



FAIRCO

EL NIÑO SOUTHERN OSCILLATION

GLOBAL CLIMATE INFLUENCER

By James Rohman | March 2014

This El Niño event had a warm Water mass of roughly 4.7 million square miles, or 1.5 times the size of the continental United States

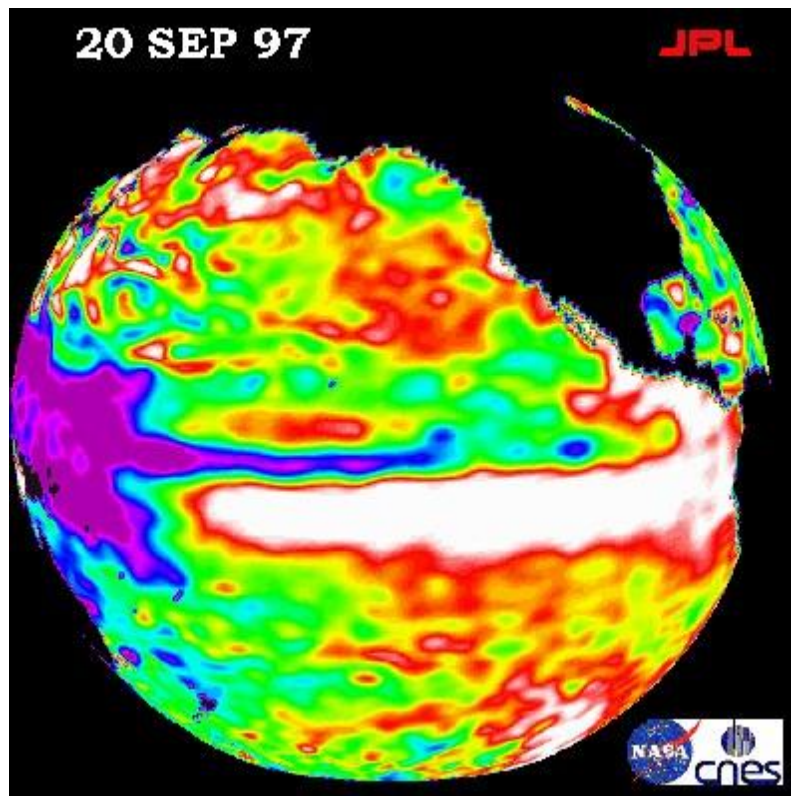


Figure 1. Warm water (red/white) spreads out from equatorial South America during a strong El Niño, September 1997.

The La Niña phenomenon can Significantly alter flood/drought patterns and tropical/extratropical cyclone genesis on approximately 60% of the earth's surface

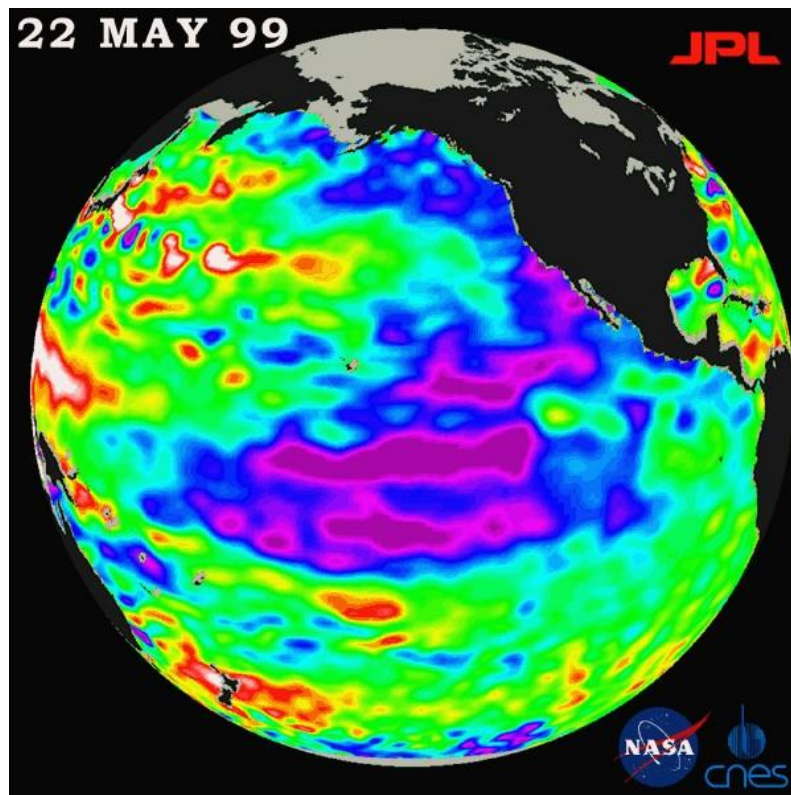


Figure 2. Cold water (blue/purple) dominates the equatorial Pacific during a strong La Niña, May 1999.

Introduction

In the world's oceans lay massive repositories of stored energy. The various cold and warm patches of ocean water act to cool or heat the atmosphere, influencing global climate patterns. The heat transfer controls weather over both land and sea. The largest such recurring climate pattern is the El Niño Southern Oscillation (ENSO) in the Pacific Ocean.

ENSO is the anomalous and recurring pattern of cold and warm patches of water periodically developing off the western coast of South America.

El Niño is the appearance of warm water along western South America, from Chile up to Peru and Ecuador. La Niña is the exact opposite, with anomalously cold water spreading across the equatorial Pacific.

In addition to changes in thermal energy in the ocean environment, the **relative height of the sea surface also relates to ENSO**. As patches of oceans warm, the sea level rises; as water cools, the sea level drops. **We find that above-normal or below-normal sea level heights along the equatorial Pacific indicate presence of El Niño or La Niña conditions.**

60% of global weather patterns are affected by ENSO, as patches of anomalously cold and warm ocean waters traverse the Pacific Ocean.

ENSO is a natural phenomenon that has been reported as far back as 1525, when Francisco de Jerez became the first European to enter Peru. **For the past 500 years, the oscillation has been scientifically recorded in cycles of 2-5 years.** In the 20th century, there were 25 full cycles.

This paper will discuss the El Niño Southern Oscillation cycle, the global weather impacts from each phase, and the resultant correlation between extreme weather events.

Normal Conditions – Walker Circulation

Under normal conditions, **Easterly trade winds push surface waters west in the tropics**, pulling water away from Peru and **resulting in an upwelling of cold deep-ocean water along South America's Pacific Coast**.

The combined Easterly winds and coastal upwelling cause the **Pacific Ocean near Peru to be colder ($\sim 20^{\circ}\text{C}$) than the Pacific Ocean near Indonesia ($\sim 28^{\circ}\text{C}$)**. The sea level in the western Pacific tends to be 30cm higher than the eastern Pacific due to differences in thermal energy.

Warm water in the western Pacific heats the atmosphere, causing moist air to generate clouds and precipitation. High Sea Surface Temperatures (SSTs) and the latent heat released by condensation form **low-pressure systems that rise and spread in the upper troposphere**. Conversely, **colder surface waters in the eastern Pacific generate high-pressure systems with sinking air**.

Pressure differences along the equatorial Pacific reinforce Easterly trade winds that generate the upwelling of cold water near Peru. The upwelling causes the thermocline - the boundary between warm surface water and cold deep-sea water - to be 80m deep near Peru. As water moves west and warms, the thermocline plunges to 200m near Indonesia. **These 'normal' conditions are referred to as the Walker Circulation.**

The Walker Cell is a model of airflow in the tropics in the lower atmosphere.

Conceptually, particles of air follow a closed circulation loop, caused by differences in heat distribution between ocean and land.

Walker Circulation creates a roughly equal spread of warm and cold water across the equatorial Pacific Ocean.

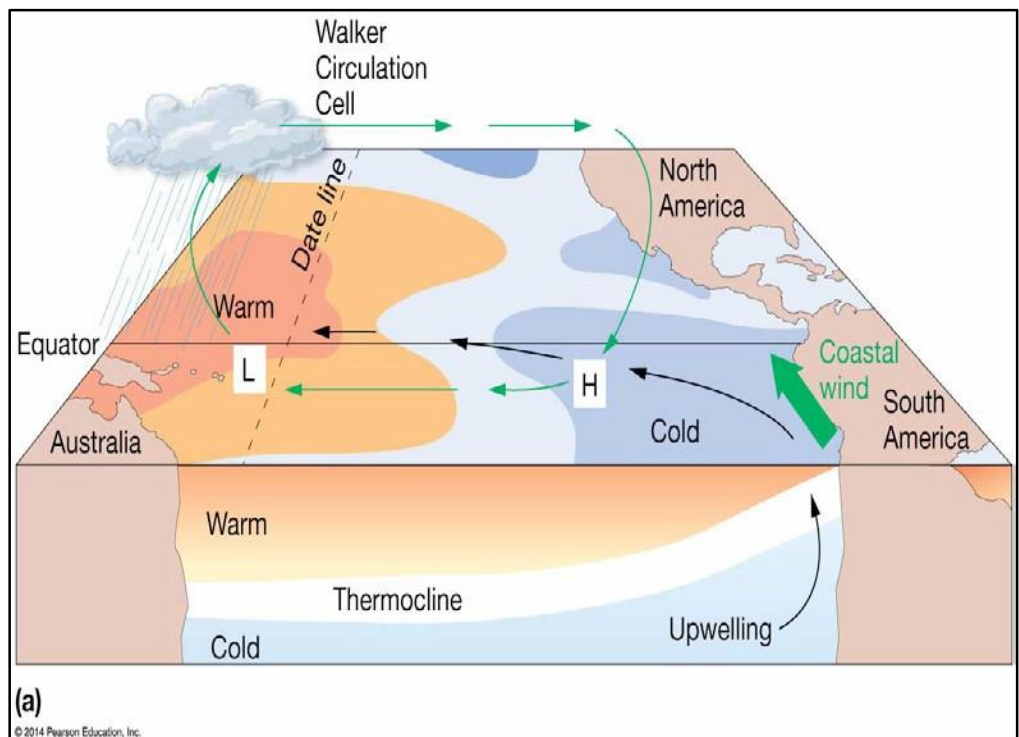


Figure 3. A fully developed Walker Cell in the Pacific shows a roughly equal distribution of warm and cool water masses.

As the sun reaches its southern zenith every December, ocean waters near Peru get warmer, the trade winds relax, and the upwelling of cold deep-sea water weakens. Warm water piled up in the western Pacific starts to flow east. On the ocean surface, these can be observed as eastward travelling patches of water with high SSTs. During most years, the SSTs near Peru change only a few degrees, and as the sun moves north again, the situation returns to normal by late January.

El Niño

However, every 2-5 years the effects are far more dramatic. The warming continues to increase rather than decrease. Trade winds disappear completely, or even reverse direction. Instead of Easterlies, Westerly trade winds begin to push warm equatorial waters towards South America and the upwelling disappears. Warm, moist air develops and rises over the central and eastern Pacific, and atmospheric circulation is reversed.

This results in dry air descending over Indonesia and Northern Australia, leading to drought conditions. The warm air over the eastern Pacific leads to flood conditions in many Central and South American countries.

This diagram shows how Walker Circulation reverses and El Niño conditions develop; Easterlies become Westerlies and the thermocline drops.

In addition to large-scale alterations in weather patterns, El Niño is associated with adverse effects on fishing and agriculture.

The strength of an El Niño system varies with the thermal energy changes (as low as 4°F, and as high as 18°F) in the equatorial Pacific.

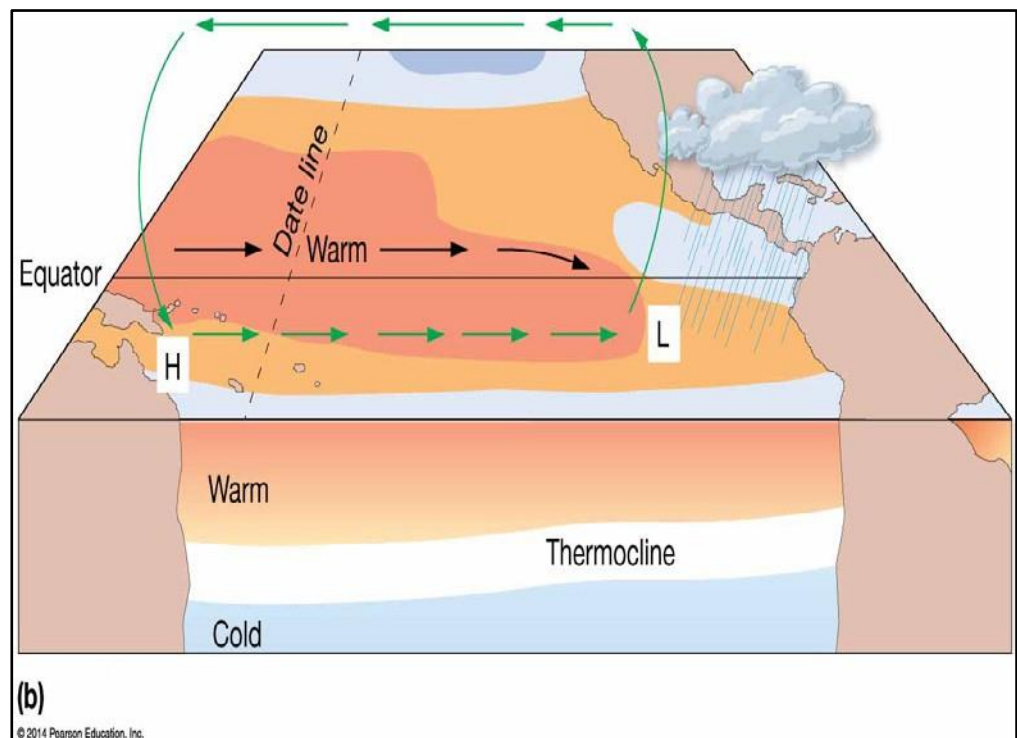


Figure 4. El Niño conditions show complete domination of warm water masses in the equatorial Pacific.

La Niña

An El Niño is often followed by a **La Niña, when the coastal waters near Peru become anomalously cold**. One of the effects of La Niña is **increased hurricane activity over the Atlantic Ocean**. Hurricane Mitch is an example of a very strong hurricane that developed in a La Niña phase.

La Niña conditions develop after the normal conditions of Walker circulation are restored and strengthened. Easterly trade winds intensify the upwelling, pushing the thermocline further west.

This isolates warm water in the western Pacific and spreads cold water into the central Pacific, resulting in **intense rainfall over Australia and Indonesia**, and **drought on the west coast of South and Central America**.

The counterpart to El Niño is La Niña, or the strengthening of a Walker Circulation Cell, and dominance of cold water in the equatorial Pacific.

While the local effects on weather and climate are generally the opposite of El Niño, the global effects can be far more complex.

La Niña turns global weather patterns upside down by redirecting the jet stream and altering the flow of dominant winds.

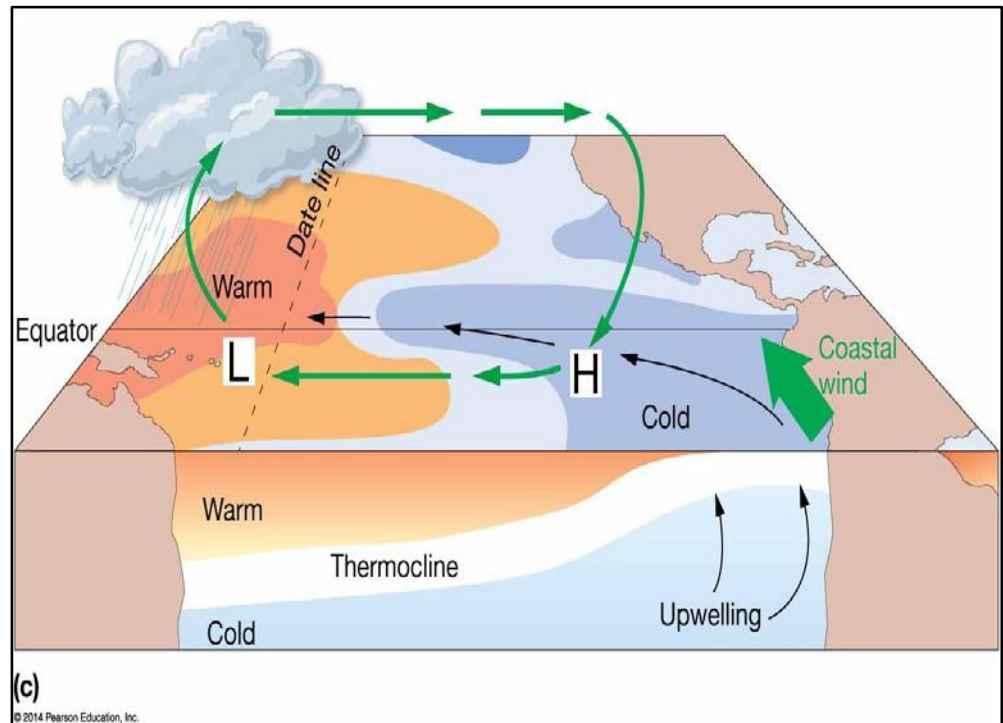


Figure 5. Fully developed La Niña conditions display a larger concentration of cold water in the equatorial Pacific zones.

To see an interactive animation of the ENSO process, please visit:
http://esminfo.prenhall.com/science/geoanimations/animations/26_Nin oNina.html

Summary of ENSO Phases

Table 1. Summary of conditions expected from each phase of ENSO.

Phase of ENSO	Region	Expected Global Forecast	Associated Climactic Rationale
La Niña	North America	Above average precipitation across northern MW, northern Rockies, California and Pacific Northwest. Precipitation in SW and SE United States is below average. More than average tropical cyclones in Atlantic, less in Pacific.	Wind-shear is reduced in Atlantic ocean, leading to increased tropical cyclone genesis. Exact opposite occurs in eastern Pacific Ocean.
	South America	Drought-like conditions along Pacific Coast and SE Brazil and Argentina. Wetter than average conditions in N and NE of continent.	Dry air descends over eastern Pacific as a result of normal Walker Circulation.
	Southeast Asia	Increases threat of typhoon landfall to mainland China. Heavy rains over Malaysia, the Phillipines, Indonesia and northern Australia.	Moist air ascends and drops rainfall over western Pacific as a result of Easterly trade winds and Walker Circulation.
	Africa	Wetter-than-normal conditions in Southern Africa, drier-than-normal conditions over equatorial East Africa.	La Niña brings wetter weather patterns to South Africa, often resulting in flood conditions.
El Niño	North America	Warmer and drier in the NE and northern MW United States. Should experience less snowfall. Pacific coast will be much cooler and wetter.	Altered distribution of warm and cool water in equatorial Pacific brings disrupted weather patterns to North America.
	South America	Intense rainfall along Pacific Coast. Major flooding along coast of Peru and Ecuador, as well as in SE Brazil and Argentina. Drought-like conditions in N and NE of the continent.	Moist air ascends and drops rainfall over eastern Pacific as a result of reversed trade winds and reversed Walker Circulation.
	Southeast Asia	Drier than average in SE Asia and northern Australia, leading to bush fires and decrease of air quality.	Dry air descends over western Pacific as a result of reversed Walker Circulation.
	Africa	Conditions will be drier than average in South and Central Africa. East Africa will experience long rains from March to May.	Convective cells return to drop rain on East Africa, but leaves South Africa drier than normal.

El Niño Effects

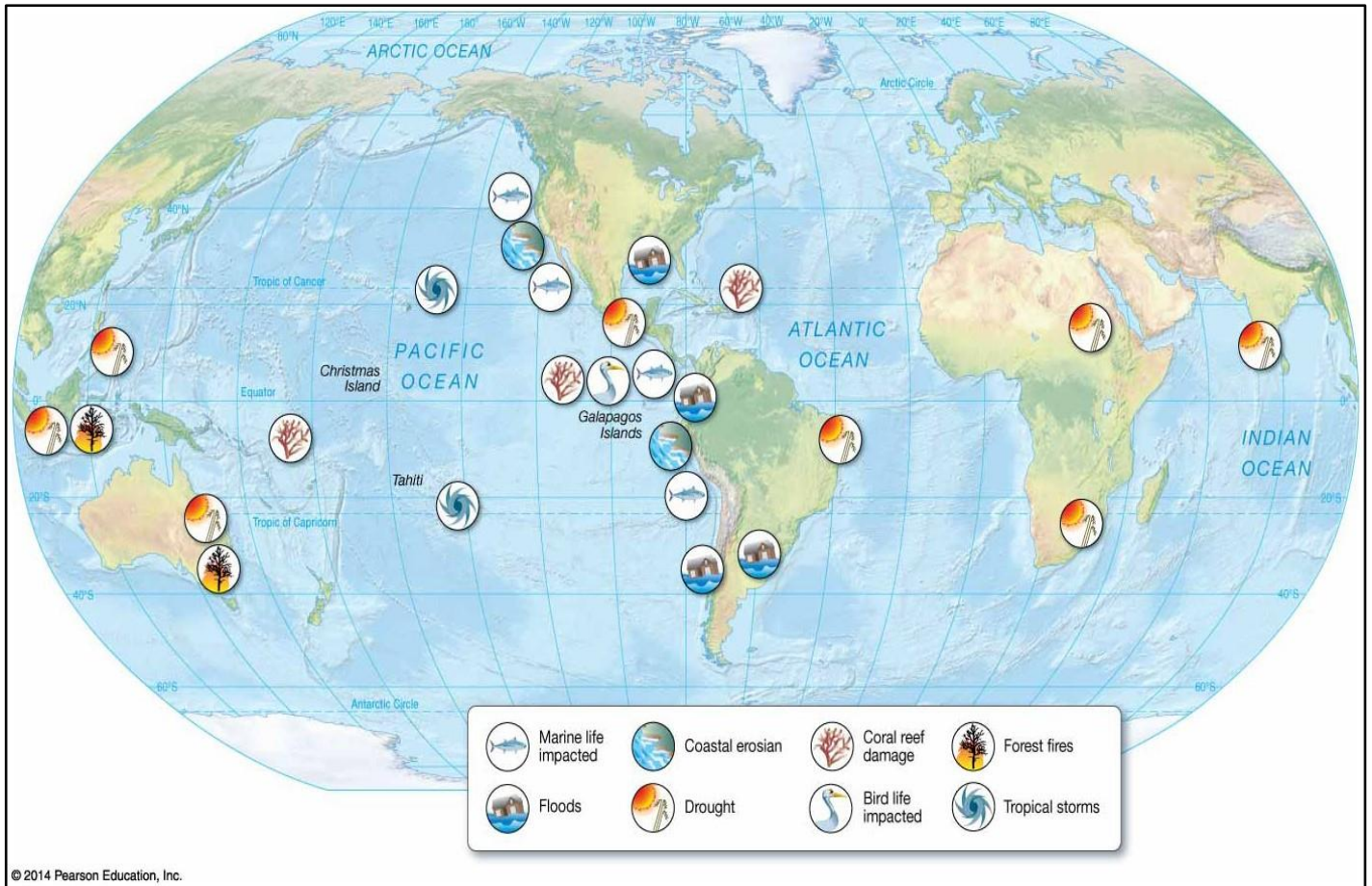


Figure 6. The global effects of the El Niño phase. The image shows how extreme global weather events that depend on ENSO are correlated with one another.

Recent Example: 1982-1983 El Niño

One of the strongest El Niño's of the 20th century began in the summer of 1982. First noticed when instrumentation buoys off coastal Peru recorded abnormally high temperatures, **SSTs in the central and eastern equatorial Pacific eventually rose 4⁰C above normal.** Spurring extreme weather on a global scale, this El Niño is noted for its irregular temporal and spatial anomalies. **The episode created \$18.4 Billion in economic losses.**

Associated Global Impacts

Due to the atypical timing of the onset (summer instead of spring) **and altered development of warm waters** (central Pacific before eastern Pacific), the **scientific community was unprepared and not expecting the episode.** Regions that might have been able to prepare for extreme weather were caught off-guard because of no warning from scientists.

In addition to \$745 Million in damage in Indonesia, droughts in Southern India, Sri Lanka and the Philippines totaled \$895 Million.

Drought and fires in Australia and New Guinea created damages of \$4.5 Billion. Nearby, 6 major tropical cyclones and hurricanes battered Tahiti and Polynesia.

Total damages throughout North America were approximately \$4.7 Billion, spread throughout Central America, Cuba, California, the Midwest, and East Coast.

Floods and droughts accounted for \$5.8 Billion between Ecuador, Peru, Bolivia, Brazil, Argentina and Paraguay.

Drought and extremely high temperatures caused around \$298 US Million in damages.

Drought and lack of agricultural production created damages of roughly \$1.5 US Billion

Indonesia

Plagued with severe drought and reductions in agricultural output. The drought coupled with the global recession to delay Indonesia's opportunity for economic development for five to ten years.

Australia

Australia was in the midst of an aggressive drought, and the El Niño intensified conditions. Agricultural and livestock losses and widespread bushfires created a national disaster.

United States of America

While the eastern US benefitted from energy savings during the warm winter, floods and mudslides hit the Californian coast, floods hit the Gulf States and drought in the Midwest reduced agricultural production.

South America

Heavy flooding in Peru and Ecuador created highly publicized damage to infrastructure. Destructive floods in Southeast Brazil showed the stark contrast to a severe drought in Northeast Brazil.

Africa

Large expanses of Africa that were previously experiencing below-average rainfall fell into deep droughts, such as the West African Sahel.

Southern Africa

Economies in Zimbabwe, Botswana, Mozambique, Angola, Lesotho and Zambia were devastated by extreme drought and lack of food production.

The Future

What do we know?

In some years the Walker circulation remains steady, and in others it leans towards El Niño or La Niña. The disturbances that push the system in either direction can be relatively small and varied in nature; a hurricane or a volcanic eruption in any Hemisphere can tip the scales either way. This may be **why the search for a single cause or long-term predictor for El Niño has not been successful.**

However, once the direction in which the system develops has been set, it tends to continue that way. It is therefore possible to successfully predict the occurrence of an El Niño or La Niña up to four to six months before the strongest effects are felt.

Why is ENSO important?

Since 1980 there has been an upward trend in global weather catastrophes. Extreme climactic events (which include heavy rainfall, high winds, hurricanes, typhoons, storm tides and severe droughts) **have impacted every continent in previously unforeseen ways.**

Increased weather catastrophes have been **coupled with distinct upward trends in the economic and insured losses associated with the extreme events.** This can be attributed to socioeconomic development along coasts, increasing vulnerability to cataclysmic weather.

What is the role of the ENSO cycle in these patterns? Through the natural oscillation between anomalous warm and cold water patches in the equatorial Pacific, 60% of global weather is disrupted.

Understanding weather phenomena such as ENSO is imperative because of their potential to cause significant loss of life and property in affected areas. **Coastal cities like São Paulo, New York City, Bangkok and Sydney are all susceptible to extreme events and significant loss from the ENSO cycle.**

What can we do?

The relationship between extreme climate events and global climate change is not yet fully understood. However, it is critical for insurers to be aware of the scientific advancements concerning monitoring, tracking and predicting natural phenomena like ENSO, and their deviations due to climate change.

Developing a greater understanding of the science underlying the El Niño Southern Oscillation can assist insurance underwriters in understanding global weather patterns and their subsequent impact on insured exposures.

Glossary

Downwelling - A downward current of surface water in the ocean, usually caused by differences in the density of seawater.

Easterly - Winds emanating from the east.

El Niño - The anomalously warm phase of ENSO.

El Niño Southern Oscillation (ENSO) - The oscillation in the Pacific Ocean between anomalously warm and cold water phases. Affects 60% of global weather patterns.

La Niña - The anomalously cold phase of ENSO.

Latent Heat - Heat released or absorbed by a body during a constant-temperature process.

Sea Surface Temperatures (SSTs) - Water temperature closest to the ocean's surface.

Thermal Energy - The energy a substance or system has related to its energy, i.e. the energy of moving or vibrating molecules.

Trade Winds - The prevailing pattern of easterly surface winds found in the tropics, within the lower portion of the Earth's atmosphere.

Troposphere - The lowest layer of the atmosphere, 6 miles (10 km) high in some areas and as much as 12 miles (20 km) high in others, within which there is a steady drop in temperature with increasing altitude and within which nearly all cloud formations occur and weather conditions manifest.

Upwelling - The process by which warm, less dense surface water is drawn away from a shore by offshore currents and replaced by cold, denser water brought up from the surface

Walker Circulation - Conceptual model of the air flow in the tropics in the lower atmosphere. The circulation is caused by differences in heat distribution.

Westerly - Winds emanating from the west.

Zenith - The imaginary point directly 'above' a given location on the imaginary celestial sphere.

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