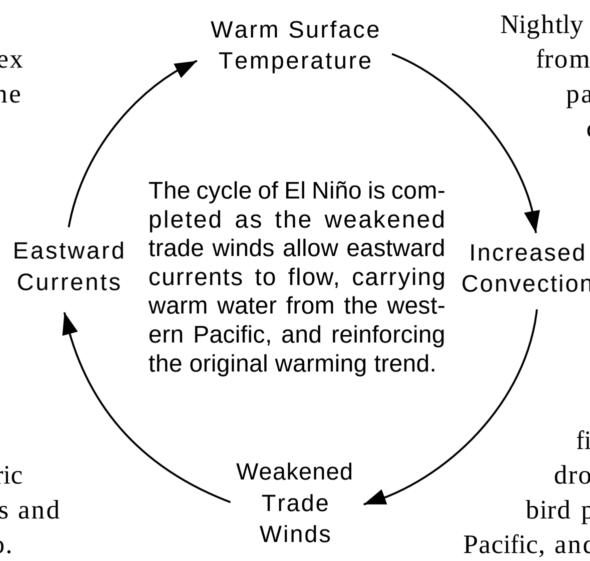
These articles consider Earth's many dynamic processes and their interactions.

El Niño

The Child

Fishermen who ply the waters of the Pacific off the coast of Peru and Ecuador have known for centuries about the El Niño. Every three to five years during the months of December and January, fish in the coastal waters off of these countries virtually vanish, causing the fishing business to come to a standstill. South American fishermen have given this phenomenon the name El Niño, which is Spanish for “The Child,” because it comes about the time of the celebration of the birth of the Christ Child.

An understanding of the complex processes at work to produce the El Niño requires information about phenomena occurring all across the tropical Pacific, not just its eastern boundary, the west coast of South America. Remote sensing, particularly from the weather satellites, has been the source of data that finally has made it possible to understand the interactions between atmospheric winds and oceanic temperatures and currents that lead to the El Niño.



Worldwide Effects

El Niño effects are not limited to the disturbed areas off of Peru and Ecuador. They can be transmitted great distances. In many parts of the world, the disruption of normal climate can have tragic and/or profound economic consequences. El Niño has been shown to be related to the unusual flooding in Texas in the winter of 1991-1992 and to the anomalous warmth experienced in the southeast United States in the same period.

Nightly cloud images on television news from weather satellites show us the paths followed by the storms that cross the Pacific and travel northward from equatorial regions to the central lands of North America. Important indirect or secondary El Niño effects have been noted in other locations worldwide. During the 1982-1983 El Niño, there were huge drought-related fires in Borneo and Australia, drought-related eradication of sea bird populations on islands in the Pacific, and flooding on the east coast of equatorial South America, the Rocky Mountain region of the United States, and in Brazil, south of the Equator.

Air/Sea Interaction

A key element of the El Niño phenomenon is the interaction between the winds in the atmosphere and the sea surface. Without this air/sea interaction, there would be no El Niño. Taking advantage of observations from the National Oceanic and Atmospheric Administration (NOAA) weather satellites, scientists have been able to track shifting patterns of sea surface temperatures. The pool of warm waters that normally resides in the western waters of the Pacific has been seen to drift eastward toward the western coast of South America. This foretells the advent of an El Niño.

NASA satellite images also help us see the shifting patterns of storms over the equator that are a consequence of the shifting locations of the warm water pool. Towering cumulus clouds, reaching high into the atmosphere with multiple regions of strong up- and-down vertical (convective) motions, form and move eastward across the Pacific as they are generated by the warm surface waters. This movement of the powerfully active convective regions alters the surface winds, and weakens the normally prevailing east-to-west trade winds. (See Figures 1 and 2.)

Space Observations Pin Down the El Niño Phenomenon

Scientists at the Goddard Space Flight Center and elsewhere have used numerical models and theoretical studies to understand the processes that lead to El Niño. Comparison with data

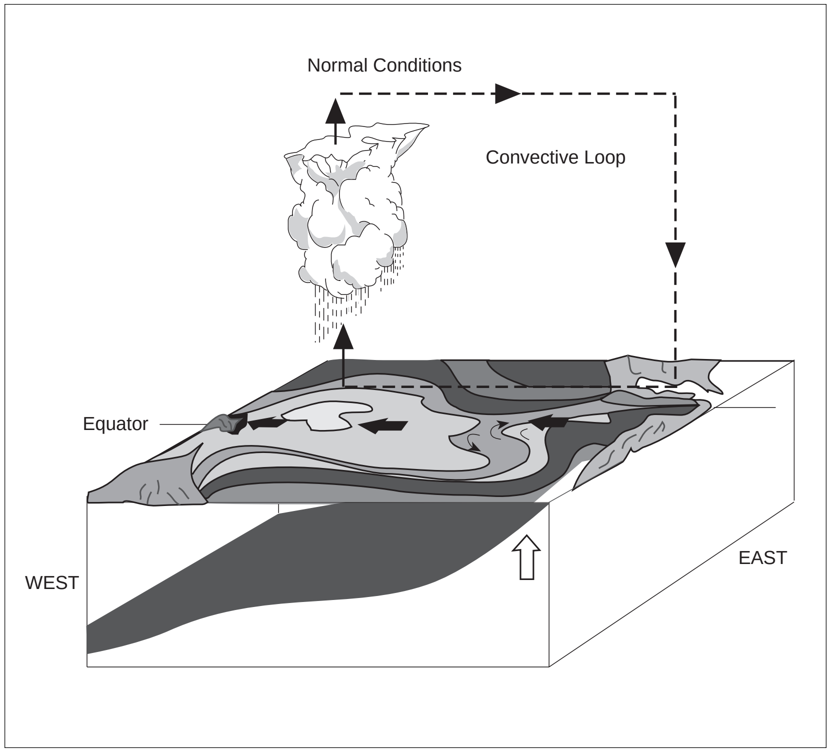


Figure 1. Normal conditions over the Pacific basin.

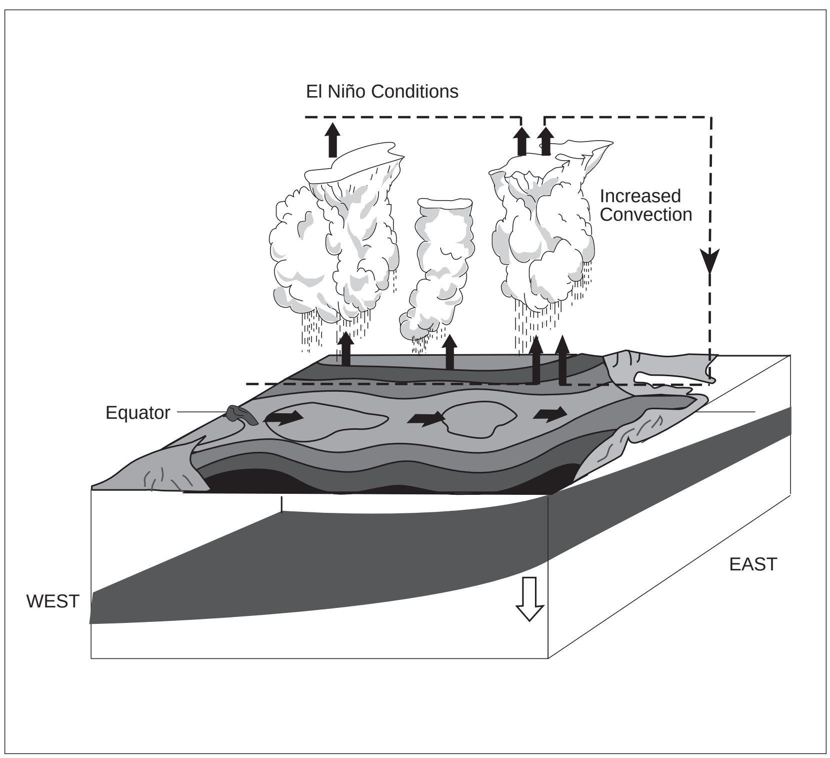


Figure 2. Disturbed conditions over the Pacific basin during an El Niño.

has shown the sequence of events leading up to El Niño.

In normal years, when there is no El Niño, the trade winds tend to blow from east to west across the waters of the eastern Pacific. They tend to drag the surface waters westward across the ocean. In turn, this causes deeper, colder waters to rise to the surface along the coast. The “upwelling” of deep ocean waters brings with it nutrients that otherwise would lie near the bottom of the ocean. The fish population living in the upper waters is dependent on these nutrients from below for survival.

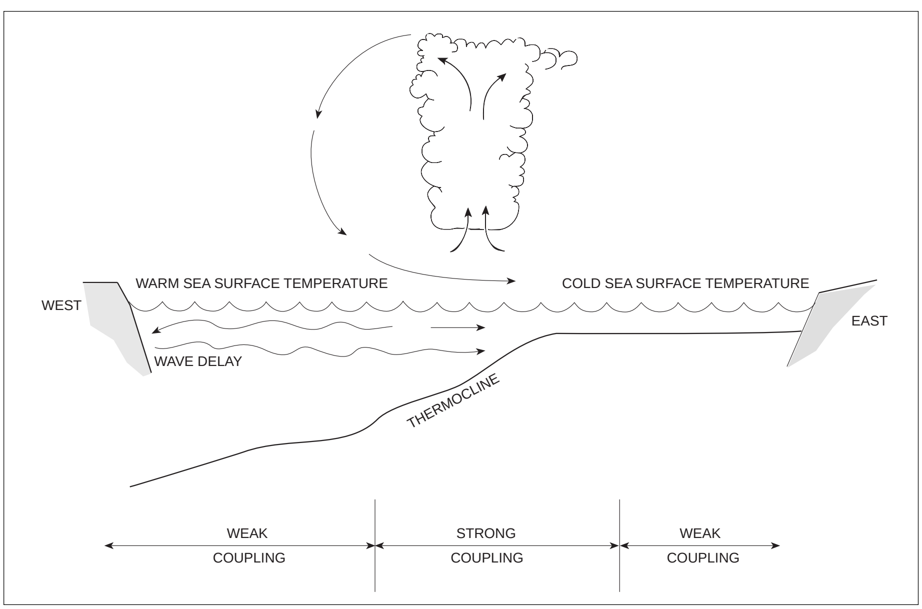
During an El Niño, the westward trade winds weaken, causing the upwelling of deep water to cease. The consequent warming of the ocean surface further weakens the trade winds, and strengthens El Niño. Without upwelling, the nutrients from the deep water are no longer available. This signals a severe reduction in the fishing industry until the time that normal conditions return.

Prediction of El Niño events is now the focus of a major scientific initiative. The prediction of El Niño requires sophisticated numerical models to simulate: 1) the changes within the ocean that cause surface temperatures to warm; 2) the changes in atmospheric convection and clouds due to surface warming; and 3) the changes in surface winds that are caused by the convective disturbances. The societal impacts of accurately forecasting El Niño up to a year in advance are huge, allowing economic and agricultural policy makers to adapt to short-term climate fluctuations in a beneficial way. Satellite observations will continue to play a crucial role in ensuring the success of these forecasts, by providing accurate measurements of the present conditions in the region, an essential first task for prediction.

NASA Missions to Study El Niño

Over the years, several NASA missions have studied the effects associated with El Niño, such as changes in sea-surface temperature (SST) and cloud cover changes. These studies are augmented by data from operational satellites of the National Oceanic and Atmospheric Administration (NOAA).

Initial efforts at mapping SST and cloud cover were conducted using data from NASA’s Nimbus series of satellites. The four-channel Advanced Very High Resolution Radiometer (AVHRR), flown on NOAA’s TIROS-N weather satellite in 1978 and on the NOAA-6 satellite in 1979, greatly increased the accurate measurements of El Niño effects. (“Four channel” means that the instrument views in four different parts of the electromagnetic visible and infrared spectrum.)



Schematic of the main processes thought to produce *El Niño*. Above-normal sea surface temperatures produce increased precipitation and changes in atmospheric circulation. These tend to maintain the warm temperatures by driving oceanic currents. Some of these effects are immediate; others act after the forced signal reflects from the western boundary and returns to the region of strong coupling.

Still further increases in accuracy resulted when a fifth channel was added to the AVHRR instrument flown on NOAA-7 in 1981, and on subsequent NOAA satellites. The fifth channel improved the measurement of SST by providing corrections for atmospheric water vapor that otherwise would have interfered with the temperature measurements.

The joint U.S.-French TOPEX/Poseidon mission was launched in 1992 and is providing global determinations of changes in ocean surface currents that are related to the El Niño phenomenon. The currents are determined from changes in ocean surface elevations measured by altimeters on TOPEX/Poseidon with accuracies of a few centimeters.

NASA has initiated a "Pathfinder Program" to make higher-quality data available from past and current missions. These efforts will lead up to the Earth Observing System (EOS), the main initiative of NASA's Earth Science Enterprise. The first in the series of EOS satellites will be launched in 1998. The accompanying table lists some of the missions that relate to the study of El Niño, and some of them are discussed briefly here.

The joint U.S.-Japanese Tropical Rainfall Measuring Mission (TRMM), launched November 27, 1997 uses for the first time, both active (radar) and passive microwave detectors from space to provide measurements of precipitation, clouds, and radiation processes in lower latitudes, including the portions of the Pacific Ocean where El Niño occurs.

A NASA scatterometer called NSCAT flew on the Japanese Advanced Earth Observing System (ADEOS) spacecraft, which was launched in August 1996. NSCAT provided very high quality data on the speed and direction of ocean-surface winds worldwide. Unfortunately, after nine months in orbit, a spacecraft failure brought to an end the stream of extremely valuable NSCAT data. Recognizing the important contributions to Earth science made by NSCAT, NASA now plans to launch a copy of the new SeaWinds scatterometer as early as November 1998 as part of a dedicated mission named QuikSCAT to bridge the gap remaining before launch (planned for August 1999) of the Japanese spacecraft designated ADEOS II, which will also carry a SeaWinds instrument.

In addition to the scatterometer measurements, which use active microwave radar systems to determine surface wind speeds and directions over the ocean, surface wind speeds are also being obtained from a passive microwave sensor on a Department of Defense spacecraft. The instrument is called the Special Sensor Microwave/ Imager (SSM/I).

Key sources of Pathfinder data related to El Niño are data from the five-channel AVHRRs flown on NOAA-7, 9, and 11. These historic data sets cover the period 1981 through 1992 and beyond and will permit more-accurate SST determinations than were previously available. These data are important to the development and testing of a new generation of computer models in which the interacting processes of the land, the atmosphere, and the oceans are coupled. These coupled models will lead the way to an increased understanding of phenomena such as El Niño and the teleconnections that link El Niño with changes in weather patterns throughout the world.

NASA's SeaWiFS (Sea-viewing Wide Field of View Sensor) was launched on the OrbView-2 satellite in August 1997. The SeaWiFS sensor is designed to detect ocean color, which is an indicator of microscopic plant life in the ocean. The growth of such plants (called phytoplankton) is affected by the changes in sea surface temperature that are related to El Niño.

With the launch of the EOS satellites, starting in 1998, we will have the means to collect and analyze the most-comprehensive data set ever acquired for the development of coupled models. This data set will increase markedly our understanding of the causes and effects of such large-scale ocean-atmosphere phenomena as El Niño.

Earth Science Enterprise

Selected Missions Related to the Study of El Niño

Mission	Launch	Scientific Objective
Nimbus Series	1964-1978	Initial global sea-surface temperature and cloud-cover mapping
TIROS-N/NOAA	1978-	Daily global sea-surface temperature and cloud-cover mapping (increased accuracy with addition of fifth channel on the NOAA-7/AVHRR in 1981)
Defense Meteorological Satellite Program (DMSP)	1987	Precipitation, ocean-surface winds from SSM/I
TOPEX/Poseidon	1992	Ocean topography and circulation
Advanced Earth Observing System (ADEOS) Japan	1996	Ocean-surface wind vectors from NASA Scatterometer (NSCAT)
SeaWiFS	1997	Ocean color, phytoplankton
Tropical Rainfall Measuring Mission (TRMM)	1997	Precipitation, clouds, and radiation processes in lower latitudes
Earth Observing System (EOS)	1998-	Advanced radiometers, sounders, altimeters, the SeaWinds scatterometer, etc., will provide the most-comprehensive data set for El Niñ o studies
QuikSCAT	1998	Ocean-surface wind vectors from the NASA SeaWinds scatterometer
ADEOS II	1999	Ocean-surface wind vectors from the NASA SeaWinds scatterometer