

El Niño/ Southern Oscillation



**World
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Organization**

Weather · Climate · Water

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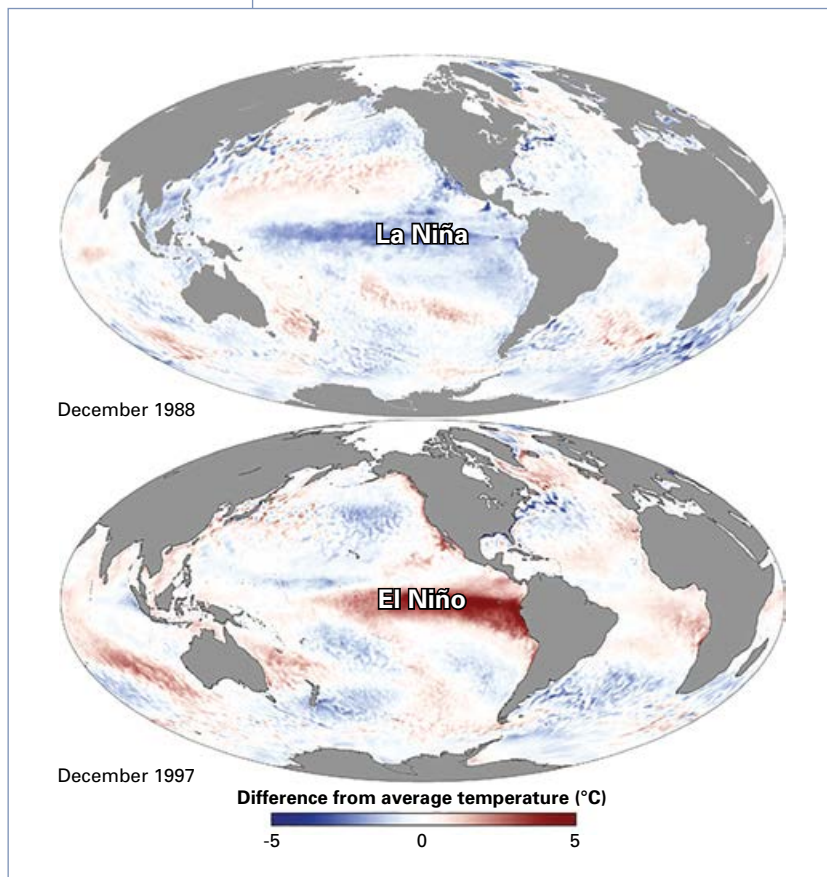
INTRODUCTION

The El Niño/Southern Oscillation (ENSO) is a naturally occurring phenomenon involving fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere. This phenomenon has a major influence on climate patterns in various parts of the world. Scientific progress on the understanding and modelling of ENSO has improved prediction skills within a range of one to nine months in advance, helping society to prepare for the associated hazards such as heavy rains, floods and drought. The value of these predictions can translate into hundreds of millions, if not billions, of dollars in potential savings.

El Niño and La Niña are the oceanic components while the Southern Oscillation is the atmospheric counterpart, thus giving rise to the term El Niño/Southern Oscillation.

The El Niño/Southern Oscillation comprises three phases: El Niño, La Niña and neutral. El Niño, meaning “boy child” in Spanish, was first used in the nineteenth century by fishermen

Maps of sea-surface temperature anomalies in the Pacific Ocean during a strong La Niña and El Niño (Source: NOAA Climate.gov)



Major flooding in the Plurinational State of Bolivia after El Niño-related events in 2007

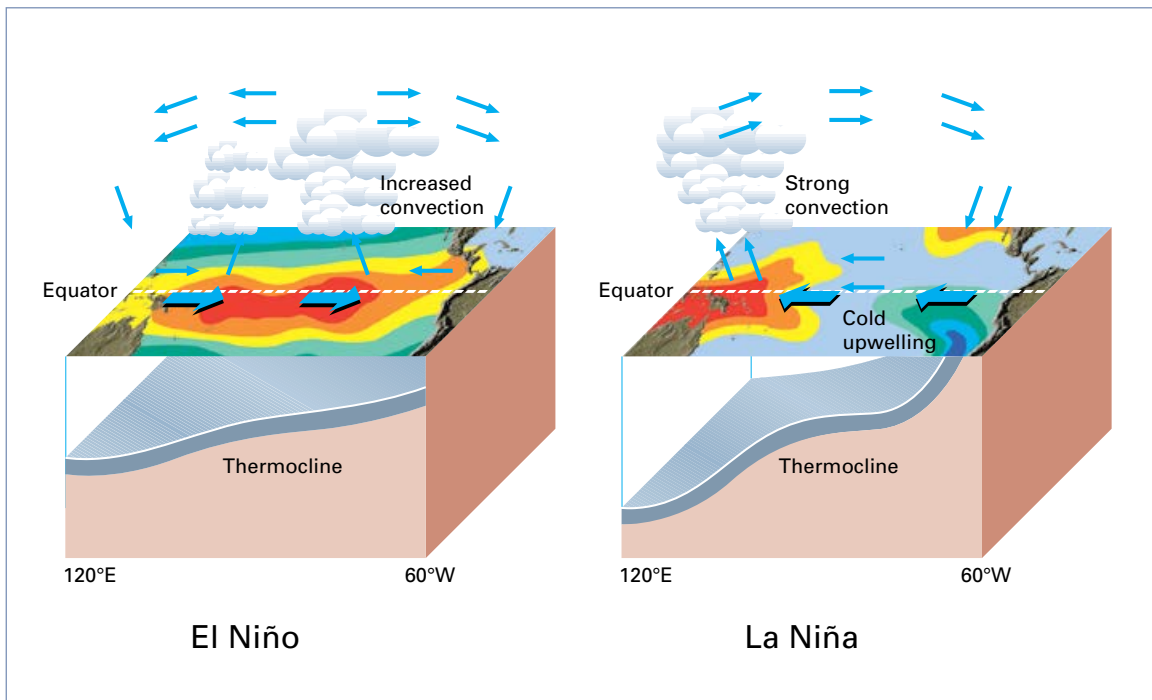
DAVID MERCADO | REUTERS

in Peru and Ecuador to refer to the unusually warm waters that reduced their catch just before Christmas. El Niño events often begin in the middle of the year with large-scale warming of surface water in the central and eastern equatorial Pacific Ocean and changes in the tropical atmospheric circulation (i.e. winds, pressure and rainfall). In general, El Niño reaches a peak during November–January and then decays over the first half of the following year. It occurs every two to seven years and can last up to 18 months. Strong and moderate El Niño events have a warming effect on average global surface temperatures.

The opposite of El Niño within the ENSO cycle is known as La Niña, which means “little girl” and refers to the large-scale cooling of the ocean surface temperatures in the same region in the equatorial Pacific, coupled with a reversal of the overlying atmospheric conditions. In many locations, especially in the tropics, La Niña (or cold episodes) produces the opposite climate variations to El Niño.

During ENSO-neutral phases, atmospheric patterns are controlled more by other climate drivers.

The World Meteorological Organization (WMO) issues regular El Niño/La Niña Updates based on observational monitoring of the current



Typical circulation patterns during El Niño and La Niña

situation, seasonal predictions through climate model simulations performed by advanced centres around the world, and input from top international experts.

The last El Niño episode was in 2009/2010. The outcomes of each El Niño event are never exactly the same: they depend on the intensity of the event, the time of year when it develops and the interaction with other climate patterns. El Niño does not affect all regions, and even in a given region, the impacts are not the same. For the most accurate information at national or local level, it is important to consult National Meteorological and Hydrological Services.

OCEAN-ATMOSPHERE INTERACTION

El Niño events begin with large-scale warming of surface water in the central and eastern equatorial Pacific Ocean. La Niña events are associated with large-scale cooling of the ocean surface temperatures in the same region in the equatorial Pacific.

The fluctuations in ocean temperatures during El Niño and La Niña are accompanied by even larger-scale fluctuations in air pressure known as the Southern Oscillation. This is an east-west see-saw-like movement of air masses between the Pacific and the Indo-Australian areas. These

changes in atmospheric circulation occur in response to changing ocean surface temperatures and at the same time influence El Niño or La Niña ocean temperature patterns.

The negative phase of the Southern Oscillation occurs during El Niño episodes, and refers to the situation when abnormally high air pressure covers Indonesia and abnormally low air pressure covers the central and/or eastern tropical Pacific. In an El Niño event, the low-level surface trade winds, which normally blow from east to west along the equator (“easterly winds”), weaken or in some cases start blowing in the opposite direction. The positive phase of the Southern Oscillation occurs during La Niña episodes, when abnormally low air pressure covers Indonesia and abnormally high air pressure covers the central and/or eastern tropical Pacific.

This difference from average air pressure patterns across the Pacific is traditionally measured using the Southern Oscillation Index (SOI), based on pressure measured by two stations: one in Darwin, Australia (south of Indonesia) and the other in Tahiti (east-central tropical Pacific). A negative SOI indicates that pressure is higher than average in Darwin and lower than average in Tahiti. There is also an Equatorial SOI, which measures the difference in pressure between larger regions over Indonesia and the eastern equatorial Pacific.

OBSERVING AND PREDICTING THE EL NIÑO/SOUTHERN OSCILLATION

The El Niño/Southern Oscillation is the most predictable season-to-season and year-to-year fluctuation of the climate system because of the way slow changes in ocean heat content precondition the system for warm and cold events to occur. The first successful prediction of El Niño was in 1986. Since then, forecast models have become more skilful. However, there is a need for prediction skills to be further improved and for the relationship dynamics between the oceans and atmosphere to be even better understood.

The meteorological and oceanographic data that allow El Niño and La Niña episodes to be monitored and forecast are drawn from observing systems, operated mainly by National Meteorological and Hydrological Services. These include satellites, which provide information on tropical rainfall estimation, wind and ocean temperatures; buoys, which provide data on upper ocean and sea-surface temperatures; and research ships and radiosondes observing the state of the atmosphere and weather patterns.

The exchange and processing of the data are carried out under programmes such as the Global Climate Observing System and the Global Ocean Observing System, which are collaborative efforts between WMO and partners, including the International Council for Science and the Intergovernmental Oceanographic

Commission of the United Nations Educational, Scientific and Cultural Organization.

Dynamical and statistical forecast models project the evolution of the tropical Pacific Ocean from its currently observed state, and expert analysis adds further value. All forecast methods try to incorporate the effects of ocean-atmosphere interactions within the climate system.

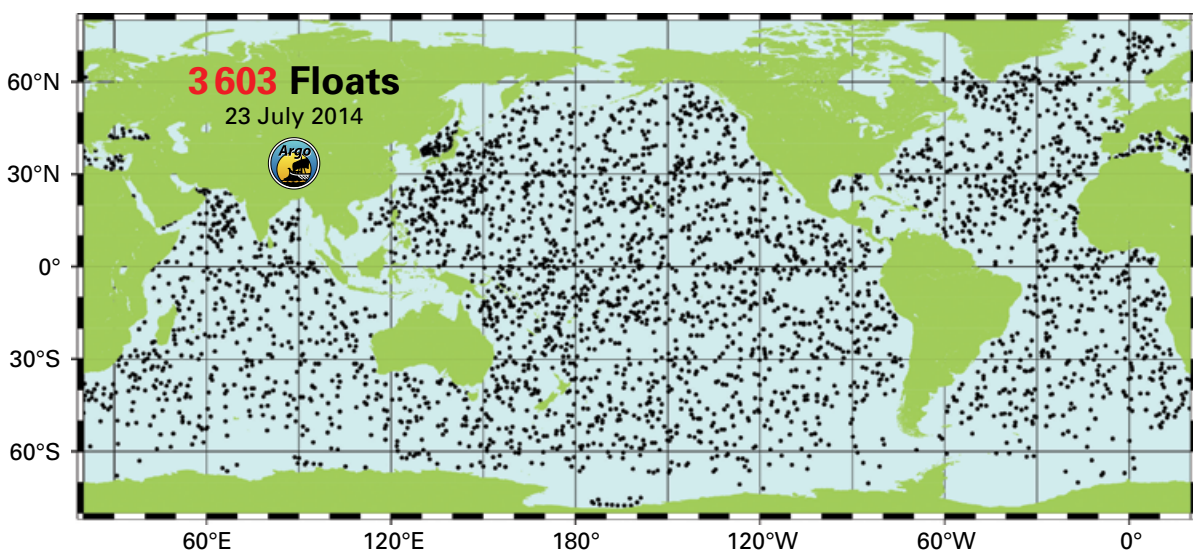
Tropical Pacific Ocean observations are vital to predicting and monitoring El Niño. The current observing system design was completed 20 years ago and now faces challenges in sustaining core components such as the deteriorating network of buoys. Efforts are underway to strengthen and improve the observing system to make it more robust and integrated to meet future requirements, as well as to engage new partners in supporting the observing system.

IMPACT ON GLOBAL TEMPERATURES

El Niño events can have the overall effect of increasing global average surface temperatures, whereas La Niña events have a cooling tendency. The strong El Niño event of 1997/1998 was followed by a prolonged La Niña phase that extended from mid-1998 to early 2001, with a clear impact on global temperatures (see graph on page 5).

However, irrespective of El Niño events, there is a long-term trend towards the warming of the

Map of Argo float locations reporting in July 2014. Argo is an array of more than 3 600 free-drifting profiling floats that measure the temperature and salinity of the upper 2000 metres of the ocean. (Source: University of California, San Diego, United States of America)





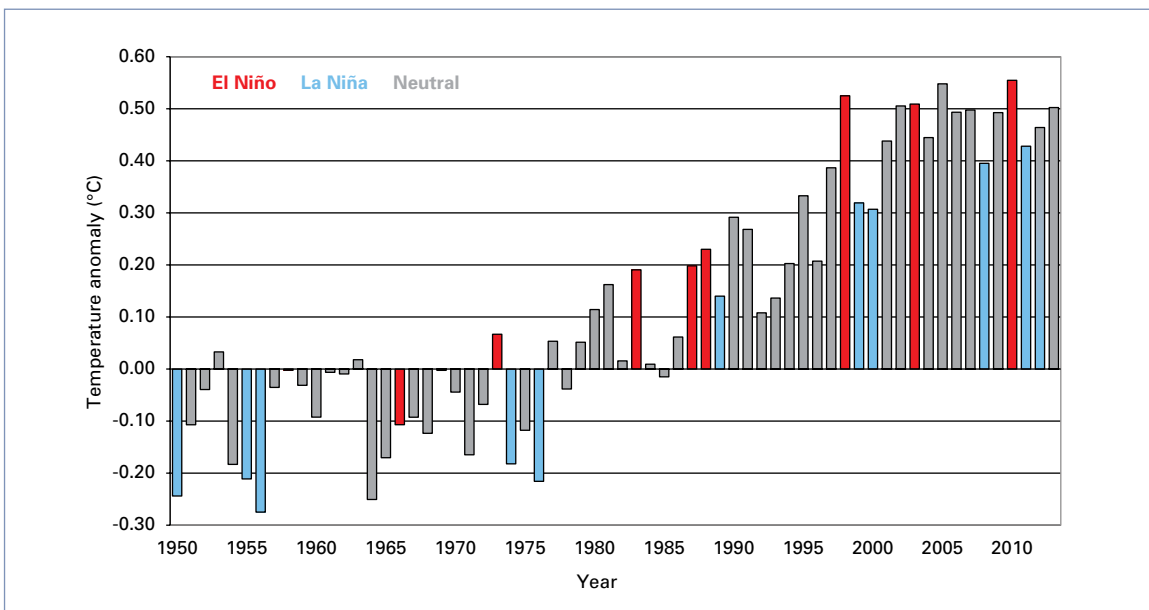
A farmer walks past his boat in Las Canoas lake, Nicaragua, in April 2010. The lack of rain linked to El Niño decreased water levels, affecting approximately 8 000 people.

Earth's climate because of rising heat-trapping greenhouse gas emissions from human and industrial activities. El Niño and La Niña events only modulate this underlying trend, the former amplifying and the latter dampening the warming in the corresponding years.

The year 1998, which had an exceptionally strong El Niño, was the second hottest year on record. The warmest year on record was 2010

(an El Niño year), tied with 2005, with global temperatures about 0.55 °C above the long-term (1961–1990) average of 14 °C.

There is as yet no conclusive evidence of the impact of climate change on the frequency, intensity and influence of El Niño/La Niña events. However, typical ENSO-related impacts may be strengthened or weakened by background climate change.



Annual global land and ocean surface temperature anomalies (relative to 1961–1990) for the period 1950–2013; years that started with a moderate or strong La Niña already in place are shown in blue; years that started with a moderate or strong El Niño already in place are shown in red; other years are shown in grey.

REGIONAL CLIMATE EFFECTS OF EL NIÑO

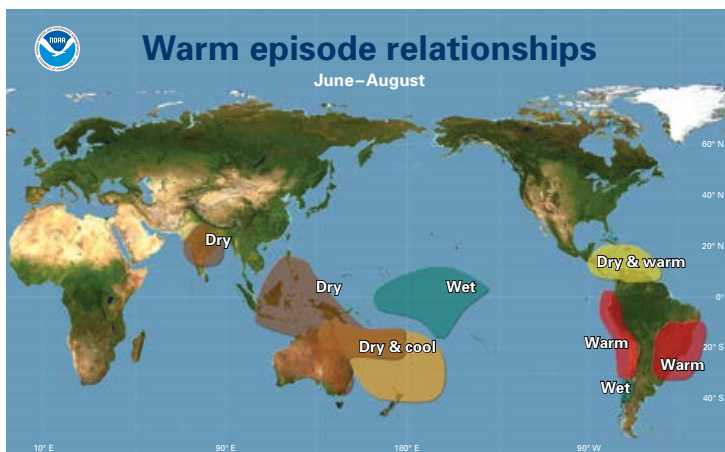
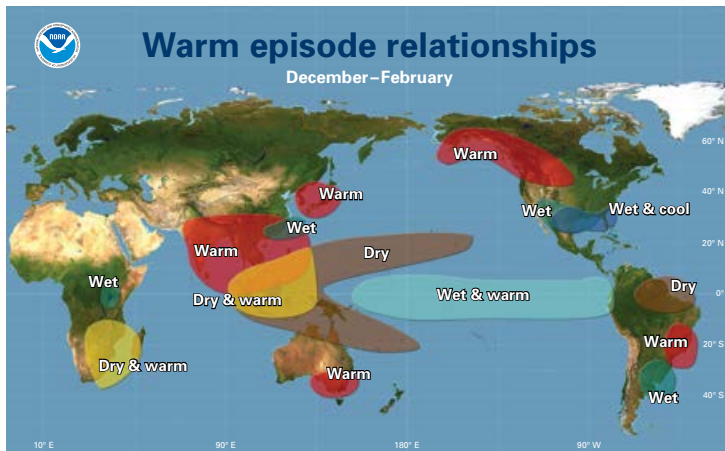
During El Niño events, the pool of warm water in the central or eastern tropical Pacific heats the overlying atmosphere, causing the air to rise. As it rises, the air cools and produces rain. In contrast, on the western side of the Pacific, the ocean surface tends to cool and there is less rising motion. These changing patterns of ascending and descending air are part of the Southern Oscillation component of ENSO as explained above.

This means that El Niño is often associated with warm and dry conditions in southern and eastern inland areas of Australia, as well as Indonesia, the Philippines, Malaysia and central Pacific islands such as Fiji, Tonga and Papua New Guinea. During the northern hemisphere summer season, the Indian monsoon rainfall generally tends to be less than normal,

especially in the north-west of India. The magnitude and scale of the changes in atmospheric circulation associated with El Niño are such that the effects on regional climate extend beyond the tropical Pacific basin. In northern hemisphere winter, drier than normal conditions are typically observed over south-eastern Africa and northern Brazil.

Wetter than normal conditions are typically observed along the Gulf Coast of the United States, the west coast of tropical South America (Colombia, Ecuador and Peru) and from southern Brazil to central Argentina. Parts of eastern Africa also usually receive above-normal rainfall. El Niño is associated with milder winters in north-western Canada and Alaska due to fewer cold air surges from the Arctic – a result of a large-scale region of lower pressure centred on the Gulf of Alaska/ North Pacific Ocean.

Maps of warm episode relationships in northern hemisphere winter (above) and northern hemisphere summer (below) (Source: NOAA National Weather Service Climate Prediction Center)



It is important to stress that these are typical effects – not specific forecasts – and that actual conditions vary according to the strength and timing of the El Niño event. Other factors (such as the Indian Ocean Dipole or the North Atlantic Oscillation/Arctic Oscillation) can also have an important influence on seasonal climate.

Regional Climate Outlook Forums in different parts of the world factor the likely development of El Niño or La Niña events into their seasonal predictions for users in the sectors of agriculture and food security, water management, health, disaster risk reduction and energy.

EL NIÑO AND TROPICAL CYCLONE ACTIVITY

El Niño tends to lead to more tropical cyclone activity in the central and eastern Pacific basins and less in the Atlantic basin.

Over the central and eastern Pacific, increased sea-level atmospheric pressure in the subtropical areas adjacent to the area of ocean warming is associated with weaker upper-level winds and reduced vertical wind shear, which favours more tropical cyclone activity. In the eastern Pacific, El Niño typically causes the track of tropical cyclones to shift northwards and tends to increase the intensity of associated rainfall.

Over the Atlantic basin, the reduced sea-level atmospheric pressure is associated with

stronger upper-level westerly winds and stronger lower-level easterly trade winds, both of which increase the vertical wind shear and hinder hurricane formation. El Niño also suppresses Atlantic hurricane activity by increasing atmospheric stability.

SOCIOECONOMIC IMPACTS OF EL NIÑO/ SOUTHERN OSCILLATION EVENTS

The United States Office of Global Programs of the National Oceanic and Atmospheric Administration (NOAA) assessed direct economic losses from the very strong 1997/1998 El Niño event at US\$ 34 billion, with a loss of 24 000 lives. However, it is important to recognize that losses associated with El Niño-related floods or droughts in some areas can be offset by gains elsewhere, for instance through reduced North Atlantic hurricane activity, lower winter heating bills or better harvests for certain crops.

The 1997/1998 El Niño episode had a devastating impact in many parts of the world. Drought hit the western Pacific islands, the Philippines and Indonesia, affecting agriculture output, water supply and hydroelectricity. It contributed to runaway wildfires that affected neighbouring countries, causing widespread respiratory health problems. North-eastern Brazil and Guyana also suffered severe drought and wildfires. On the other hand, this record-breaking El Niño showed no perceptible influence on the Indian summer monsoon, which ended up being normal.

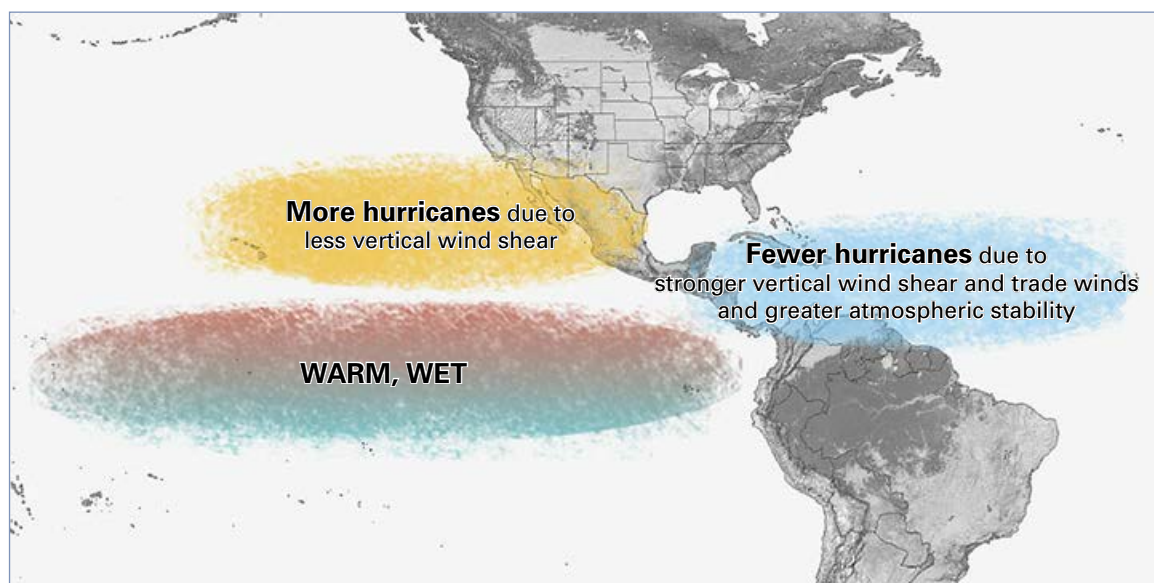
Heavy rains, which broke many records, caused serious flooding in southern Brazil, Paraguay, Uruguay and Argentina. In coastal Ecuador and Peru, rainfall amounting to more than 10 times normal levels caused flooding and erosion and destroyed infrastructure. There was a collapse in the anchovy catch because of the warming of the usually cold, nutrient-rich thermocline water that supports major fisheries. The Peruvian government estimated that the 1997/1998 El Niño event cost about US\$ 3.5 billion, or about 5% of gross domestic product.

There was extreme rainfall over the southeastern United States, leading to mudslides in California. In the northern United States and Canada, winter temperatures were 3 °C warmer over large regions.

Periods of heavy rain and flooding were experienced in East Africa, which disrupted transport and food supplies. In China, there were abnormally high rainfalls and record floods over the Yangtze basin.

Since 1998, more accurate scientific predictions have facilitated improvements in the level of preparedness and coping mechanisms. This has helped to save lives, limit economic losses and, equally important, maximize the benefits in areas where El Niño has a positive influence. The value of these forecasts translates into hundreds of millions, if not billions, of dollars.

Advance forecasts, coupled with higher levels of awareness, enable governments, the



Typical influence of El Niño on Pacific and Atlantic seasonal hurricane activity (Source: NOAA Climate.gov; based on originals by Gerry Bell)

commercial sector and humanitarian agencies to make contingency plans to boost resilience and limit the socioeconomic impact in key sectors such as agriculture and fisheries, water management, health and energy.

Disaster management authorities in countries that typically receive below-normal rainfall can prepare for the risk of wildfires enhanced by drought and anticipate adverse effects on food security. In areas that receive above-average rainfall, measures can be taken to limit the risk of landslides and flooding.

Water managers can consider policy options in anticipation of reduced rainfall, to suitably regulate dam flow or build additional storage facilities.

The agriculture sector can act on advice to adjust the planting times and crop varieties, use water-wise techniques and build up buffer stocks.

El Niño forecasts enable the energy sector to prepare for shifts in demand patterns – for more air conditioning or less winter heating – as well as possible disruptions to supplies in the event of drought.

The health sector is increasingly factoring El Niño information into disease surveillance and management plans. In addition to causing physical damage to health infrastructure, floods can also increase the risk of diarrhoeal and mosquito-borne diseases like malaria and dengue fever. Drought and high temperatures can increase under-nutrition and respiratory problems.

The World Meteorological Organization is working closely with other United Nations and international partners to facilitate a cross-cutting multidisciplinary approach to limit socioeconomic risks and maximize the benefits.

IMPROVING CLIMATE SERVICES

El Niño/Southern Oscillation forecasts are a good example of a climate service that helps communities adapt to natural variations in the climate and to long-term climate change. The Global Framework for Climate Services, spearheaded by WMO, aims to improve such services and increase their outreach to the most vulnerable.

The Global Framework for Climate Services also brings meteorological services together with the key user sectors (agriculture and food security, disaster risk reduction, health, and water management) to ensure that climate services like ENSO predictions are accessible, understandable and relevant to the needs of modern society.

Despite the huge scientific progress made in the past 30 years, more work needs to be done to further improve operational ENSO predictions, strengthen understanding of regional impacts and reinforce socioeconomic resilience to these events. Global warming and climate change will pose new challenges and increase the urgency of strengthening climate services worldwide.



SHUTTERSTOCK

Further reading:

Australia Bureau of Meteorology

<http://www.bom.gov.au/climate/enso/>

<http://www.bom.gov.au/climate/enso/enlist/>

Global Climate Observing System

<http://www.wmo.int/pages/prog/gcos/index.php?name=AboutGCOS>

Global Framework for Climate Services

<http://www.gfcs-climate.org>

Global Ocean Observing System

<http://www.ioc-goos.org/>

International Research Centre on El Niño

<http://www.ciifen.org/>

International Research Institute for Climate and Society

<http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/>

<http://iri.columbia.edu/news/el-nino-primer-for-the-global-health-community/>

United States National Oceanic and Atmospheric Administration

<http://ncdc.noaa.gov/teleconnections/enso/>

<http://www.climate.gov/news-features/department/8443/all>

World Meteorological Organization

http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html

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