Forecasting El Niño: Science's Gift to the 21st Century

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Thank Heaven for the 1982-83 El Niño event! But why would anyone thank Heaven for a natural disaster? Well, this particular disaster was like an early wake-up call. It was the biggest El Niño in about 100 years and provided the scientific community with convincing arguments about why research funding for an improvement in the understanding of the phenomenon would be of great value to societies around the world.

What El Niño Is

El Niño is a recurrent, quasi-periodic appearance of warm sea surface water in the central and eastern equatorial Pacific Ocean. There is a lack of agreement in the scientific literature regarding its return period. One view suggests that a minor El Niño event returns every two to three years and a major event every eight to 11 years. Another suggests that it returns every four to seven years.

A minor event is one during which the sea surface temperatures in the central and eastern equatorial Pacific increase by only a few degrees Celsius, over a relatively small area. A major event is accompanied by a large increase in sea surface temperatures covering a large expanse of the equatorial Pacific. The larger the increase, the more destructive the impacts of El Niño are likely to be.

Folklore suggests that the warming of these particular waters was named El Niño, after the Christ Child, because of the short-term annual warming for a few months beginning in December. Although it originally referred to the local condition along Peru's northwestern coast, usage of the term "El Niño" has been broadened by many to represent all sea surface warmings in the equatorial Pacific. The phenomenon has other names as well, such as "warm event."

El Niño is also associated with changes in sea level pressure at locations at opposite sides of the Pacific basin. In the early decades of the twentieth century Sir Gilbert Walker identified a seesaw pressure pattern between Darwin (Australia) and Tahiti. When pressure is high in Tahiti it is low in Darwin and vice versa. This pattern is referred to as the Southern Oscillation. These two natural processes --- El Niño and the Southern Oscillation --- combine to form ENSO. Many scientists refer to the warming of sea surface temperatures in the equatorial Pacific as ENSO, but the lay public still refers to these air-sea interactions as El Niño.

Figure 1 depicts schematically how an El Niño works. Warm air rises, creating clouds. Cold air descends, inhibiting cloud formation. The former process leads to rainfall, while the latter tends to stifle processes that lead to precipitation. As shown in Figure 1, the rain follows the pool of warmed sea surface temperatures.

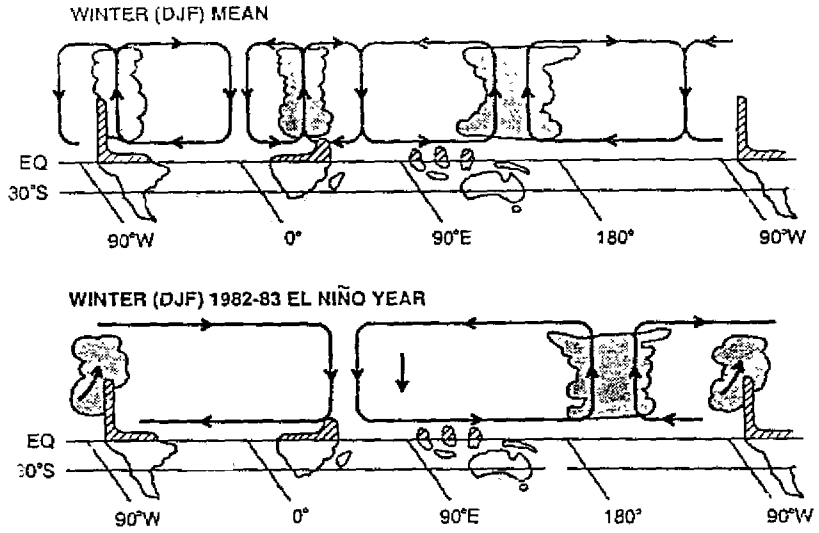


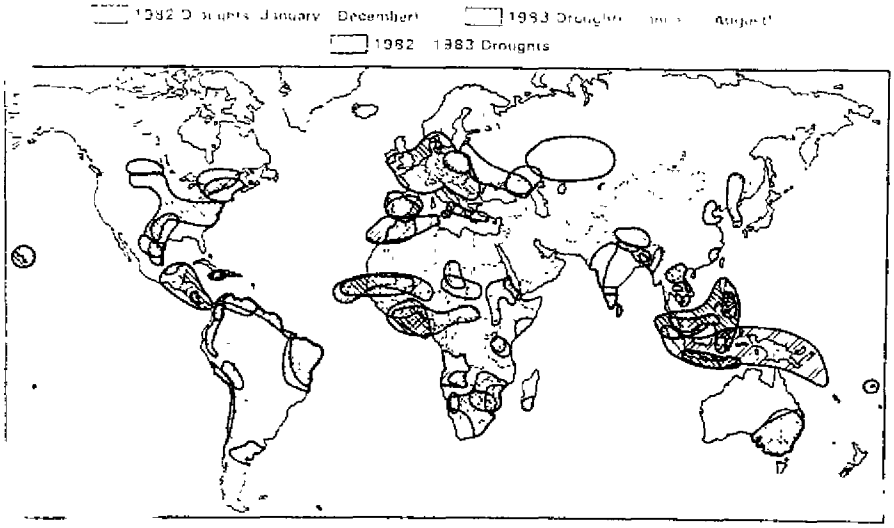
Figure 1. Schematic of the Walker Circulation based on computations of upper and lower tropospheric divergent winds. (a) Winter (DJF) mean east-west overturning Walker Circulation. (b) ENSO Winter 1982-83 pattern. Note the shift of the ascending branch to the east of the date line and suppressed convection (subsidence) over the rest of the tropics. (From *The Global Climate System: A Critical Review During 1982-1984*, World Climate Data Programme, WMO, Geneva, Switzerland, 1984.)

In practical terms this means that normally wet regions such as Indonesia become dry, while normally dry areas, such as the western coast of South America, become wet. The availability and abundance of fish populations in coastal areas shift. This has undesired repercussions with adverse impacts on food production and fish landings, fishmeal production and exports, the frequency of brush fires, and so forth. With declines in food production some countries are forced to import food supplies to meet national needs, forcing them to use their scarce foreign exchange reserves.

What El Niño Does

While the equatorial Pacific Ocean constitutes the field of action for El Niño events, the impacts associated with these events girdle the globe in the tropics. As a result, we hear about possible connections between an El Niño and, for example, flooding in the south central United States; mild winter in the northeastern part of North America; reduced numbers of hurricanes along the Atlantic Coast of North America; droughts in Northeast Brazil, in Australia, and in northeast, east and southern Africa; failure of the Indian monsoon; cool

summer in Japan, and so forth. These associated weather anomalies have been referred to as "teleconne[illegible]" or linkages over great distances of weather anomalies (Figure 2).



Some of those linkages may be based on identifiable geophysical processes that scientists have observed and verified. Others are based on statistical correlations that suggest that when an El Niño occurs, there is a high probability that a drought in Mozambique, for example, might also occur. Still others are based on "wishful thinking," or the belief that such linkages may exist and remain reliable over time, despite the absence of apparent connections. Depending on their degree of reliability, teleconnections can be used cautiously for economic development and disaster preparedness planning purposes.

El Niño has different consequences for different groups. To a Peruvian fisherman, an El Niño event can be a two-edged sword; a sharp increase in the catches of some types of fish and a decline in others. To Peruvian politicians, El Niño is bad news, as it usually means an abrupt decline in the fishing sector's productivity (especially of the anchoveta, which is converted to fishmeal and mostly exported as feed supplement for poultry) and, therefore, in sorely needed foreign exchange earnings that are used to support economic development programs. This decline leads to increased unemployment, loss of markets, loss of tax revenue, and labor unrest. In addition, flooding and mudslides resulting from heavy rains that accompany El Niño in parts of Peru and Ecuador destroy infrastructure (such as roads, bridges, and rail lines).

To a Chilean fisherman, El Niño can sometimes be good news, as changes in ocean temperatures may cause pelagic fish populations to increase in Chilean coastal waters. To American or Brazilian farmers who grow soybeans (or commodity speculators who trade them), El Niño could be good news as there would be a rise in the demand and price for soymeal, often used as an alternate protein feed supplement for livestock when fishmeal becomes unavailable. The North American weather patterns, however, vary from one El Niño

year to another. To the Indonesian rice farmer or the Australian wheat farmer, El Niño can be devastating, as droughts accompany major El Niño events in these regions.

Forecast Value

Today, El Niño has become a household word in many parts of the globe. Articles on it and its impacts have appeared in such mass media publications as *Reader's Digest, National Geographic, Time, Newsweek,* and *Business Week.*

If El Niño events can be forecast some months in advance, societies could prepare to prevent or to mitigate their impacts (at least in theory). In practice, of course, societies, that is, governments, corporations and individuals, respond in different ways to the threat of impending natural hazards. Some societies are risk-averse and tend to prepare early; others are risk-takers and may not take preventive measures at all. Societal responses depend on many factors, including the credibility of the forecasters, the ability of a government to engage in disaster preparedness, and the ability of a government to communicate to its citizens the risks involved with the occurrence of such a potentially disastrous event as El Niño.

There is growing optimism about the prospects of forecasting the onset of El Niño events from four to 12 months in advance. There have actually been some success stories related to El Niño forecasts. For example, El Niño modelers Mark Cane and Steven Zebiak forecast the onset of an event in 1986, going public with their prediction. This success was followed by another in 1990 for the 1991-92 El Niño. The success of these forecasts prompted others to go public with their projections on El Niño occurrences, despite existing scientific uncertainties. They readily admit that their forecasts are experimental and that along with some successes there have also been failed forecasts. Clearly, forecasts are just forecasts, they are not guarantees. There are probabilities associated with forecasts and people must learn how to use them to their advantage, as they hedge their decisions using such information.

The 1982-83 Event

In early 1982 scientists believed that they had enough scientific observations to describe with some degree of confidence a typical El Niño event, referred to as a "canonical" El Niño. Some researchers in the scientific community believed that they had successfully identified the life cycle of El Niño events, and had, therefore, increased their ability to predict the event. This view was shattered several months later with the appearance of a "rogue" El Niño that did not fit the profile of a typical one described a few months earlier. The scientific community responded by stating that no two El Niño events were alike.

TOGA

The 1982-83 event, the biggest in a century with alleged impacts on the order of billions of dollars in damage around the globe, triggered a great deal of physical science research. A major effort within the international scientific research community was developed to improve basic understanding of the El Niño-Southern Oscillation phenomenon. A decade-long program called TOGA (Tropical Ocean-Global Atmosphere) was launched in the mid-1980s. Its goals were

1. To determine the extent to which the behavior of the tropical oceans and related planetary-scale atmospheric circulation patterns are predictable on time scales ranging from weeks to a few years and to understand the mechanisms that give rise to this predictability.

2. To explore the potential of coupled atmosphere-ocean system models for predicting climatic variability on these time scales and to develop an observing and data management system to support operational climate prediction.

No one ever said that forecasting the onset, duration and end of El Niño events would be an easy scientific task. Take, for example, the recent El Niño that began in 1991. It was successfully forecast, generating a degree of euphoria and optimism within the forecast community. The end of the event was also forecast for late 1992 but it continued to flourish for another year or so. It has now become one of the longest events in a hundred years. Thus, forecasting El Niño's demise can be as important as forecasting its onset.

Scientific breakthroughs are expected and likely. This optimism is not based on wishful thinking but on the day-to-day basic and applied research activities of scores of scientists in many countries, including the US, Australia, Peru, Chile, Canada, China, Brazil, Japan and South Africa. Unlocking the mystery of forecasting El Niño could improve the planning at the national level of numerous human activities; managing productive but fragile fisheries, improving agricultural production efforts, minimizing potential adverse human health consequences, making better trade deals especially for commodities, mitigating natural hazards such as brush- and forest fires, floods and droughts, preparing for the possibility of increases in rural-urban migration, and so forth. The potential uses of such information as a guide to a wide range of human activities is almost limitless.

Despite the potential value to societies around the globe of El Niño information, the scientific community has until recently virtually ignored supporting investigations of the societal aspects of El Niño events, including how best to use El Niño forecast information. In the mid-1980s the United Nations Environment Programme (UNEP) attempted to fill this gap by supporting activities on the socio-economic aspects of El Niño. A UNEP working group identified El Niño impacts, teleconnections, potential changes in El Niño in response to global warming, and most recently, the use of El Niño information in famine early warning systems

in sub-Saharan Africa.

For those who may be skeptical about the research community's ability to forecast El Niño events up to a year in advance (as scientists claim), there is still a silver lining with regard to the potential value of El Niño information.

(a) *Look at your competitors.* Kenya grows and exports coffee. The linkages of its climate anomalies to El Niño events are not very clear. Therefore, there is a tendency for Kenyans not to care much about the warming of sea surface temperatures halfway around the globe. But many of the competitors of Kenyan coffee growers (such as those in Brazil or Indonesia) are adversely affected by these events, which can reduce their ability to meet the demand for their coffee in the international marketplace. Similar arguments can be made for corporations or countries that are concerned about importing such goods as squid. During El Niño events squid numbers off the coast of California tend to decline forcing those companies that must fill orders, for example, to Japan are then forced to buy squid elsewhere at higher prices in order to fulfill their trade agreements. A similar situation occurs for palm oil future purchase. Palm oil production in the Philippines declines during El Niño events, so those who wish to purchase it at a low price must see other sources in, for example, West Africa.

(b) *Wait until El Niño starts.* Once an El Niño event "locks in," it will likely run for 12 to 18 months, and some of its impacts occur after it is well under way. If the scientific community can say with a high level of confidence that such an event has started, the decision makers, with the cautious use of teleconnections, can identify ways they can prepare for likely El Niño impacts in their countries or in their economic sectors. Knowing that it is likely to begin several months in advance of its onset is value added to El Niño information that already has a potentially high value to decision makers who use it judiciously.

Global Warming and El Niño Events

The global climate regime is constantly changing. For example, the early decades of the 20th century were relatively cool, while the '20s and '30s were warm, the 1940s to '60s cool and the 1970s and '80s warm yet again. Today, there is considerable discussion about the possibility of a global warming of the Earth's atmosphere. Many scientific reports suggest that given current understanding of greenhouse gases emissions and atmospheric changes there is likely to be a 3 degree Celsius increase in atmospheric temperatures by the latter half of the 21st century. At a recent workshop in Bangkok, Thailand, participants addressed how a global warming might affect the frequency, intensity and location of El Niño events. The prevailing view was that El Niño will likely continue to occur, could become more intense, could possibly change in frequency but not likely in duration. Teleconnection patterns in the tropics are likely to be similar to those of today while those in the areas outside the tropics are likely to change. Associated changes of sea surface temperature and atmospheric

convection have major yet-unknown implications for monsoons and typhoon activity.

International Prediction Centers

Policymakers and social scientists are increasingly focusing on El Niño as one of the few bright spots in forecasting future states of the atmosphere and their impacts on societal activities. There is an intergovernmental movement afoot to create an independent international center for prediction, first suggested in Rio de Janeiro in June 1992 at the UN Conference on Environment and Development (UNCED). An initial focus of concern will be El Niño. Such an institute can be honestly "sold" to policymakers at the highest levels of government as a necessity, oriented toward the application of forecasts to societal needs. The fundamental goal of the International Research Institute for Climate Prediction would be "to provide socially and economically useful research climate predictions to its participating countries." A center, such as the one proposed for prediction, can fulfill the needs of the scientific community while meeting the needs of societies.

Concluding Comment

There will still be some failures in forecasts of El Niño, but scientists are increasingly building on their understanding of this important phenomenon. Combining this increased knowledge with improved understanding of teleconnections around the globe will surely enable governments and people to prepare for, as well as mitigate, the weather anomalies associated with El Niño events. Only recently have international agencies coping with food security problems in southern and northeastern Africa come to realize the potential value of El Niño forecasts. A judicious use of El Niño forecast information could provide considerable lead time for agencies to prepare for likely food production problems linked to El Niño related drought episodes.