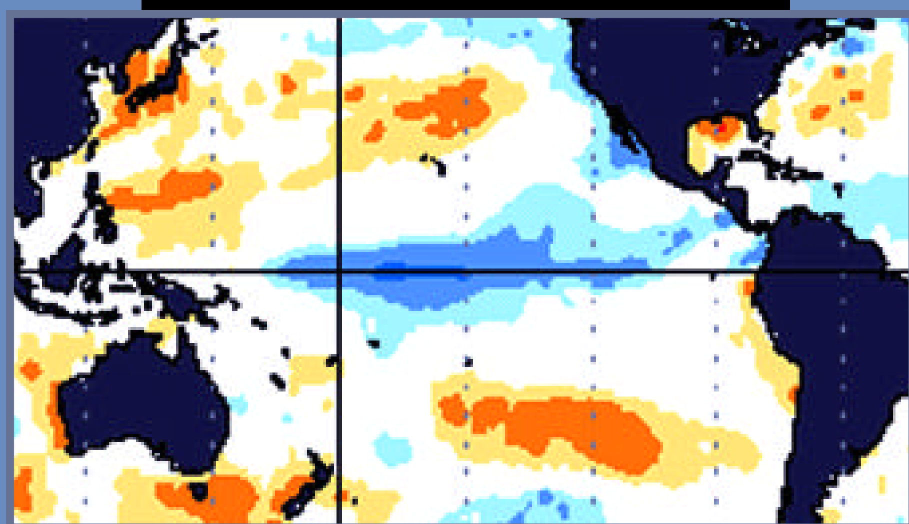
La Niña and Its Impacts



Facts and Speculation

Edited by
Michael H. Glantz

La Niña and its impacts: Facts and speculation

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La Niña: An overview of the process

Michael H. Glantz

Background

For millennia, people have tried to understand, predict, forecast, and guess what might be the natural variations of local and regional climate on seasonal and on year-to-year time scales. Among the earliest recorded treatises on weather and climate was Aristotle's *Meteorologica*, written in the fifth century BC. At least since then, seasonal and interannual variations have been a major concern to leaders and followers alike for many reasons, including food production, water resources management, shelter, and public safety. Other reasons for concern about climate and weather include general interest, curiosity, and an ever-present human desire to foresee the future. It was only toward the end of the nineteenth century that the forecasting of weather and climate started to become a growth research industry. Societal interests and concerns have been discussed by Hubert Lamb (1977) and Reid Bryson and Thomas Murray (1977), among many others.

Following a devastating famine in India in the late 1870s, interest in forecasting the behavior of the Asian monsoon received considerable attention from the British. How to predict the behavior of the Indian monsoon sparked numerous studies by various researchers who attempted to forecast the breakdown of the rain-bearing South Asian monsoon, in order to avert food shortages and famines on the Indian subcontinent, at the time a colony in the British Empire. Some researchers focused on the possibility that an understanding of temperature anomalies in the tropical Pacific and Indian Oceans was the key to the improved forecasting of potential food production problems in India.

During the next few decades, researchers such as Charles Todd, Henry Blanford, J.N. Lockyer and Hugo Hildebrandson searched for reasons behind India's monsoon failure. In the earliest decades of the twentieth century, Gilbert Walker studied changes in atmospheric pressure at sea level in the western and central Pacific Ocean and in the Indian Ocean. He identified a seesaw-like process, naming it the Southern Oscillation. Scientists have since developed a Southern Oscillation Index, which has served as a statistical measure to identify the likely onset of an El Niño or a La Niña event, when sea level pressure is low in Darwin, Australia (i.e., rainy conditions prevail), it is usually high in Tahiti (i.e., dry conditions prevail), and vice versa.

The way that many of Walker's peers in the meteorological profession looked at his teleconnections work was captured in his obituary that appeared in 1959 in the *Quarterly Journal of the Royal Meteorological Society*:

> Walker's hope was presumably not only to unearth relations useful for forecasting, but to discover sufficient and sufficiently important relations to provide a productive starting point for a theory of world weather. It hardly seems to be working out like that.

Meanwhile, in the early 1890s on the eastern side of the Pacific, Peruvian geographers began to write about a shift every few years or so in their coastal ocean current that brought heavy rainfall to coastal desert areas in northern Peru and affected navigation, the abundance and types of fish caught, and increased vegetative growth along the usually arid Peruvian coast. At a conference in Lima (Peru) in 1892, Peruvian geographers referred to (and perhaps named) this phenomenon as El Niño, apparently for the first time. In earlier decades in the 1800s and in preceding centuries, however, Peruvians would refer to the "septennial" torrential rains that seemed to reappear every seven years or so (Sears, 1895). Septennial rains were most likely a reference to El Niño-related periodic heavy rains and destructive flooding in northern Peru.

In the late 1960s, UCLA Professor Jakob Bjerknes, using data collected during the 1957–58 International Geophysical Year (IGY) and existing research produced by others on Peru's coastal currents, identified the physical mechanisms linking sea surface temperature changes in the eastern equatorial Pacific off the coast of Peru with sea level pressure changes in the western Pacific. This basin-wide process of air-sea interaction along the equator, as opposed to the local air-sea interactions off the coast of Peru, became referred to by two meteorologists (Rasmusson and Carpenter, 1982) in the early 1980s as ENSO, the El Niño/Southern Oscillation. It is now recognized that ENSO's warm and cold extremes affect weather and climate systems around the globe.

It was not long before Bjerknes's hypothesis was successfully tested by nature, with the onset of the strong 1972–73 El Niño event. With each event since then, the scientific community has become increasingly interested in and more knowledgeable about the phenomenon. Although the 1972–73 El Niño was devastating in its own right, especially to Peru, and although it piqued the interest of some physical scientists, it was really the 1982–83 event that prompted the scientific community and a handful of governments to focus on improving their understanding and their forecasts of this phenomenon in order to prepare for its possible impacts. No researcher had publicly forecast the 1982 event well in advance of its onset and, as a result, scientists and societies around the globe were blind-sided by the timing and magnitude of this event. Because of its intensity and the high visibility and high costs of its impacts on societies and on ecosystems, it earned the label at the time as the ''El Niño of the Century.''

The 1997–98 El Niño was another example of an El Niño that surprised the research community, because of its rapid onset and, later, because of its unexpected intensity. After all, there had already been an El Niño of the Century. Yet, in the short time span of just 15 years, the 1982–83 event was replaced by the 1997–98 event as the El Niño of the Century. Many potential users of weather information came to regard El Niño-related information more seriously for use in their particular decision-making activities. All of this is good news to researchers, governments, and societies in general. However, during the recent period of growing interest in and concern about warm events, other parts of the ENSO cycle – normal conditions and cold events – were given much less attention.

Introducing La Niña

Figures 1-1 (*c*) and 1-2 (*c*) depict the comparisons of selected major El Niño events and of La Niña events, using a composite index, the MEI (Multivariate ENSO Index). The index was constructed by NOAA scientist Klaus Wolter, using a set of six variables, as noted in the caption for Figure 1-1.

Until the late 1990s, there had been relatively little interest worldwide in the societal impacts of La Niña. It is likely that the intense 1997–98 El Niño and its rapid demise in May 1998 sparked considerable interest in forecasts of an intense cold event to begin in the summer of 1998. Scientists forecast a strong La Niña by the end of 1998. We now know with hindsight that only a moderate, but prolonged, La Niña event did develop then. It continued into the year 2000, making it one of the longest La Niña events in recent decades.

Even so, La Niña events still fail to command the level of attention achieved by El Niño among the public, the media, or decision makers. While media coverage of El Niño in the past seldom referred to La Niña, stories about La Niña usually made reference to El Niño. By inference, then, La Niña appears to be viewed as an outgrowth of El Niño, and not in any way as its equal. At the risk of reinforcing this misconception, the best place to begin a discussion of La Niña is with reference to the 1997–98 El Niño. In fact, they are of equal importance to many societies, which tend to suffer different but equally devastating impacts associated with each extreme.

Interest in retrospective assessments of the societal impacts of various El Niño events became widespread in the final years of the 1990s, as a result of the 1997–98 El Niño. Such assessments were separately undertaken by United Nations agencies, regional organizations, humanitarian aid agencies, national governments, non-governmental organizations, industries, educational institutions, official and unofficial internet websites, as well as by decision makers in a wide range of economic and social activities around the globe. A notable global effort was the response of UN agencies to the November 1997 UN General Assembly Resolution that called for an El Niño impacts assessment. This UN review of the physical (e.g., technical) aspects of the event was the responsibility of the World Meteorological Organization (WMO), while the societal aspects were coordinated by the IDNDR (International Decade for Natural Hazard Reduction, now the International Strategy for Disaster Reduction, ISDR). Each of these UN agencies established a UN task force to carry out its contribution to the overall assessment. Although there had been minimal interaction between these two assessment processes, all groups were brought together to deliver their findings at an international conference on "A Retrospective Assessment of the 1997–98 El Niño" convened in Guayaquil, Ecuador from 9–13 November 1998 (WMO, 1999).

Another assessment of the impacts of and response strategies for the 1997–98 El Niño was undertaken as the result of a grant to the United Nations Environment Programme (UNEP) and the National Center for Atmospheric Research (NCAR) from a recently established US nonprofit research organization (the UN Foundation). Case studies were undertaken in 16 countries to identify the strengths and weaknesses of societal responses to both the forecast as well as the impacts of the 1997–98 El Niño (Glantz, 2001). Countries in the study included China, Vietnam, the Philippines, Indonesia, Papua New Guinea, Bangladesh, Fiji, Mozambique, Ethiopia, Kenya, Ecuador, Peru, Costa Rica, Cuba, Paraguay, and the operations of the Panama Canal. The study teams were primarily non-governmental. That was done to objectively identify lessons for use by their respective governments. Research for each case study did, however, involve the participation of relevant government agencies. This UNEP/NCAR project, which also involved the UNU, the WMO, and the IDNDR, was designed to improve societal coping mechanisms in the face of future ENSO's extreme warm *or* cold events.

Independent research findings have shown over the past two and a half decades that climate-related extremes, such as droughts, frosts, floods, blizzards, and fires, easily capture the attention of the public, policy makers, international and non-governmental organizations and especially the media, in particular when these events are in progress. For a variety of reasons, however, sympathetic interest quickly dissipates. Such usual (and now, expectable) dissipation of media, policy maker and societal interest in post-disaster recovery brings to mind the adage, "out of sight, out of mind." A similar response occurs with regard to El Niño and La Niña events and, compared to El Niño, there appears to be an even faster drop in interest in La Niña, except perhaps among researchers.

Until the mid-1990s, many studies and the graphics within them would refer to the ENSO cycle only in terms of El Niño and non-El Niño conditions in the tropical Pacific Ocean, as shown in Figures 1-3 and 1-4. For the most part, researchers apparently did not see the need to distinguish between normal (i.e., average) and La Niña conditions. Yet, each of these conditions in the central Pacific surely has different implications for attempts to forecast climate and climate-related anomalies around the globe.

In many parts of the world, people consider El Niño as *the* climate-related "hazard" that *they* need to be concerned about (Glantz, 2001). When El Niño goes away, the cause of many of their worst climate-related problems is believed to have disappeared – at least for a while – until the next El Niño develops (or so they believe). To them it is of little, if any, concern if the sea surface temperatures (SSTs) return to a normal range in the tropical Pacific or if those SSTs move into La Niña conditions. They tend to see both of these conditions as "normal." In this regard, then, to them normal could be defined as the absence of an El Niño episode. This view has unwittingly been reinforced by the media, which tend to lose interest in El Niño as it shows signs of weakening. Then, topical political or economic issues tend to push El Niño off the front page or the TV screen.

For many other regions, in terms of anomalies spawned by the *extreme* cold phase of the ENSO cycle, what might take place is quite uncertain.

This is not necessarily because La Niña events are less predictable (as some scientists have suggested), but because fewer La Niña events have occurred since the mid-1970s relative to the previous (1950–77) period. The frequency and intensity of recent ENSO extremes are suggested in the following chart (Figure 1-3).

La Niña events were not observed in previous decades at the high level of scrutiny of the 1990s. Cold events were apparently viewed by many as providing an interlude between two potentially harmful El Niño events. Because of these factors, the societal and environmental impacts of specific La Niña events have been reconstructed using historical, anecdotal, and proxy information. Although very useful, such information becomes increasingly uncertain and unreliable as one looks further back in time.

Much of what one hears about La Niña's climate-related impacts in various locations around the globe is either speculation by media reporters or are ''guesstimates'' provided by knowledgeable researchers. The public is left to itself to decide which teleconnections (i.e., distant impacts) are reliable.

Today, the mere mention of the possible onset of a La Niña event will likely spark reactions from decision makers in countries where a strong (usually adverse) La Niña disruption of their regional climate is believed to exist (e.g., Philippines, Malaysia, Brunei, the United States). It is important, however, to keep the following points in mind: (1) forecasting related to La Niña or El Niño is not a perfect science, as witnessed by the forecast community's inability to correctly forecast the duration of the 1998–2000 La Niña or the onset of the 1997–98 event; (2) a drop in sea surface temperatures in the tropical Pacific from relatively high levels does not ensure that a La Niña event will immediately follow; (3) a strong La Niña event does not necessarily follow a strong El Niño; (4) cold events, like the warm ones, have varying levels of intensity, each of which is accompanied by its own combination of worldwide teleconnections.

Over the years, most scientists have focused on forecasting the onset of ENSO's warm extreme and to a much lesser extent on the onset of its cold extreme. As a result, they have had less skill at forecasting either the intensity of these events or the locations and severity of their environmental and societal impacts worldwide. This is an important point in light of efforts by various scientific groups to put the reliability of their forecast in the best light possible. For example, Barnston et al. (1999a) assessed the correctness of 15 experimental forecasts of the 1997–98 El Niño. They concluded the following:

It becomes clear on review of the various forecasts that were issued quarterly in the *ELLF Bulletin* that most of the forecasts did not identify a tendency toward

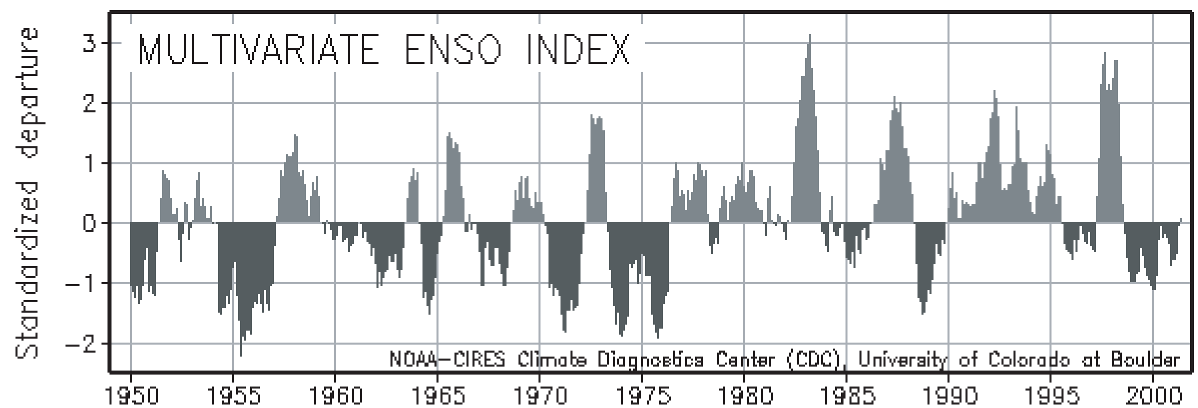


Fig. 1-3 Time series of the El Niño/Southern Oscillation using the MEI (definition of MEI: see Figure 1-1) (from www.cd.noaa.gov/~kew/MEI/).

an El Niño onset until the first quarter (i.e., March) of 1997, when rapid warming was just beginning to occur. Similarly, they did not acknowledge the appearance of an exceptionally strong event until the June 1997 forecast, when the event was becoming very strong. (p. 235)

Yet, the findings were contrary to public statements by those forecasters and modelers who reported their ''forecasting successes'' (Barnston et al., 1999b).

What La Niña is

Under non-El Niño conditions, a pool of warm water is usually located in the western equatorial Pacific. It provides moisture to the atmosphere through evaporative processes which lead to the formation of convective activity and rain-producing cloud systems in that region. As a result, heavy rains, considered by many in the region to be normal, provide the water resources needed in East, South and Southeast Asian countries and in the Pacific islands for agriculture, hydropower, water supplies and navigation. Meanwhile, extremely cold upwelled water along the equator in the eastern part of the Pacific and along the Peruvian coast creates atmospheric subsidence (i.e., descending motion of the atmosphere). This inhibits cloud formation and enhances the arid conditions along the western coast of South America. This represents the non-El Niño conditions referred to earlier, which to many observers include both La Niña *and* normal conditions.

As noted earlier, many of the pre-1997 diagrams that depicted the ENSO process presented only two states of air-sea interaction in the tropical Pacific – El Niño and normal (shown in Figure 1-4). In fact, many diagrams continue to show only these two stages of air-sea interaction in the region. Today, however, new diagrams are appearing that depict La Niña conditions as different from normal (Figure 1-5).

Figure 1-6 provides another way to show that there are the three different states of SST conditions in the equatorial Pacific. As one can see from Figure 1-6, La Niña and normal conditions appear to be relatively close to each other, especially to those living in the western part of the Pacific basin.

It was only at the very end of the twentieth century that the media took an interest in the La Niña phenomenon. Interestingly, La Niña headlines appear to have been much less threatening in tone than those used for El Niño stories, as suggested in Figure 1-7.

In a strict sense, La Niña exists only when relatively extreme cold sea surface temperatures appear for a designated period of time (several

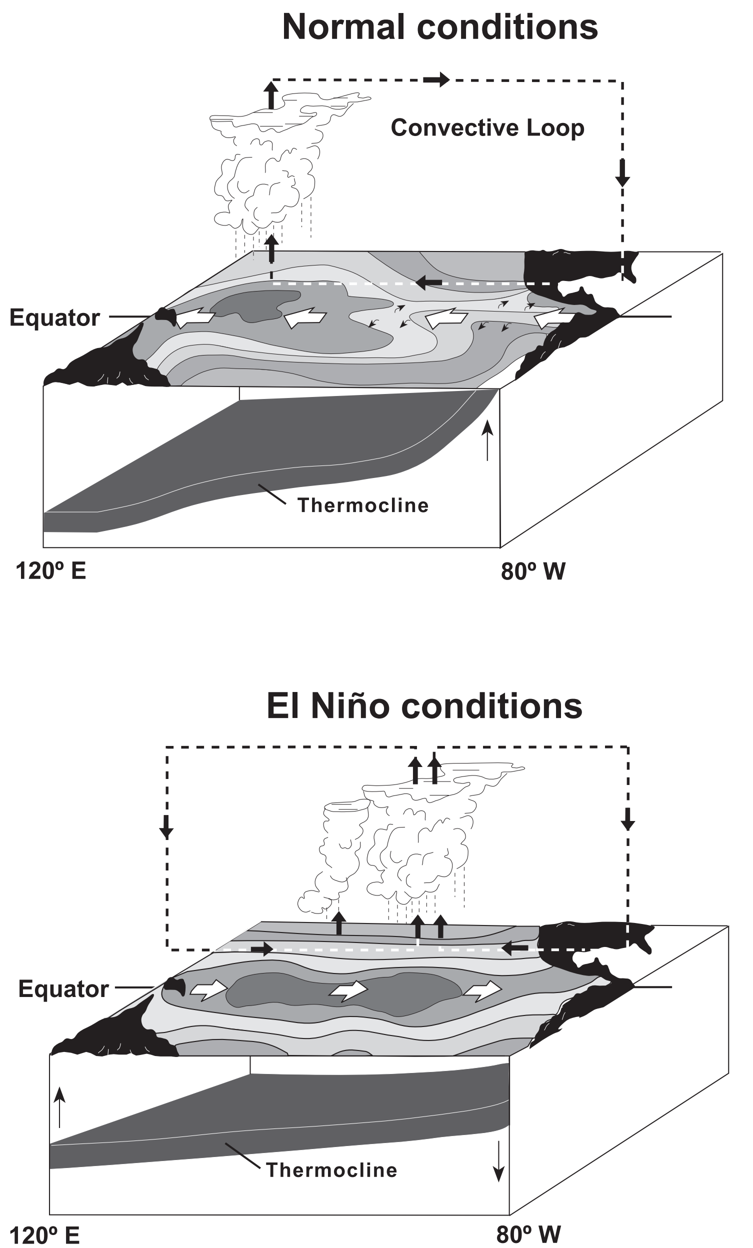


Fig. 1-4 Normal and El Niño conditions (from NOAA/PMEL/TAO Project Office, www.pmel.noaa.gov/tao/proj_over/diagrams/).

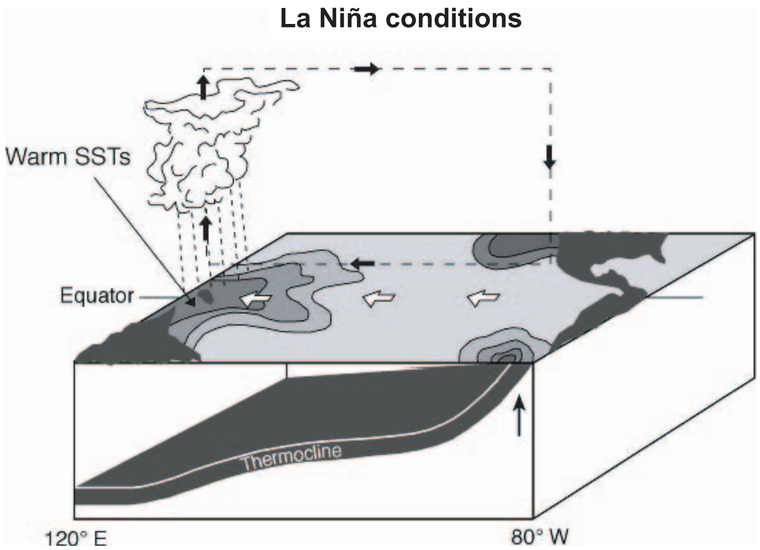


Fig. 1-5 La Niña conditions (from ESIG/NCAR).

months) in the central and eastern equatorial Pacific Ocean. This condition occurs when westward-blowing winds are strong, when the value of the Southern Oscillation Index is highly positive, when the thermocline in the western Pacific is depressed and in the eastern Pacific is near the ocean's surface (as shown in Figure 1-5). La Niña events can be weak, moderate, strong, very strong and extraordinary. Researchers have said that the 1988–89 La Niña was strong, and that the 1995 event was a weak one. Others have suggested that La Niña events such as the one in 1984–85 were weak. A first comparison of the intensities of La Niña events noted that "The sea surface temperature indices indicate that the 1998–2000 cold episode is comparable in intensity to the cold episodes of 1970–71 and 1973–76, is stronger than the cold episode in the mid-1980s, and is weaker than the cold episode of 1988–89" (NCEP, 2000). Such designations are important because the environmental and societal impacts of a cold event will depend on the level of intensity to which it develops, other things being equal. However, there have been only a few La Niña events observed in recent decades, making it difficult to use these categories at present with any degree of accuracy.

What La Niña does

Many of the existing climate impacts maps depicting the possible impacts of La Niña around the globe are variations of maps produced in the

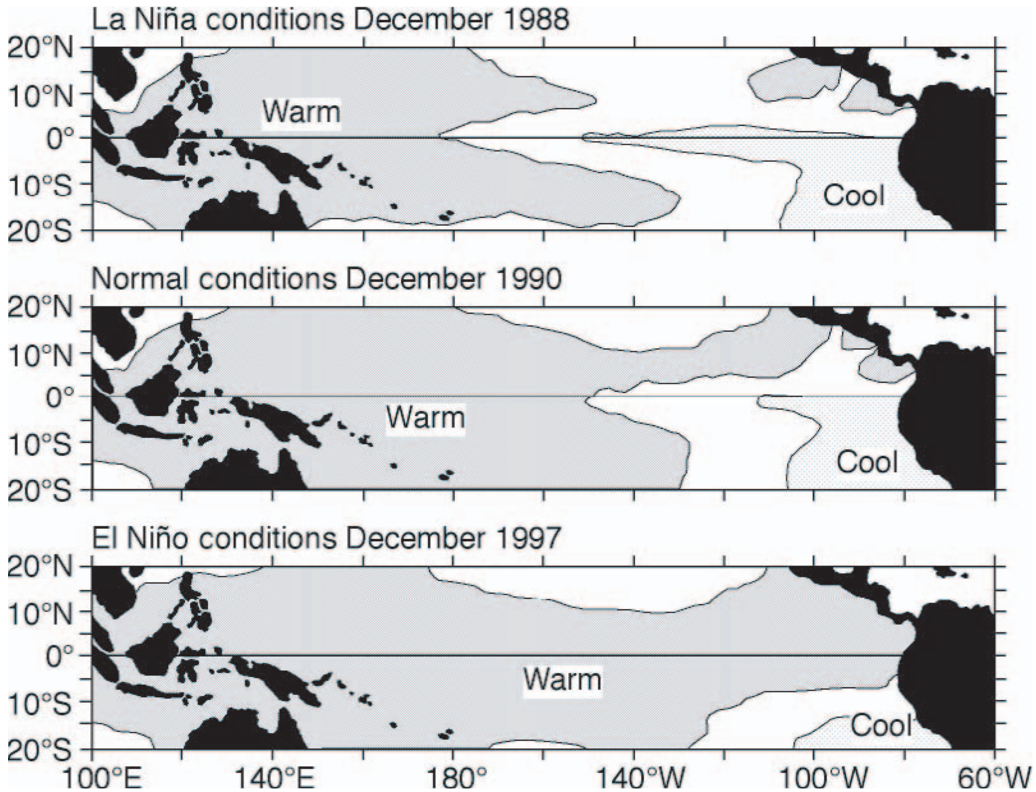


Fig. 1-6 La Niña, El Niño, and normal sea surface temperature (SST) conditions. Redrawn from NOAA's PMEL website (www.pmel.noaa.gov/tao/proj_over/diagrams/).

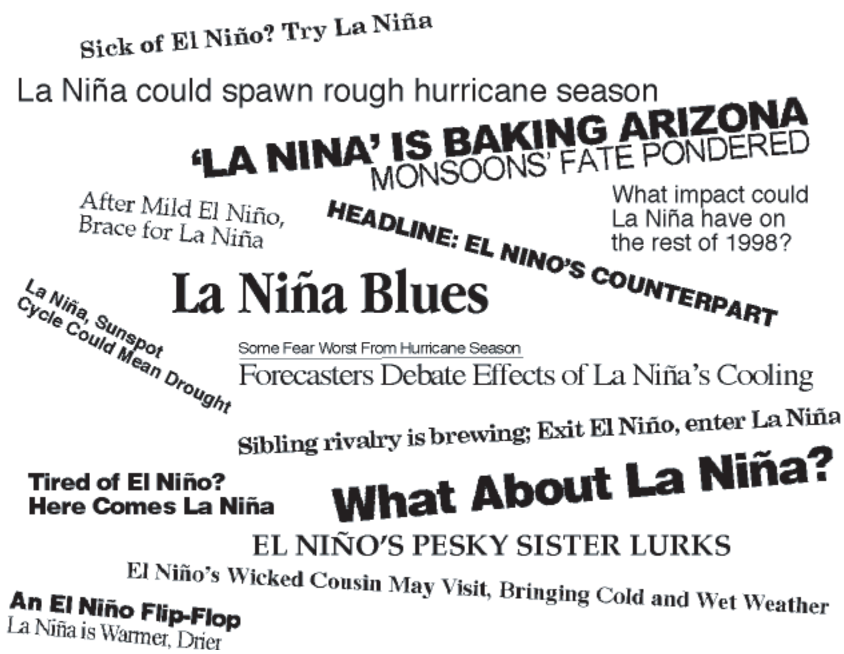


Fig. 1-7 La Niña headlines taken from the international media (from ESIG/ NCAR).

mid-1980s by Ropelewski and Halpert (1987). Since then, however, additional El Niño and La Niña events have occurred. Therefore, it is necessary that the scientific community update and recalibrate those original impacts maps, especially because they are frequently used by forecasters, researchers, the media and the public for decision-making purposes. Other aspects of La Niña also require careful consideration. They include the following: the symmetry of its impacts when compared to El Niño; the attribution of climate-related impacts occurring at the time of a cold event; the strength of teleconnections; monitoring approaches to ENSO's warm and cold extremes; and global warming's influence on the ENSO cycle. This was the reason for convening the La Niña Summit in July 1998. Although briefly noted in the next few paragraphs, these issues are discussed by the experts in the chapters that follow.

An example of the attribution problem would be the following: A major drought took place in the US Midwest in the summer of 1988. This severe and most costly drought in US history (at a cost of an estimated US$40 billion) was cited by some researchers to reinforce the argument that global warming would mean an increase in similarly intense droughts in the future (e.g., Hansen, 1988). However, an equally plausible scenario, suggested by Trenberth (1988), was that the 1988 Midwest drought was attributed to La Niña conditions in the equatorial Pacific. If so, how was La Niña involved? Could one have then predicted that there was a higher probability of a similarly intense drought occurring in the same region during the 1998–2000 La Niña?

As it happened, there was a major drought in the US in the summer of 1998. However, it occurred in the US Northeast, and not in the Midwest. There is some evidence, but not nearly enough, to say with certainty that a La Niña summer in North America is likely to be hotter and drier than normal. Attribution problems are linked to scientific uncertainty and to the absence of long-term reliable scientific data. Which distant climate-related impacts might one reliably ‘‘blame’’ on La Niña?

Similar questions of attribution can be raised for the January 1998 devastating ice storm in the Northeast of North America. To what extent was the 1997–98 El Niño involved in its occurrence or in its severity? A recent study by Barsugli et al. (1999) did suggest that El Niño had an influence on the occurrence of this unusual and rare ice storm.

A basic concern is the importance of knowing which years or, better yet, which parts of years were truly La Niña conditions. Such basic information is needed by those hoping to develop effective strategies to prevent, mitigate, or adapt to the impacts of either of the extremes of the ENSO cycle. Physical scientists, however, appear to be less concerned about what societal impacts researchers might consider to be the imprecise labeling of specific years as either ENSO cold or warm event years. For their work, scientists rely on time series of sea surface temperatures (in one part or another of the equatorial Pacific), sea level pressure, thermocline depth and outgoing long-wave radiation. For them, these time series identify the occurrence of ENSO's extremes. While labeling specific calendar years as La Niña or El Niño may be shorthand for knowledgeable scientists, it can be misleading to non-specialists who rely on these researchers to identify and date with accuracy the onset and decay of El Niño and La Niña episodes.

Putting a cost on ENSO's impacts

Costing out both the positive and negative effects of an ENSO warm or cold extreme is admittedly not an easy task. To do it correctly involves identifying first-, second- and maybe even third-order impacts, e.g., those adverse effects that ripple through an economic or social system. Because data collection is not done using the same guidelines or according to the same standard in all countries, information about La Niña and El Niño and their impacts is often anecdotal and subjective. Hence, the estimates of the global economic impacts of El Niño are wide-ranging and, for the case of the 1997–98 El Niño, varied by a factor of three: $30 billion to $100 billion (Sponberg, 1999). As poor as data collection might be during ''normal'' climate disruptions, it becomes more difficult during years of natural disaster-related emergencies.

One American author recently suggested that La Niña events are more costly for the US than El Niño events (Changnon, 1999), basing this view on an evaluation of the ENSO extremes in the 1997–99 period. His assessment received widespread coverage in the popular press in the United States. Aside from reviewing the appropriateness of the methods used to gather the information used to support such a statement, it is important to note that there have been twice as many warm events as cold events since the mid-1970s. Thus, it is not yet clear whether, on an event-by-event or on a collective basis, cold events would still be considered more damaging to the US than warm ones. Furthermore, from a US national perspective, El Niño events appear to be more damaging to its West Coast states than La Niña events. La Niña events appear, however, to be more damaging to its East Coast states. So, there is a regional consideration that need to be accounted for when determining the societal costs and benefits to a nation of either of ENSO's extremes. Such an objective assessment has not yet been done.

Physical indicators of La Niña

The following items are *some* of the characteristics or telltale signs that a La Niña event may be emerging:

- unusually cold temperature in the central and eastern equatorial Pacific Ocean
- unusually low pressures west of the date line, and high pressure east of the date line in the low-latitude Pacific
- the Southern Oscillation Index (SOI) is positive
- stronger than normal easterlies (i.e., westward-blowing trade winds)
- deep and cold water welling up to the ocean surface along the Peruvian coast and the equator in the central and eastern equatorial Pacific
- heavy rainfall over the warmer-than-normal water in the western Pacific
- a rise in sea level in the western Pacific and decline in the eastern Pacific
- a depressed thermocline in the western equatorial Pacific
- compression of convection into smaller and smaller areas in the western Pacific
- strong surface winds pushing greater amounts of warm surface water toward the western Pacific

Suggested global impacts of La Niña

A rule of thumb that has emerged is that La Niña's global impacts are generally opposite to those that accompany an El Niño. For some regions, that statement is valid. For example, droughts tend to accompany El Niño in northeastern Australia, Indonesia, and the Southern Philippines, whereas heavy rains and flooding have a higher probability of accompanying La Niña in these same locations. Another example would be the coastal zone of northern Peru which is flood-prone during El Niño but usually returns to arid conditions during normal and La Niña periods. Southern Africa tends to be drought-plagued during El Niño episodes, but flood-prone during La Niña.

As noted earlier, researchers have compiled maps depicting the type and/or the timing of impacts associated with La Niña. Clearly, the composite maps published by Ropelewski and Halpert in 1987 provided a useful ''statistically based'' generalization of the potential effects of ENSO warm and cold extremes. The maps that follow (Figures 1-8 and 1-9) were modified for the US Department of Agriculture in order to provide needed information about the months during which La Niña-related temperature and precipitation anomalies can be expected to occur.

Many variations of such composite maps for La Niña and El Niño anomalies have been based on the Ropelewski-Halpert maps and, therefore, should not be viewed as independently derived depictions of ENSO's potential impacts. Some impacts maps are composites of the impacts that occurred during several events, while others represent impacts during an individual calendar year designated as a year in which an ENSO extreme event occurred. These two highly visual and highly popular methods are used by researchers, governments, and the media to identify what is likely to happen during a La Niña event: (1) composite maps (Figures 1-8, 1-9 and 1-10), and (2) single-year impacts maps (Figures 1-11 and 1-12).

1. Composite maps draw generalized conclusions, based on a review of impacts for a set of La Niña events. These maps average the impacts of weak as well as strong events. Figure 1-10 represents one type of composite map for cold events (Northern Hemisphere winter and spring), as produced by the Center for Ocean-Atmospheric Prediction Studies (COAPS) at Florida State University.
2. The single-year impacts map is based on the selection of a known specific past La Niña year and the assumption that many of the climate-related impacts in that particular year could be associated with that specific event and are typical of cold events. The following figures are impacts maps for La Niña years 1974 and 1988.

The texts that accompany such graphics do not note that with composites,

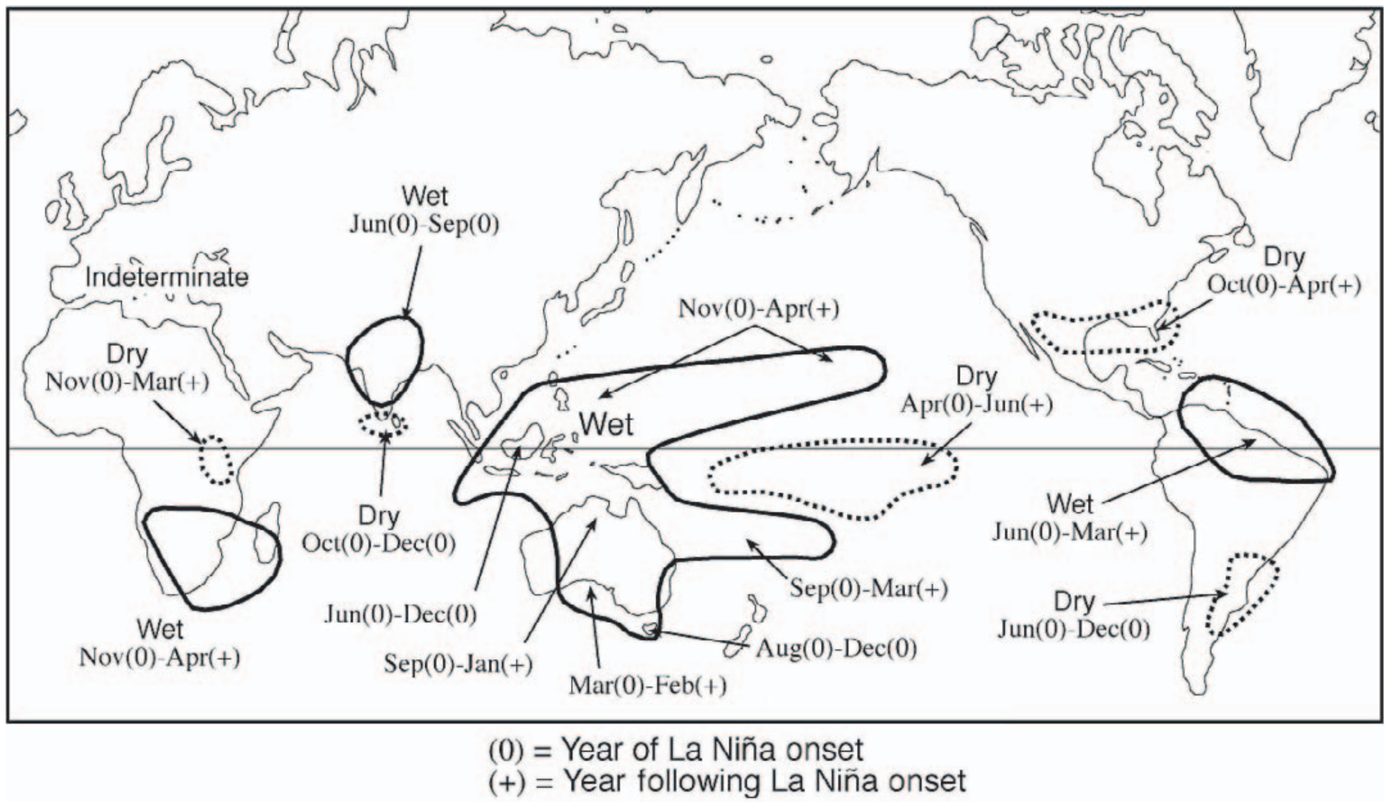


Fig. 1-8 Idealized potential rainfall impacts during La Niña events (cold episodes) (after Ropelewski and Halpert, 1987).

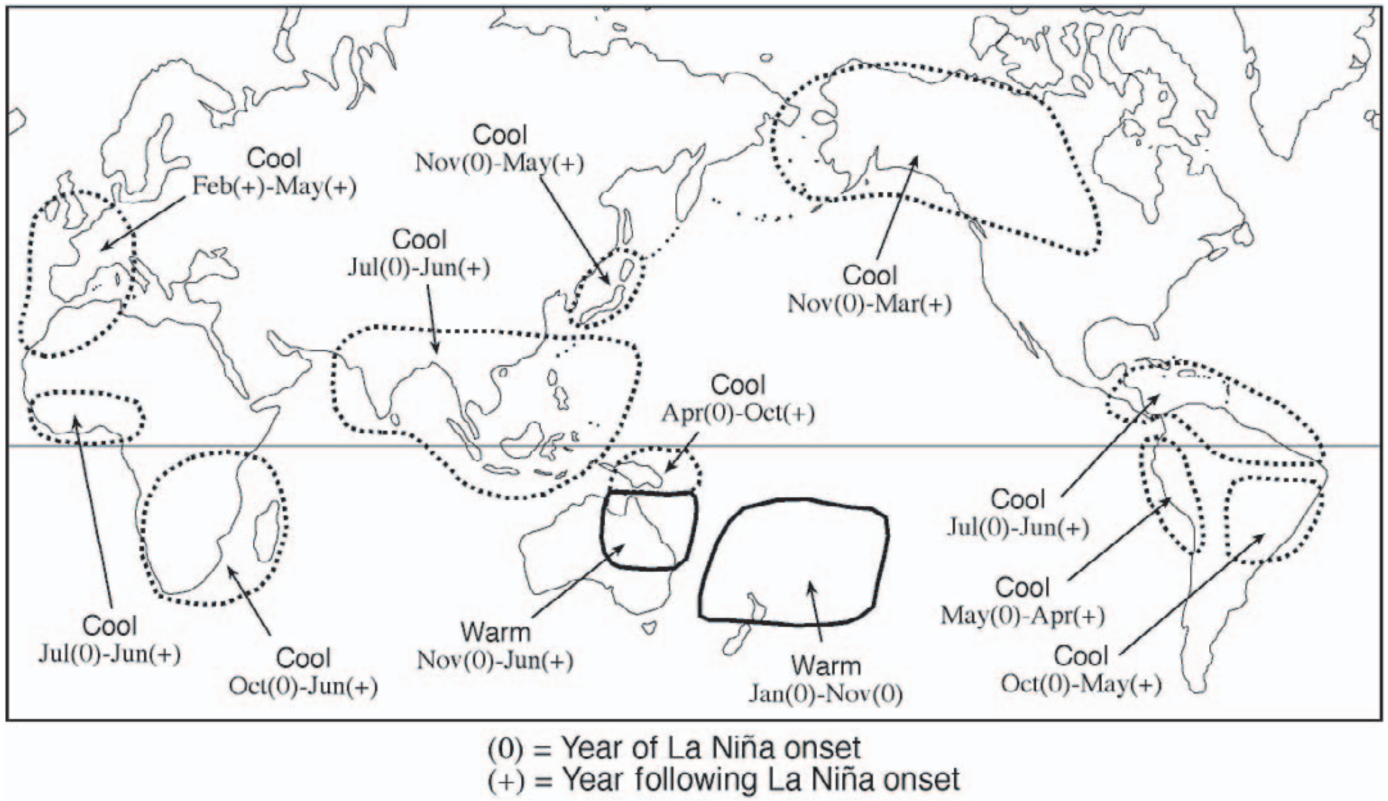
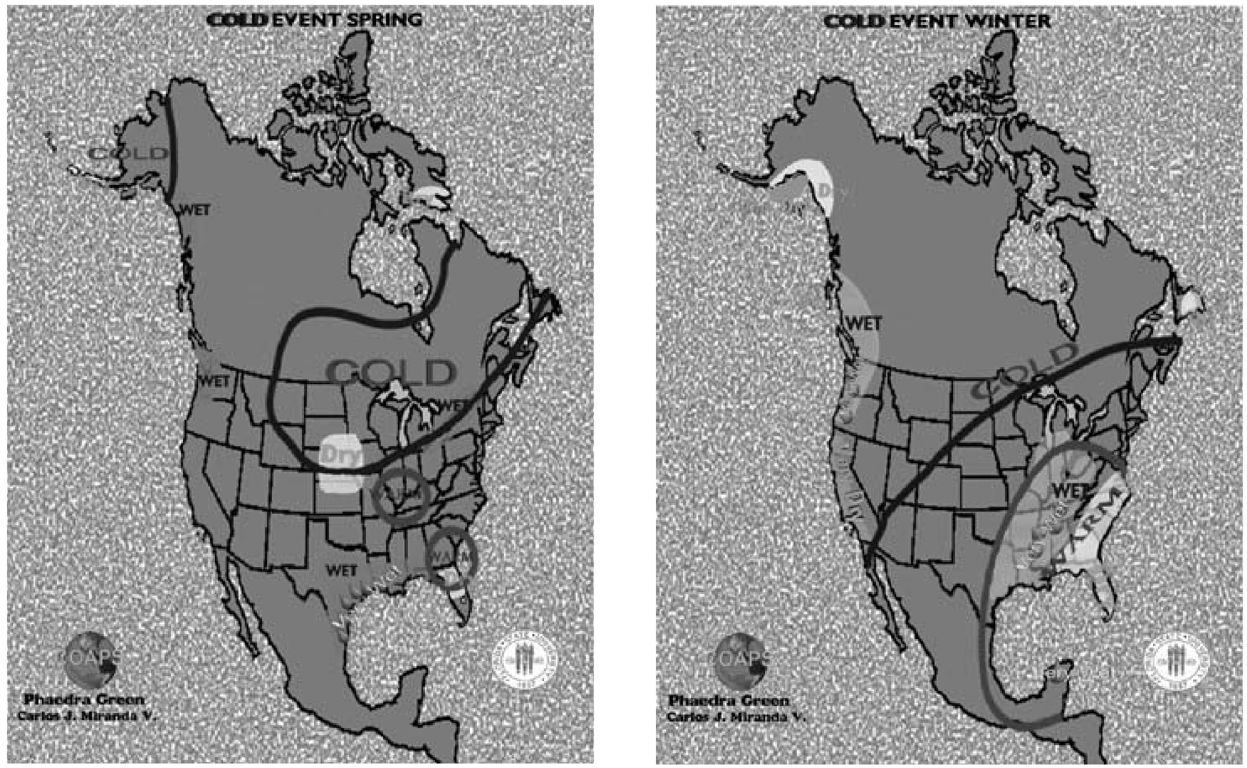


Fig. 1-9 Idealized potential temperature impacts during La Niña events (cold episodes) (after Ropelewski and Halpert, 1987).



a b

Fig. 1-10 Cold event (a) spring, and (b) winter (from Green et al., 1997, www.coaps.fsu.edu/lib/booklet/).

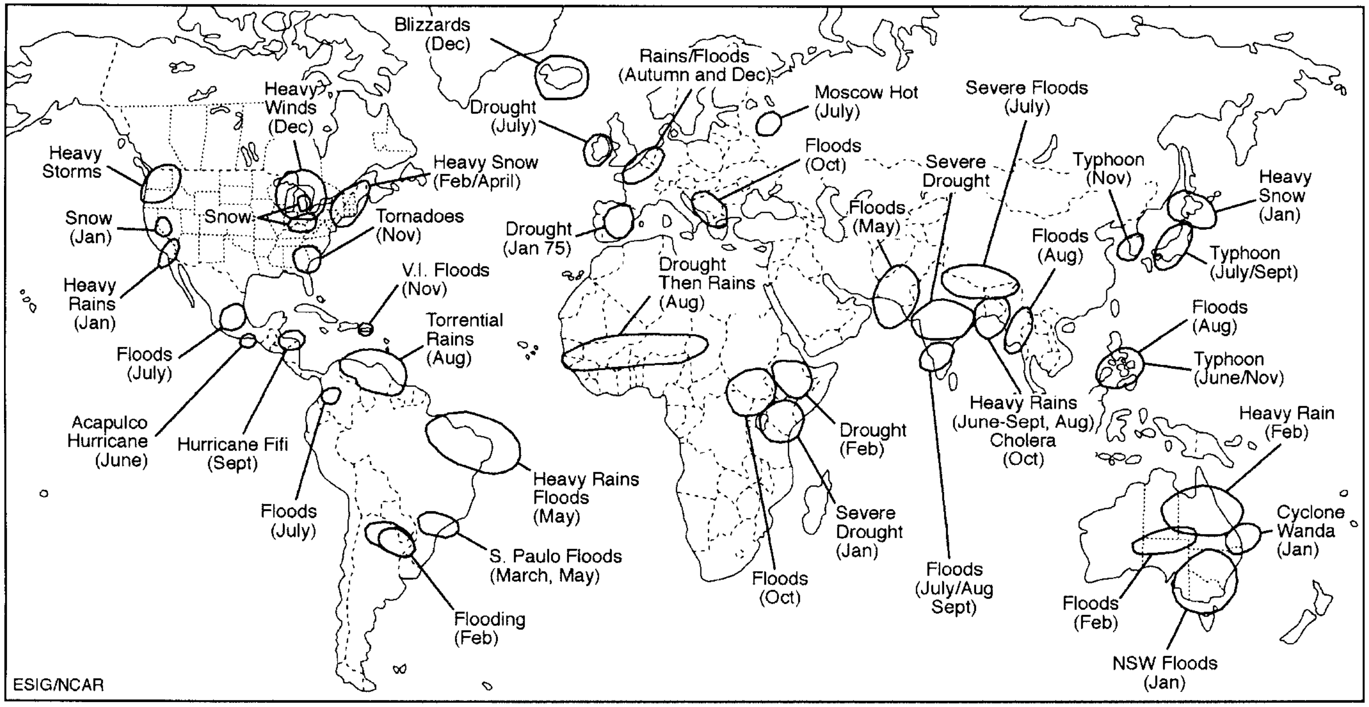


Fig. 1-11 1974 anomalies during a La Niña year. According to Trenberth (1997), a La Niña event began in June 1973 and ended in 1974, and another La Niña event began in September 1974 and ended in April 1976.

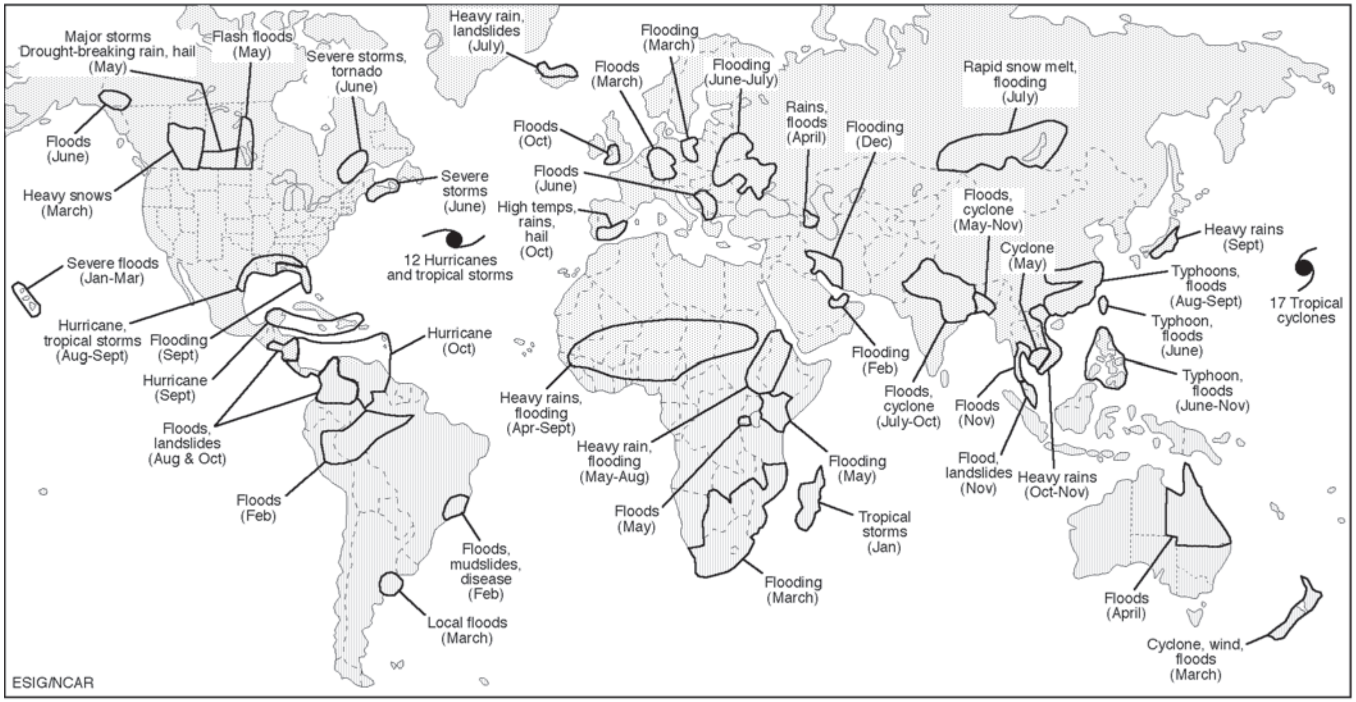


Fig. 1-12 1988 anomalies during a La Niña year. According to Trenberth (1977), this La Niña event began in May 1988 and ended in June 1989.

large events have clearer ''fingerprints,'' i.e., attributable impacts, than the weak ones. When intense and weak events are averaged together, there is a loss of detailed information about the changes in impacts from event to event. With respect to a single-year map for a given La Niña event, the use of a single year to serve as *the* analogue for impacts resulting from cold events, while suggestive, is fraught with misinformation. While certain impacts may accompany a particular La Niña event with some degree of reliability, there is no assurance that those impacts will accompany each and every event. Furthermore, La Niña's impacts in a specific locale can either be worsened or mitigated by local and regional factors. And, because La Niña events usually straddle parts of calendar years (not so for 1999), the use of only one calendar year to identify its likely impacts would be incomplete and misleading.

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La Niña and Its Impacts: Facts and Speculation

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La Niña and Its Impacts is based on a meeting of researchers, forecasters, and users of La Niña forecasts, held at the U.S. National Center for Atmospheric Research in Boulder, Colorado. La Niña, the result of air-sea interaction, can briefly be described as the appearance of cold surface water in the central and eastern equatorial Pacific Ocean. While people around the globe have become familiar with El Niño and its impacts, its counterpart, La Niña, is not so well known. Researchers at this La Niña Summit indicated that for many societies La Niña events can be as devastating as those of El Niño.

The overriding purpose of the Summit was to draw attention to the importance of improving our understanding of the La Niña phenomenon, identifying what is known, what is not yet known, and what societies need to know in order to prepare for La Niña's impacts. This volume provides the current state of the science of forecasting La Niña as well as case studies of La Niña impacts around the world and in different economic sectors.

La Niña and Its Impacts presents updated La Niña Summit papers to introduce the reader to La Niña and offers a glimpse of the state of scientific knowledge about cold events and their impacts in developing as well as industrialized societies.

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