
RESPONSES TO EL NIÑO 97-98: Implications for Forecast Value and the Future of Climate Services

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INTRODUCTION

El Niño 97-98 will be remembered as one of the strongest ever recorded (Glantz, 1999). For the first time, climate anomalies associated the event were anticipated by scientists and this information was communicated to the public and policy makers to prepare for the "meteorological mayhem that climatologists are predicting will beset the entire globe this winter. The source of coming chaos is El Niño . . ." (Brownlee and Tangle, 1997). Congress and government agencies reacted in varying ways as illustrated by the headlines in Figure 7-1.

The linkages of El Niño events and seasonal weather and climate anomalies across the globe are called teleconnections (Glantz et al., 1991). Typically during an El Niño cycle hurricane frequencies in the Atlantic are depressed, the southeast United States receives more rain (chapter 2), and parts of Australia, Africa, and South America experience drought. Global attention became focused on the El Niño phenomenon following the 1982-1983 event which, at that time, had the greatest magnitude observed in more than a century. Following the 1982-1983 El Niño, many seasonal anomalies that occurred during its two years were attributed, rightly or wrongly, to its influence on the atmosphere. As a consequence of the event, societies around the world experienced both costs and benefits (Glantz et al., 1987).

Another lasting consequence of the 1982-1983 event was the stimulation of research into the phenomenon. One result of this research in the late 1990s has been the production of forecasts of El Niño (and La Niña) events and the seasonal climate anomalies associated with them. This chapter discusses the use of climate forecasts by policy makers, drawing on experiences from El Niño 97-98, which replaced the 1982-1983 event as the "climate event of the century." The purpose of this chapter is to draw lessons from the use of El Niño-based climate forecasts during the 1997-1998 event in order to improve the future production, delivery, and use of climate predictions. This chapter focuses on examples of federal, state, and local responses in California, Florida, and Colorado to illustrate the lessons. A full accounting of the use, misuse, costs, and benefits of the recent event awaits full documentation. Nonetheless, it is not too early to begin consideration of the implications of the 1997-1998 event for how we think about value of climate forecasts and

the future of climate services in both the public and private sectors.

El Niño-related forecasts lend themselves to confusion as scientists predict a range of different phenomena (chapter 4). First, there are predictions of the onset, duration, and intensity of the El Niño (or La Niña) phenomenon itself. Such forecasts are typically associated with the state of the sea surface temperature (SST) in the equatorial Pacific, as explained chapter 2. Because these predictions are focused on the El Niño phenomenon, they do not lend themselves in a straightforward way to expectations of regional climate anomalies or variations. There is some question as to how well the onset and magnitude of the El Niño 97-98 was predicted. According to Michael McPhaden of the National Oceanic and Atmospheric Administration, "I don't think anyone in the community realized how strong it would be. Another great surprise was how quickly it ended" (Anon., 1999). Ants Leetma, Director of NOAA's Climate Prediction Center, stated, "If you look at all the forecast models, there was no consensus at the outset that this would be a major event" (Spotts, 1998). And, according to the World Meteorological Organization, it "developed more quickly and with higher temperature rises than ever recorded" (WMO, 1998).

But, there is no question that once the event was underway, scientists in the United States did an impressive job of predicting a range of seasonal climate anomalies for the following fall, winter, and spring. These ranged from excessive rainfall and storms in California and Florida to depressed hurricane activity in the Atlantic basin. Chapters 2 and 5 document many of these skillful forecasts. Because of this apparent success, the climate community has raised expectations that climate predictions will become more and more skillful (e.g., Uppenbrink, 1997). As the scientific community begins to move towards "operational forecasting," it will be important for the nation to develop a robust program of *climate services*. That is, for society to realize the benefits related to the use of climate predictions, attention will have to be paid to both the production of forecasts and the use of forecasts by decision makers. This chapter focuses on how we might begin to evaluate a program of climate forecasts with the goal of improving the use, and ultimately, their benefits to society. Chapter 5 illustrates many of the problems faced by decision makers in deciding whether to use the 1997-1998 forecasts.

FORECAST GOODNESS: USE, MISUSE, AND NONUSE OF PREDICTIONS

Predictive information has become fundamental to a wide range of decisions. Weather forecasts are the most ubiquitous, but in recent years climate forecasting has gained prominence, but only as experiments—not as full fledged "operational" products. The scientific community has for the most part labeled predictions of seasonal climate anomalies associated with El Niño 97-98 as an example of a truly successful operational climate forecast. Consequently, both scientists and decision makers have asked "how good were the climate forecasts?" of 1997-1998, and what should be expected for the future (see, e.g., Barnston et al., 1999; Baker, 1998).

Decision makers have long faced challenges in the evaluation of predictions that they use even as demand for predictive information grows (Sarewitz et al., 2000). Because

decisions are by their nature forward looking, decision makers seek knowledge of the future. Similarly, scientists and other experts have taken advantage of growing computer power and enormous databases to produce a growing range of predictive information. This growth in the predictive enterprise and its value can become problematical if predictions are misunderstood, misleading, or misused.

Society's ability to answer the question "what is a good forecast?" is central to important policy decisions related to weather and climate, especially protection of life and property from extreme events. Being able to answer this question is also important with respect to policy makers' ability to effectively allocate resources among support for forecasting and weather-related research versus alternative means to benefit decision makers (e.g., hazard mitigation policies). On a broader scale, the answer to this question is central to the ability of policy makers to allocate scarce resources between weather-related concerns and the many others demands for federal support.

Murphy (1993) used the phrase "forecast goodness" to refer to the broad societal benefits of a forecasting process. He used the broad term because evaluation of forecasts requires consideration of a range of dimensions. This chapter pays explicit attention to two of these dimensions: forecast skill and forecast value (Roebber and Bosart, 1996). The former refers to the scientific success of a forecast, and the latter to the economic benefits associated with the forecast. For a forecasting process to be considered a success, it must show both skill and value.

Prediction As A Process, Not Simply A Product

Before discussing the concepts of skill and value, it is important to present the notion of a *prediction process*. Too often we think of forecasts as simply products and neglect the broader context in which predictions occur. A growing body of experience suggests that the successful use of predictions depend more upon a healthy process than just on "good" information (Sarewitz et al., 2000; see also chapter 5). The prediction process can be thought of as three parallel processes of decision (cf. Glantz and Tarlton, 1991):

<i>Prediction Process</i>	includes the fundamental research, observations, etc. as well as forecasters' judgements and the organizational structure which go into the production of operational forecasts.
<i>Communication Process</i>	includes both the sending and receiving of information; a classic model of communication is: who, says what, to whom, how, and with what effect.
<i>Choice Process</i>	includes the incorporation of weather forecast information in decision making. Of course, decisions are typically contingent upon many factors other than forecast information.

Often, some persons mistakenly ascribe a linear relation to the processes. From the perspective of societal benefits, these three processes are better thought of as components of a broader *prediction process*, with each of the sub-processes taking place in parallel, with significant feedbacks and interrelations between them.

A central, but often overlooked, point is that success, according to the criteria of any subset of the three processes, does not necessarily result in benefits to society (chapter 5). A technically skillful forecast that is mis-communicated or misused can actually result in costs to society (e.g., see the case of forecasts of flood crests in Pielke, 1999). Similarly, effective communication and use of a misleading forecast can lead to decisions with undesirable outcomes. For society to realize the benefits of the resources invested in the science and technology of forecasting, success is necessary in all three elements of the forecast process: prediction, communication, and choice. Further, success requires healthy connections between each of the elements; they cannot be considered in isolation.

Defining Skill and Value

Because the forecast process is comprised of multiple elements, there is no single measure that captures the societal "goodness" of a forecast process (Murphy, 1993). Instead, multiple measures are needed to evaluate the technical, communication, and use dimensions of forecasts. Typically, policy makers have focused attention on the simple economics of forecasts in order to determine a "bottom line" assessment of value. Social scientists have studied the communication process (e.g., warnings), and physical scientists have evaluated forecasts according to technical criteria like skill scores and critical success indexes. These different foci are clearly important; however, the segregation of evaluation tasks has meant that *no one is responsible for evaluation of the entire forecast process*. The net result is that we tend to view the forecast process as a series of independent tasks rather than as inter-related decision processes, resulting in partial evaluations at best.

How does one know if a forecast is a good one? The answer is a bit trickier than one might think. Consider the case of early tornado forecasts (Murphy 1996). In the 1880s a weather forecaster began issuing daily tornado forecasts in which he would predict for the day "tornado" or "no tornado." After a period of issuing forecasts, the forecaster found his forecasts to be 96.6% correct — a performance that would merit a solid "A" in any grade school. But others who looked at the forecaster's performance discovered that simply issuing a standing forecast of no tornadoes would result in an accuracy of 98.2%! This finding suggested that in spite of the high degree of correct forecasts, the forecaster was providing predictions with little *skill* — defined as the improvement of a forecast over some naïve standard -- and in fact could result in costs rather than benefits.

Simply comparing a prediction with actual events does not provide enough information with which to evaluate their performance. A more sophisticated approach is needed.

Scientists have a range of techniques that they use to assess the skill of a forecast (Murphy, 1997). One way to evaluate skill is to compare the prediction with some baseline.

Climatology, that is historical weather information aggregated over time and space, provides such a baseline because it provides the best estimate of the future occurrence of weather events, absent any other information. Thus, a forecast is considered skillful if it improves upon a prediction based on climatology. For instance, the average high temperature over the past 100 years in London on September 6 might be, say, 10°C (i.e., the climatological mean for that date). Absent any other information, the best prediction of the temperature on the next September 6 is thus 10° . Any forecast for that particular day would be considered skillful if it were to improve upon climatology in comparison to the actual temperature recorded on that date. For forecasts that are probabilistic, rather than categorical, the evaluation of skill can be somewhat more complicated, but adheres to the same principles (see Murphy, 1997).

Another way to evaluate a forecast is to assess whether it had *value* to a decision maker, where value is typically measured in economic units. Katz and Murphy (1997) note that a forecast has no value if it does not affect a decision. Consequently, even a highly skillful forecast might not have value. For instance, it might be the case that the decision maker has no flexibility to use the forecast, or that the prediction arrives in a form or at a time irrelevant to the decision context. For example, a prediction of seasonal hurricane activity is of little value to the reinsurance industry if the forecast is made after they have already negotiated contracts with their clients (Malmquist and Michaels, 1999). It is also possible that a forecast could have negative value; that is, it could result in costs rather than benefits. This could occur if the forecast is misunderstood, mis-communicated, or misused in some fashion. In the 1997 flooding of the Red River of the North, many decision makers failed to appreciate the uncertainty present in what turned out to be a skillful forecast of the flood crest (Pielke, 1999). As a result, their decisions based on that forecast arguably led to costs rather than benefits.

In short, a skillful forecast is not a sufficient condition for a forecast to have value (see Stewart, 1997 on theoretical value considerations, and Sarewitz et al., 2000, for a set of practical case studies). In some cases, a skillful forecast is not even *necessary* for the forecast to have value (on this issue, the history of earthquake prediction is instructive, see Sarewitz et al., 2000). The relationship of forecast skill and its value to society is complex and context-sensitive.

Figure 7-2 is a 2x2 matrix showing forecast skill along one axis and forecast value along the other axis. The resulting four quadrants show four possible outcomes: 1) skill and value, 2) no skill and value, 3) skill and no value, and 4) no skill and no value. To understand the aggregate value of a particular climate forecast, one must carefully consider the full range of skill and value outcomes. For a mature forecasting process, a policy goal might include seeking certain levels of success on a systematic basis with respect to both skill and value. But for a new forecasting process, it is likely that outcomes will occur in each quadrant, providing a significant body of experience on which to improve performance of the system. In other words, the purpose of such a typology is to identify outcomes that fall into categories 2, 3, and 4 in order to modify the forecasting process in such a way as to shape future outcomes toward one of skill and value (category 1). The case studies of

predictions described in the next section are identified in each of the four boxes on Figure 7-2.

EXAMPLES OF FORECAST APPLICATIONS DURING THE 1997-1998 EVENT

It is important to recognize that a comprehensive evaluation of the skill and value of any forecasting process requires a considerable research effort. Consider that for the United States, the National Oceanic and Atmospheric Administration (NOAA) issued seasonal predictions for the entire country that were broadly disseminated through the media to millions of potential decision makers. The purpose of presenting the four sets of examples below is not to provide a bottom line assessment of the "benefits" of El Niño related-predictions. It is instead to illustrate a framework for feedback to the scientific and policy communities about how climate services can be improved in the future and also to suggest a mechanism for their evaluation.

Skill and Value: Responses in California

The case of predictions of seasonal anomalies in California is perhaps the most widely publicized (chapters 3 and 6). A growing body of evidence suggests that these forecasts were effectively used in many instances by decision makers to prepare for exceptionally heavy precipitation (chapter 5). For instance, James Baker, Administrator of NOAA testified before Congress in October 1998 about the responses his agency sought to stimulate based on the prior year's El Niño forecasts and observations of the event. "There is strong evidence that the \$500+ million in damages in California in the first three months of 1998 compared to \$1.8 billion in the first three months of '95 and '97 was due to better preparation by state and local officials" (Baker, 1998).

Decision makers indeed conducted a wide range of preparatory actions in California to El Niño-related climate predictions. For instance:

- On October 6, 1997, Governor Pete Wilson convened an "El Niño Summit" of 14 agency secretaries and department directors to go over state preparations (CRA, October 6, 1997). The Governor signed legislation that earmarked \$7.5 million specifically for El Niño preparations, including funding for levee work and increased staff to monitor flood forecasts and reservoir operations. The Governor also signed an executive order to coordinate the state response, set in motion planning for seven regional briefings for the months of October and November, 1997, and submitted a letter to President Clinton requesting federal aid for various projects. The summit received tremendous media attention, with over 100 media sources in attendance (FEMA, 1997). As a result of this high-level attention, Douglas Wheeler, Secretary of Resources for the State of California, stated that "El Nino preparation is now a cabinet-level priority" (Showstack, 1997).

● On October 15, 1997, a second, highly-visible "El Niño Summit" was organized by the White House, at the behest of California Senator Barbara Boxer (C. Visserig, pers. comm.). This Summit garnered tremendous national attention and led to a cascading series of preparatory actions by the State of California and its communities. For instance, on December 8, 1997, the Association of Bay Area Governments, the Governors Office of Emergency Services, and the U.S. Geological Society held a conference for local officials to help them prepare for expected heavy precipitation.

● The Federal Emergency Management Agency took a number of actions in California. These included: streamlining the processing time for "typical small disaster survey reports;" prioritizing jointly with the Governor's Office of Emergency Services, flood-related projects; developing an expedited review process of outstanding hazard-related assistance and projects to clear the way for future needs; and initiating various public affairs operations (Armstrong, 1997). Other Federal agencies taking actions in California included the Environmental Protection Agency which gave attention to toxic cleanup sites and landfills, and the Army Corps of Engineers which worked on flood control projects (Barnum, 1997).

● As a result of the various summits, briefings, and constant media attention, many decision makers in California took action in preparation for anomalous heavy rainfall. According to NOAA's California Pilot Project on the Use of Climate Forecast Information, the Orange County Sanitation District (OCSD) began taking action in the summer of 1997 (NOAA, March 10, 1998; see also Epstein, 1997). The District manages wastewater collection, treatment, and disposal service for 23 of the county's 31 cities. Actions taken by the district included plugging holes in manhole cover and public education about water usage during periods of high precipitation. Both of these activities can contribute to lessening the total volume of water flowing through the wastewater systems, thereby reducing the chances of exceeding system capacity. The District also developed a high-flow emergency plan that would be triggered by forecasts of pending heavy precipitation. According to the OCSD, the advance planning paid off during heavy rains related to the El Niño event. "Approximately \$300,000 worth of damage to OCSD's facilities resulted from the high flows of the winter storms of 1995. Flows of similar magnitude during December 1997– February 1998 were managed more effectively, due in part to the advance notice that the OCSD received of major precipitation events, and resulted in no major facility damage" (NOAA, March 10, 1998).

● Other examples of the multitude of preparatory actions in California in the fall of 1997 included: San Diego lifeguards receiving special training for river rescues; the city staff of Malibu was trained in special disaster-response drills; and Southern California Edison trained 500 employees to use a "multi-

million-dollar power failure management system" (Scheeres, 1997). Chapter 5 and other sources (CRA, October 20, 1997; Barnum, 1997; *USA Today*, 1997; and Epstein, 1997) provide additional examples of the wide range of preparations that occurred in California.

The use of climate predictions in California seems very much like a best case scenario, although flooding was still a major problem, as illustrated in Figure 7-3. But, important lessons for wise use of predictions can still be learned.

First, the effective use of a skillful prediction does not always mean benefits. In one instance, prediction-based preparations caused some controversy. In Los Angeles, efforts to clear the clear trees and brush from several river channels ran into opposition from environmental groups seeking to preserve habitats for riverine species (*New York Times*, 1997). Predictive information led to costs, rather than benefits, from the perspective of those wanting to preserve the flora and fauna that had come to occupy the Los Angeles flood ways. *The lesson here is that in addition to aggregate outcomes, often the value of predictive information also includes considerations of who benefits and who does not.* More precisely, for each case, the regional applications of forecasts, there will be a set of outcomes that could be described by the four quadrants of Figure 7-2. Hence, placing the responses in California in just one quadrant oversimplifies the richness of the responses.

Second, forecasters must be careful to manage the expectations of decision makers. The case of California is a success story, and forecasters have not been shy in touting their success. But what would have happened if the storms had failed to materialize? Michael Glantz, of the National Center for Atmospheric Research, commented in September 1997 that "if southern California doesn't get slammed, there's going to be hell to pay" (Frankowski, 1997). The connection of El Niño with seasonal climate anomalies in California is well documented. But all predictions of climate are necessarily probabilistic, meaning that there will be times when a skillful prediction is made yet the event being predicted does not materialize. In a case like California, *an important challenge for forecasters might well be to manage expectations following realized forecasts.*

No Skill and Value: The Colorado Blizzard

As it became apparent that El Niño 97-98 was going to be the most intense in 15 years, residents of Colorado began to compare its potential impacts with those of the 1982-/1983 event. Along Colorado's Front Range, where Denver and three million persons reside, this meant references to the largest blizzard in recent memory. "This year's conditions appear to parallel those in 1982-83 . . . when Denver experienced the Blizzard of '82" (Schrader, July 26, 1997). Figure 3-4 from a Denver newspaper in September helps explain the local situation. But some scientists expressed caution about drawing too close an analogy to only one previous El Niño. Several local atmospheric scientists were quoted in July 1997 as warning that the developing El Niño could bring "drought or deluge" to Colorado (Schrader, July 26, 1997). According to Michael Glantz, a scientist at nearby

NCAR, the comparisons with the 1982 blizzard is "starting to become a myth. There's an aura starting to develop around the '82-'83 event" (Frankowski, 1997).

As a result of the various ominous climate forecasts appearing in the media, City of Denver officials met with scientists at the NOAA offices in Boulder in mid-October 1997 for a briefing on what winter conditions might be expected (Flynn, 1997). The Denver Mayor's office was sensitive about any hint of the potential for a blizzard, as Mayor Bill McNichols who was in office in 1982, was widely blamed for the city's inability to handle the tremendous 1982 snowfall, and was subsequently voted out of office (Martinez, 1997). The message of the NOAA scientists to Denver city officials was summarized as "Denver could experience a drier-than-normal winter followed by a wet spring, when the region could be buried under heavier-than-normal precipitation" (Martinez, 1997). In response, Denver Mayor Wellington Webb announced on October 23 that he had rearranged the city's snow-plowing plans, made plans to stockpile salt and deicing chemicals, and budgeted additional funds for overtime snow-plow operations (Martinez, 1997; Flynn, 1997). The new plan concentrated snow-plowing activities on the city's major streets, leaving other streets to be plowed after any major storm subsided.

Just a week following the Mayor's announced plans, a major blizzard struck the Colorado Front Range and extending eastward across the High Plains. More than two feet of snow fell in Denver. The storm was Denver's worst in October since 1923 (Lowe and McPhee, 1997). While the city of Denver seemed well prepared for the storm, the main highway to Denver International Airport became impassible, meaning that passengers were stranded at the airport, which had remained open for much of the storm (Martinez and Hughes, 1997). The Mayor and the management of the Denver International Airport faced some brief criticism following the blizzard (Snel, 1997, Martinez and Hughes, 1997). Figure 7-4 is an example of the local reactions to the blizzard problems beyond the city's boundaries. Within the city of Denver, major thoroughways were kept open and the new snow-plowing plan was evaluated as a success (Lowe and McPhee, 1997).

Following the blizzard, atmospheric scientists offered conflicting opinions as to whether or not the storm could be attributed to El Niño. After the blizzard, a headline in one Denver paper, *The Rocky Mountain News*, proclaimed "El Niño not to Blame for Blizzard," while the front page of Denver's other major paper, *The Denver Post*, stated "El Niño's First Strike" (Weber, 1997, Lowe, 1997). More of the conflicting statements are found in news stories by Schrader (October 28, 1997); and Lowe (October 30, 1997). Regardless of the scientific controversies, this major early blizzard, which produced major damages in six states, became a key factor in developing widespread belief and national media acceptance of the reality of the El Niño climate predictions and the event's capability to produce severe weather, a condition explored in chapter 3.

Scientists continued into 1999 to debate whether or not the storm was directly caused by El Niño. But from the perspective of policy, the lessons of the Colorado blizzard do not depend on resolving this issue. For purposes of argument, simply assume that the blizzard was unrelated to the El Niño; in other words, assume that the predictions based on the 1982 Colorado blizzard had no skill. Even under these circumstances, a compelling case can be

made that the predictions still had value. The reason for this is that the 1997 predictions (and memory of past problems) motivated decision makers to take action on policy processes that needed fixing—in this circumstance the snow-plowing routes in Denver. The outcome suggests that city officials were only partly successful in their efforts as the roads to the airport became impassible.

In short, there are two lessons. First, because there was room for improvement in the city's snow-plowing plans, the predictions stimulated a "no-regrets" response that would have made sense even without the predictions, but probably would not have occurred without the El Niño predictions. Second, even a skillful prediction would not have addressed the city's lack of attention to the roads to the airport. *The bottom line is that the strengths and weaknesses of existing decision processes are a key factor in whether or not a forecast leads to societal benefits.*

Skill and No Value: Florida Tornadoes

Florida held an El Niño Summit on December 15, 1997, two months after the California summit. But unlike California's summit, the one in Florida was motivated by actual events, not just predictions. "Since last September, severe weather—believed to be largely the result of El Niño—has caused more than \$21 million of property damage in Florida, with 1,100 buildings or homes being damaged or destroyed" (Kleindienst, 1997). The Summit was encouraged by FEMA and organized by the Florida Department of Community Affairs in order to increase public awareness about the possibility of freezes, increased rainfall, and "more violent storms, especially over central Florida, with a greater chance of more tornadoes" (Kleindienst, 1997). The Summit also had the objectives of 1) securing funding for placing NOAA weather radios in every school by June 1, 1998; 2) promoting 100% participation in the National Flood Insurance Program; 3) enhancing interagency communications to protect Florida agriculture, and 4) improving the consistency of severe weather warnings for preparedness efforts (FDCA, 1997).

As had been predicted, Florida did experience unusually severe weather during the winter of 1997-1998, with damages totaling more than \$500 million (NWS, 1998). The most prominent event in Florida was the tornado outbreak of February 22-23, 1998, that led to \$100 million in damages, the loss of 42 lives, and more than 260 injuries (NWS, 1998). It was the single greatest loss of life to a tornado event in Florida history.

The potential for severe weather, including tornado outbreaks, was anticipated as early as December 15 at the Florida El Niño summit, based on information provided by the National Weather Service Office in Melbourne, Florida. As a result, forecasters underwent special training and provided to the public special studies of severe weather impacts and preparedness. Ironically, the week of February 22-28 had been designated as 1997's annual Florida Hazardous Weather Awareness Week. In addition to the longer term climate outlooks, the specific event was well predicted several days in advance by the NWS's Storm Prediction Center in Norman, Oklahoma. Further, this information was received by the Florida Department of Emergency Management, the Orange County Emergency Manager,

and the Winter Garden City Manager. As the storms unfolded, tornado warnings (which are issued for specific tornadoes) were issued with accuracy at levels much higher than national averages. In particular, the four counties that experienced the fatalities were provided average lead times of 23 minutes before the tornadoes struck.

The apparently skillful predictions coupled with the tremendous losses led one official in the Florida Department of Emergency Management to wonder "if the forecasts had any value at all?" (C. Fugate, pers. comm.). There are several possible answers to such a query. One is that the predictions were in fact effectively used by a range of decision makers, but that the loss statistics reflect casualties and damages, rather than lives saved and damages avoided. While it is certainly possible that casualties were reduced and damages mitigated based on the predictions, a more satisfactory explanation can be gleaned from the findings of the NWS Service Assessment following the event. The Service Assessment (NWS, 1998) identified "problem areas" in the forecast process.

The overarching problem in this case was that "even though advance watch and warning information was available and a severe weather effort has existed . . . numerous residents failed to receive or respond properly to the warnings." This occurred in part because the storms struck late at night, but also because of technical problems with the dissemination and receipt of warnings. The NWS Assessment team also expressed concern that the extended period of heightened awareness served to "desensitize" people to the threatening conditions. Also, the team found that the Floridians focused to a much greater extent on hurricane preparedness, rather than on tornado preparedness. Most of the deaths (40 of 42) occurred in mobile homes or recreational vehicles, suggesting that structural performance was a factor in the distribution of casualties. What these findings also suggest is that even with the provision of skillful predictions, the broad forecast process (including long-term considerations like structural integrity and the provision of safe refuges) did not perform as well as it might have.

It is impossible to answer with certainty how many (or even if) lives would have been saved (or how much losses avoided) if the broad forecast process had worked more effectively. It is clear in this case that even a highly skilled prediction does not necessarily lead to highly valued outcomes. It is even possible that a skillful prediction might lead to costs rather than benefits, as was the case of use and misuse of flood crest predictions during a major 1997 flood (Pielke, 1999). The case of the tornado outbreak in Florida in February 1997 should serve as an important lesson—*skillful predictions, by themselves, are an insufficient condition for society to realize benefits. An effective forecast process is necessary for the predictive information to be well used and benefits to result.*

No Skill and No Value: El Niño Hype

As the rapidly warming sea surface temperatures of the Pacific in May 1997 confirmed the onset of a record El Niño event, the public was warned to prepare for "history's most costly weather tantrum" (Spotts, 1998). Other's saw El Niño as a scapegoat. "Magazines and computer Web sites have bulged with fingers pointing the blame at El Niño

when anything went wrong” (Pool, 1998). The salience of the phenomenon amongst the American public led to El Niño jokes making the rounds of late night talk shows and appearing in advertisements for firewood, snowplows, and even Italian designer clothing (chapter 3). Figure 7-5 illustrates that the El Niño event equaled other major national issues found in the news. On the one hand, greater awareness of factors that can affect climate variability is a good thing, but on the other hand, mistaken impressions of what El Niño actually is can lead to misuse of climate forecasts.

El Niño 97-98 clearly led to heightened awareness. Figure 7-6 shows a measure of media attention to El Niño in eight Midwestern newspapers. It reveals that attention in this region was at its highest during the time of the greatest U.S. impacts, and not during the time that the climate forecasts were being issued. A similar pattern was documented by Hare (1998) who found in a more comprehensive national analysis of media coverage that,

“early stories focused on predictions that the 1997-1998 event would likely challenge the 1982-1983 event as the strongest in modern history. By October [1997] stories started appearing on preparation being undertaken to minimize the impact of El-Niño fueled storms along with estimates of the potential worldwide damage in dollars. In November and December, stories about actual impacts – speculatively linked to El Niño – dominated the stories. . . In February . . . the number of stories skyrocketed as the southwest and southeast United States both experienced record amounts of rainfall with widespread flooding and damage. In March, reports began to appear on the financial damage resulting from El Niño storms along with stories about the accuracy of El Niño forecasts several months before the onset of the event . . .”

Then, in mid-1998 scientists began to see signs of a coming La Niña event which began a new cycle of media attention.

The heightened awareness of El Niño that developed in the summer of 1997 did raise questions of a possible overreaction. For instance, consider the following exchange in a Congressional hearing on El Niño in an exchange between Congressman Calvert (R-CA) and Tim Barnett, a leading El Niño expert from Scripps Institution of Oceanography (House Science Committee, 1997).

CONGRESSMAN CALVERT: Is there any concern of overreaction? You said prepare for the worst. But sometimes we know they can be very dramatic about certain stories. *Time* magazine had a story recently warning of landslides, flash floods, droughts, crop failures during this coming year. Is this a problem? Do you think this is appropriate?

TIM BARNETT: Worries the hell out of me, very frankly. I think what has been lost in the translation from the scientists and the people that do forecasting like myself to the press is the statement of uncertainty associated with it.

Although it is given to the press, it oftentimes does not appear and people take it as a certainty that California will be washed away this wintertime.

The many warnings of weather-related dangers issued by the Federal Emergency Management Agency during the August-September 1997 period, as a result of NOAA's El Niño climate forecasts, is an example of how the connection between scientists and decision makers broke down because of "El Niño hype." In the Spring of 1998, the Federal Emergency Management Agency stated that the El Niño winter of 1997-1998 did not turn out as they had expected. From November 1, 1997, to March 31, 1998, the agency had committed about \$290 million in response to Presidentially-declared disasters. This amount is about the same as FEMA committed in each of the two previous winters. This statistic surprised FEMA, with one agency spokesperson commenting that "everybody was screaming that El Niño was going to be Armageddon, but our data reveals that's not what it's turned out to be" (ref. 1998). Figure 7-7 illustrates in humorous fashion how the public jokingly blamed everything bad on El Niño.

Experience shows that El Niño impacts in the United States overall do not mean "Armageddon." What El Niño means is that different regions of the country are more or less likely to suffer particular weather events than in La Niña or neutral years. In fact, simply because hurricane damages are much larger during La Niña events, it is probably the case that the nation as a whole experiences *less* overall economic impacts in El Niño years than in La Niña years, as shown in chapter 6. Even so, for those individuals in places with highly likely damaging weather during El Niño events (like certain parts of coastal California), El Niño events might seem like "Armageddon." In aggregate, however, El Niño is better thought of as a shift in the sort of weather impacts that we normally see, rather than as an overall increase for everyone.

As has been shown in the case examples, skillful predictions of El Niño-related impacts can reduce disaster costs. The very fact that El Niño shifts the type and places of impacts that the nation experiences from those one sees during non-El Niño years could provide usable information for those who are potentially affected (e.g., Pielke and Landsea, 1999). The summer and fall of 1997 saw a number of policy responses to scientific and media pronouncements that the Pacific Ocean was warming at an unprecedented rate. For instance, the El Niño summit in California focused attention on the possibility of strong coastal storms, and a wide range of decision makers used that information to taken preparatory actions. The state of Florida organized its El Niño summit to focus attention on the possibility of extreme weather associated with thunderstorms, but with less apparent success in reducing impacts. In both instances, the advance preparation proved prescient, as both states experienced extreme weather. These examples (and there are many others) provide a better picture of what El Niño information means to the nation than is provided by looking at aggregate impacts. Climate conditions and extreme events like droughts and floods vary regionally across the U.S., and consequently losses and gains in any given season, year, or decade vary regionally (Kunkel et al., 1999).

Disaster costs alone do not provide a measure of the value of advance preparation. One might be tempted to conclude that advance preparation efforts had little value because the past winter's disaster losses (according to FEMA) were similar to the previous two winters. This would be a mistake. Because weather impacts are highly random and FEMA's tabulation represents only a subset of the documented impacts (see chapter 6), one cannot compare different years and expect to see indication of the value of preparation. Consider that some in the insurance industry have speculated that better preparation for Hurricane Andrew might have saved \$5 billion. But, Andrew would have still been the costliest storm ever (in inflation-adjusted dollars only). Assessing the value of preparation, including advance warnings and forecasts, requires careful attention to the details of specific cases. This demands a considerable investment of time and attention. But if advance preparation is ever going to become a larger element of the nation's response to extreme weather, then we must know its costs and benefits.

The 1998 FEMA announcement of fewer losses than expected suggests that perhaps the scientific community was at once too successful and not successful enough in publicizing the coming El Niño. They were too successful to the extent that people came to associate El Niño with Armageddon, and not successful enough to the extent that the public failed to appreciate the subtleties of extreme weather related to El Niño. *If the media and the public fail to accurately understand El Niño, much less El Niño predictions, then chances are decreased that even skillful forecasts will have value to decision makers.* These are important lessons to learn as the nation develops skill in seasonal climate forecasting.

THE FUTURE OF CLIMATE SERVICES

Weather Forecasts and Climate Forecasts

The National Weather Service issues on the order of 10 million official weather forecasts annually, to an audience of perhaps 500 million individuals, companies, governments, and other organizations (W. Hooke, pers. comm.). The number of forecasts and decision makers using them provides a body of experience that allows for a stabilization of expectations on the part of decision makers about the goodness of weather forecasts. As a result, you and I know when to take an umbrella when we leave the house, and many sophisticated decision makers have a systematic understanding of the skill, quality, and value of weather forecasts. This also means that a decision made with today's forecast is likely to be substantially similar to a decision made tomorrow with the same forecast, and the next day, and so on.

Such an experiential basis does not exist in the case of climate forecasts. Decision makers do not have an experiential basis for understanding the goodness of forecasts, much less the skill, quality, and value of such forecasts. Thus, decision makers are far more prone to the misuse of climate forecasts. Learning through trial and error will take much longer and will not be as substantial as in the case of weather forecasts as climate forecasts will be made much less frequently. Decision makers must take care to avoid over interpretation of

the significance of any one forecast. For instance, a realized forecast does not mean that all forecasts will have such success and an unrealized forecast does not portend future failures. As the nation moves towards the regular provision of more precise climate predictions, the development of a body of shared experience will be critical to effective use (and limiting misuse) of forecasts.

Another, more technical issue, is associated with how scientists assess the value of climate forecasts. One common method is to create models of decision routines and use the model to assess the value of improved information. But because decision makers' understandings of climate forecasts have yet to be stabilized, the decision environment is dynamic, and difficult to model. Until such expectations do become stabilized, idealized assessments of climate forecast value are unlikely to accurately reflect the actual value of forecasts. This means that case studies, as in chapter 5, are more apt to lead to accurate assessments of the use and value of climate forecasts (on descriptive approaches, see Stewart, 1997).

Uncertainty

Nobel laureate Kenneth Arrow relates a story from his experiences as a weather forecaster in the Air Force in World War II. A group of the forecasters had been assigned the task of forecasting the weather one month in advance. Arrow found that the one month forecasts developed were no better than simply rolling dice. The other forecasters agreed and asked their superiors to be relieved of this duty. The reply sent back to the forecasters was that "the commanding general is well aware that the forecasts are no good. However, he needs them for planning purposes" (as related by Bernstein, 1997).

The anecdote illustrates the well-known tendency of organizations to gather information, even if the information does not contain useful knowledge (e.g., Feldman and March, 1981). While forecasters cannot control how decision makers use information, they do have control of the information that is provided. Because climate forecasts are necessarily probabilistic, forecasters can communicate in the language of uncertainty/probabilities to give decision makers a rich sense of the seasonal anomalies that they might expect (see Pielke, 1999, for an argument on why probabilistic climate forecasts are important).

The following examples from NOAA press releases prior to El Niño 97-98, and one prior to the 1998 La Niña, suggest that climate forecasters are inconsistent at best in how they communicate uncertainties (compare Barnston et al., 1999).

Example 1 "Strong El Nino conditions are currently developing in the tropical Pacific. The warm event will bring wetter, cooler weather for the southern half of the United States from November through March, while the northern part of the country from Washington east to the western Great Lakes will experience warmer than normal temperatures" (NOAA, June 17, 1997).

This statement is expressed in categorical, rather than probabilistic terms. No sense of

uncertainty is provided.

Example 2 “California, Texas, and Florida and other states throughout the south are likely to see significant precipitation in the next several months. Based on historical data during past El Niño events, some areas may see as much as 150 to 200 percent of normal. While we tend to view the increased precipitation as a threat, in some instances there are benefits such as decreasing the chance for wintertime drought in the Southwest and southern Plains and reducing the wildfire danger in Florida” (NOAA, November 5, 1997).

By way of contrast, this statement uses probabilistic language, e.g., “likely,” but does so in a qualitative manner. It also refers to climatology as an indication of the threshold for a skillful forecast.

Example 3 “What we’re looking at with La Niña is a tilt of the odds toward a colder winter in the Northeast with more snow and perhaps bigger storms than usual. The further north you go, the greater the chance of milder than normal weather with less precipitation” (NOAA, September 9, 1998).

This statement goes even further in its presentation of probabilistic information, but again does so in a qualitative manner. It does provide a sense of the geographical relationship to probabilities.

Example 4 “The long-term climate outlook issued by NOAA today calls for warm and dry conditions in the Southwest during July, August, and September, and these are forecast to continue through the fall and winter . . . the outlooks are also for cool conditions in the northern Great Plains, and dry conditions in interior Washington and Oregon during the next three months” (NOAA, June 22, 1998).

This final example returns to a more deterministic expression of the forecast information. It is not be surprising that this wide range of styles in presentation of information to the public resulted in some confusion among decision makers as to what climate forecasts actually mean (see chapter 5).

Before a Congressional hearing, Ants Leetma, head of NOAA’s Climate Prediction Center, stated that “if the forecasts don’t come true, you have me to blame” (House Science Committee, 1997). In this instance, the forecasts, for the most part, did “come true.” But they will not always come true. Even so, such a statement is misleading. Just because a single seasonal forecast is unrealized does not mean that a forecast is not “true.” Just like five heads in a row when flipping a coin does not necessarily imply that the coin is loaded.

These various examples suggest that forecasters have an opportunity to improve the use and value of their products by paying more attention to the provision and communication of information in a manner that more accurately reflects the nature of the phenomena being predicted.

CONCLUSIONS

This review of policy responses to the seasonal climate forecasts based on El Niño 97-98 largely support the notion that the forecast process led to positive outcomes in the use of the forecasts, particularly in the case of California. At the same time, it is clear that there are a great many opportunities to improve the forecast process as the nation moves towards the development of full-fledged climate services. The most important lie in the following areas:

- A skillful forecast does not directly lead to value. Each case shows that the decision environment plays a critical factor in the value that is attained through the use of climate forecasts. The strengths and weaknesses of existing decision processes are a key factor in whether or not a forecast leads to societal benefits.
- Forecasters must be careful to manage the expectations of decision makers. It is easy to oversell climate forecasts.
- The Colorado snowstorm case illustrated how a prediction can stimulate a “no-regrets” response that would have made sense even without the prediction, but probably would not have occurred without the prediction acting as a catalyst.
- If the media and the public fail to understand El Niño, much less El Niño predictions, then chances are decreased that even skillful forecasts will have value to decision makers. This places responsibility on forecasters to effectively communicate the significance of climate forecasts to decision makers.
- There is an opportunity for forecasters to improve how probabilistic information is communicated to decision makers. Without an understanding of the probabilistic nature of climate forecasts, decision makers will not make the most effective use of climate forecasts.

The use of climate forecasts will never mirror the use of weather forecasts. But with attention to the effectiveness of climate services, and attention to the interrelationships of forecast skill and value, the nation has great potential to develop information products that aid decision makers. El Niño 97-98 is but a first step down that path.

Captions

FIGURE 6-4. The number of catastrophes (defined as an event causing national insured losses of greater than \$25 million) related to El Niño-generated weather conditions and occurring between September 1997 and May 1998. Shown are the number of times a catastrophic event occurred in each state (most weather catastrophes resulted in losses in several states). The values in parenthesis are the number of times when the national insured losses of the catastrophic event were greater than \$100 million. Florida led in both categories with 5 catastrophes (of >\$25 million) producing losses and 3 catastrophes (>\$100 million) producing losses in that state.

FIGURE 6-5. These headlines from a variety of newspapers published during the January-June 1998 period illustrate the variety of problems caused by El Niño weather conditions. Problems are shown for tourism, agriculture, water supplies, homes, and transportation.

FIGURE 6-6. Comparison of residential bills for electric and gas service (at a Midwestern home partly heated by electricity but mainly by natural gas) for 1) the El Niño winter from January to March 1998 (with a mean temperature 7°F above normal), and 2) for the prior winter (1997) which had near normal temperatures (+1.2°F). The El Niño winter led to a 33% reduction in gas costs (31% in therms) and a 17% reduction in electricity costs (15% in kwh).

FIGURE 6-7 and its caption are already integrated in text

FIGURE 6-8. Workers are busy filling and disbursing sandbags at Colusa, California, to retain rising flood waters from nearby farm fields during mid-February 1998. (Courtesy Robert A. Eplett, California Office of Emergency Services).

FIGURE 6-9. Headlines tell the story of the benefits and economic gains resulting from the El Niño-generated weather conditions during October 1997 to July 1998.

FIGURE 6-10. Shoppers fill North Michigan Avenue in Chicago on a mild afternoon in February 1998. The mild Midwestern winter led to extensive shopping which set all-time records for retail sales in January, February, and March.

FIGURE 6-11. The mild, dry, and largely snow-free winter of 1997-1998 in the Midwest brought many benefits, as illustrated by these headlines from regional newspapers.

FIGURE 6-12. The likely distribution of precipitation amounts during January-March in the Midwest. The values shown are based on conditions in ten past periods of strong El Niño events. This statistical distribution results in an outlook for extremely low precipitation. (Climate Prediction Center).

FIGURE 6-13. The climate forecasts, as issued by various groups during the winter of 1997-1998, for the weather conditions expected in the 1998 growing season differed, ranging from very good to very bad outcomes, and these created major uncertainties amongst agricultural decision makers.

FIGURE 7-1. Government agencies and officials reacted to the El Niño-based forecasts with mitigative actions in some states, and then followed up government relief and with assistance based on the losses caused by the damaging weather, as illustrated here. Federal, state, and local agencies all got into the act in those states where bad outcomes were

predicted and occurred.

FIGURE 7-2. The relationship between forecast skill and forecast value with examples of each outcome indicated and related to cases of predictions described in the text.

FIGURE 7-3. The wet winter in California brought extensive flooding, as illustrated by this meaningful February photograph taken in flooded California (Courtesy Robert A. Eplett, California Office of Emergency Services).

FIGURE 7-4. The early NOAA announcements about the development of El Niño 97-98 and the FEMA warnings about the bad weather led to some preparations for heavy snowfall in Denver. However, not all the preparations needed were made and an early October blizzard created a series of problems in the Denver area, as illustrated here (Reprinted with permission of Ed Stein, courtesy of the *Rocky Mountain News*).

FIGURE 7-5. The great media hype and ensuing public attention to El Niño led to the event being rated alongside other major national news issues (Reprinted with permission of Ed Stein, courtesy of the *Rocky Mountain News*).

FIGURE 7-6. The time distribution of news stories dealing with El Niño as published in eight major newspapers.

FIGURE 7-7. This early October 1997 cartoon illustrates how El Niño had invaded the popular culture and become a humorous excuse, or cause, for all types of personal problems. (Copyright Tribune Media Services, Inc., all rights reserved, reprinted with permission).

FIGURE 8-1. El Niño 97-98 became a household word for many months and constantly created headlines in the national news. This cartoon, which was widely published in early March, reveals that the El Niño event ranked alongside another story of major national interest (Reprinted with permission of Don Wright).

FIGURE 8-2. Headlines illustrating some of major outcomes and certain reactions resulting from the El Niño-related weather conditions during 1997-1998. These reflect both the positive and negative outcomes experienced.

SPRING'S FLOOD POTENTIAL BEARS EL NINO FINGERPRINTS;
COMMERCE SECRETARY WILLIAM M. DALEY ANNOUNCES DISAST
REDUCTION INITIATIVE

California readies itself for El Nino ahead of time

SANTA MONICA, Calif. (Knight-Ridder) — The winds have yet to blow. The rain has yet to pour. But this fall, the threat of a powerful wallop from El Nino hangs like a rare storm cloud over the

Gore, who brought his own graphs to explain the phenomenon in detail to an invited audience of about 400, said this year's El Nino may well

would do everything in the power to protect citizens, the calm panel came from

Clinton Offers Millions in Aid
President Clinton extended a helping hand

"The people of California and now the people of Florida are giving the people of the United States some very painful examples of the excesses of this El Niño."
—President Clinton

Slipping and Sliding on Landslide Insurance

Whether it's a river of mud or a cascade of rain-saturated soil that damages your home during or after a storm can make all the difference if you are counting on insurance to help cover reconstruction costs.

SECRETARY OF COMMERCE
WILLIAM M. DALEY ANNOUNCES: EL
NIÑO STILL GOING STRONG;
IMPACTS FELT AROUND THE
COUNTRY

Bill Daley talks up a storm, and its name isn't Monica

WASHINGTON—All Monica all the time was briefly derailed by a force more powerful than oral sex: El Niño. America's Chief Weatherman, Commerce Secretary Bill Daley, was facing a battery of group of blue-biased newsmen and a battery of TV cameras last week and somehow briefly avoided the capital's obsession with human failings by addressing the topic of natural disaster. "Weather in this country is a very serious business," he said. "We cannot prevent bad weather. But we can predict it. and that's a

Senate Approves Disaster Aid for California, IMF Funding

From a Times Staff Writer

WASHINGTON—The Senate approved a package Thursday of disaster aid and IMF funding.

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

CAPITOL/POLITICS

L.A. summit seeks joint approach to El Nino "Preparing for El Niño"

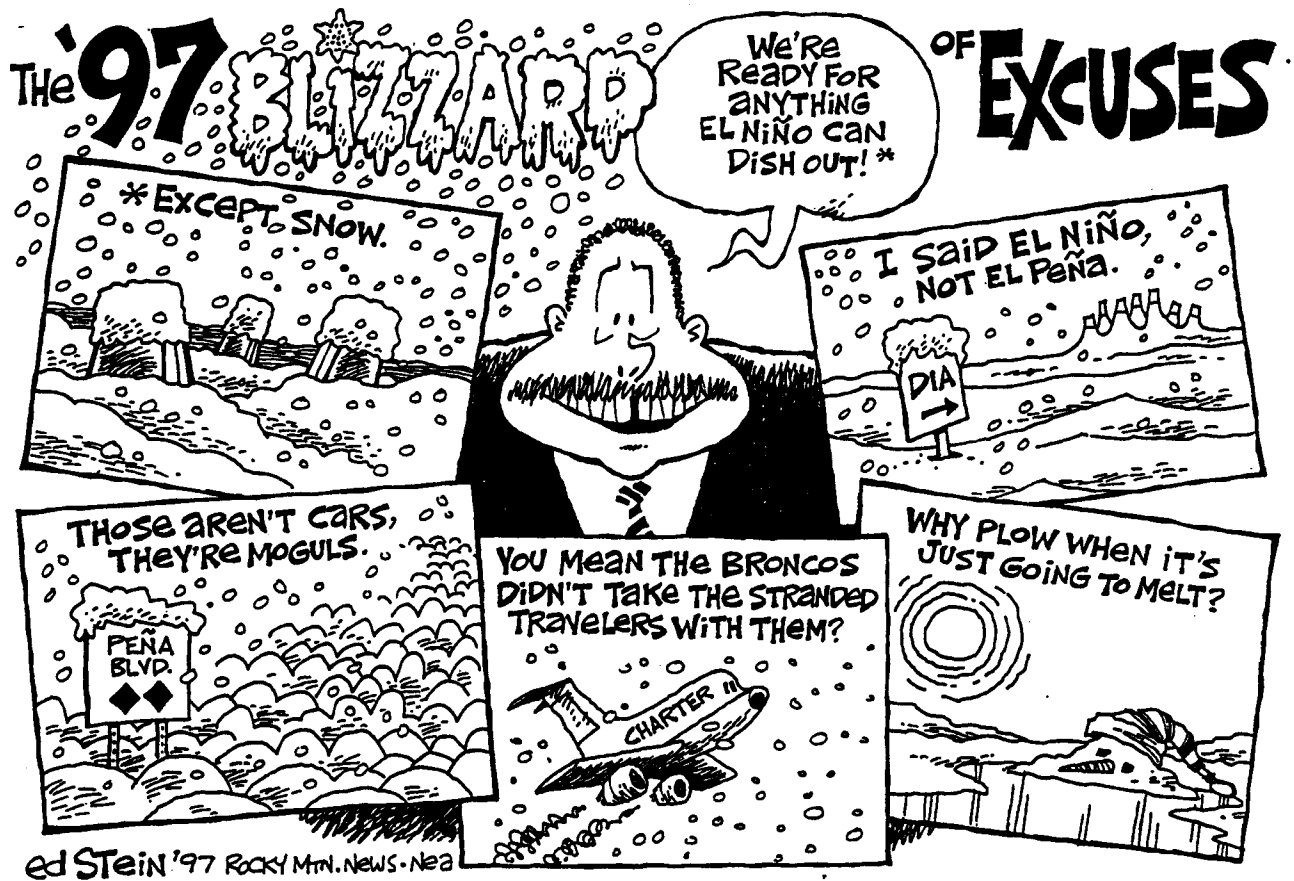
Hearing
on

		Value to society?	
		Y	N
Predictive skill?	Y	1 California	2 Florida
	N	3 Colorado	4 FEMA

FIG. 7-2



FIG. 7-3



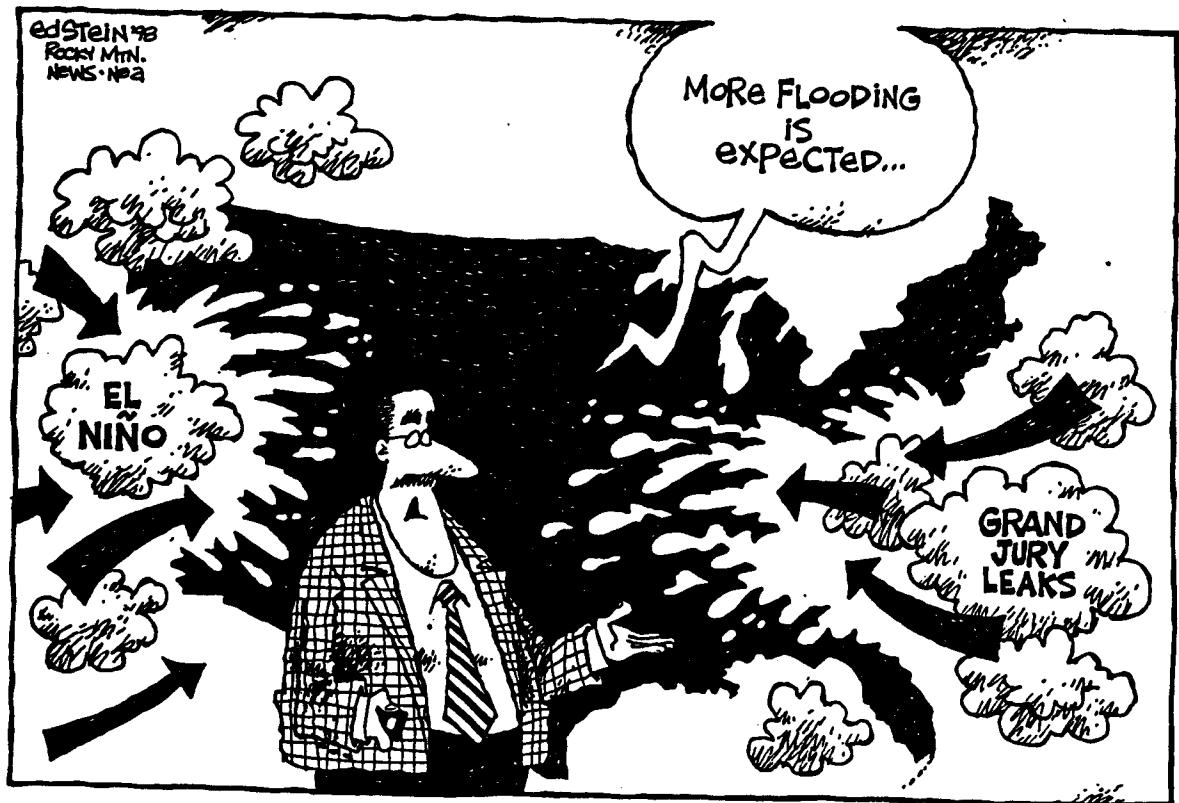


FIG. 7-5

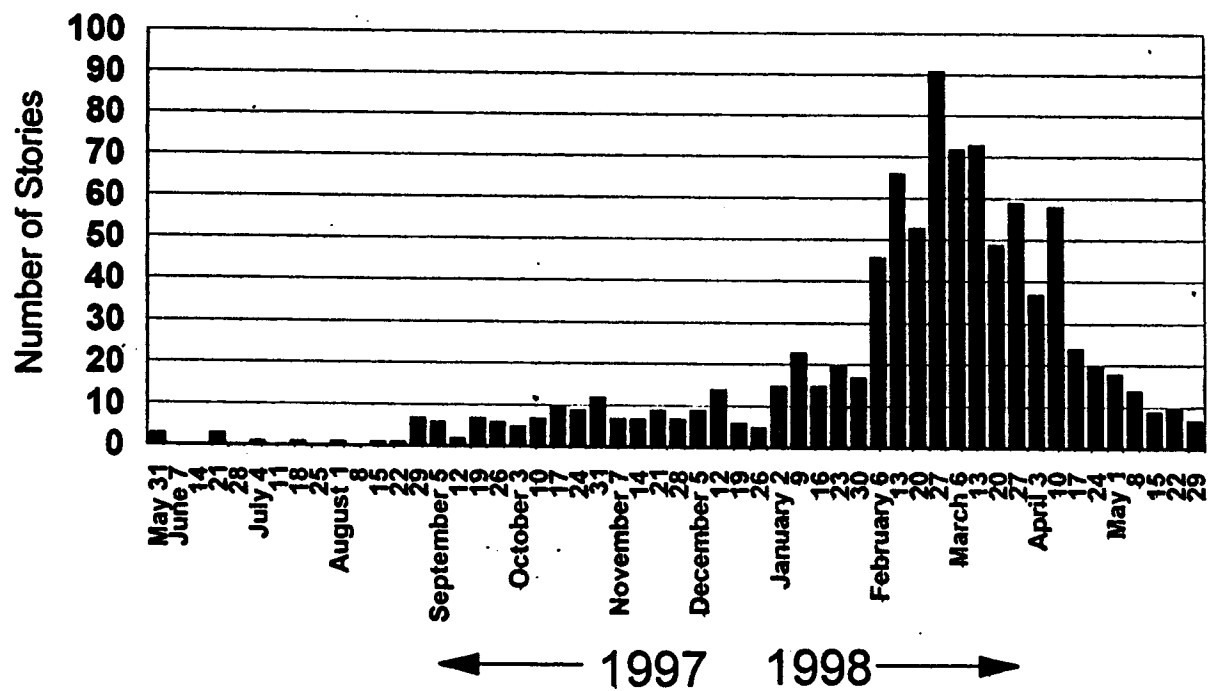


FIG. 7-6

...EL NIÑO FINDS ITS WAY INTO THE AMERICAN VERNACULAR...

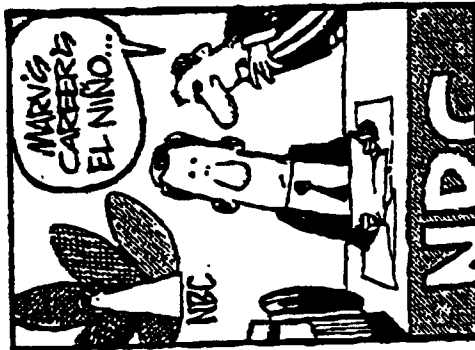
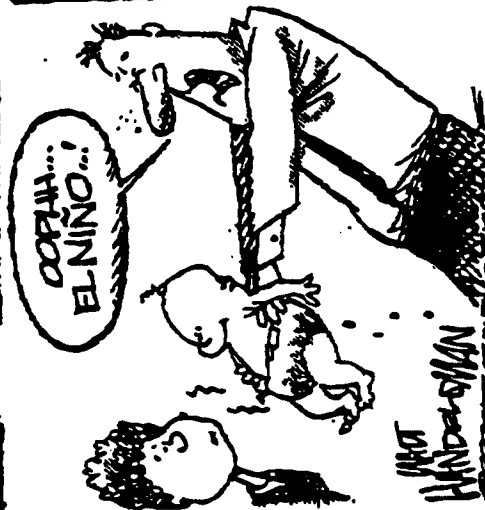
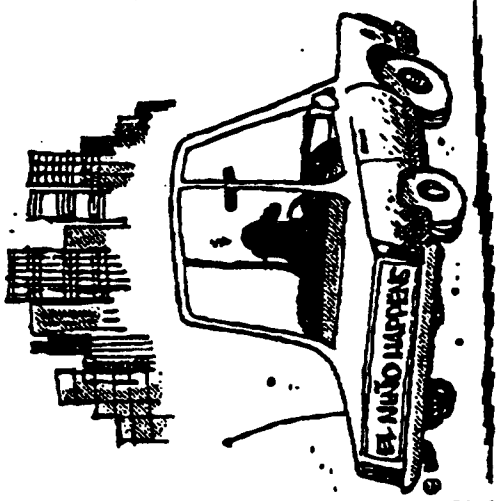
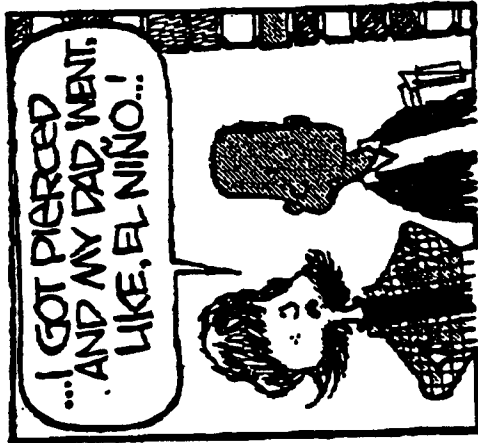


FIG. 7-7