Summary of Workshop Discussions

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The following section is a summary of all discussion sessions held throughout the workshop. The reader is forewarned that the workshop was held to identify problems associated with the use of El Niño information, including forecasts. The discussions were for the most part centered on those problems. Workshop participants recognized that there are several positive aspects of the use of El Niño information in North America, and those will likely be enhanced and expanded as research on the El Niño phenomenon progresses. Accounts of such positive value are available (e.g., Brazil workshop).

The process by which this section was put together is as follows: The discussions were transcribed by a rapporteur. The workshop organizer identified several themes which reappeared throughout the discussion sessions on a variety of topics. Each of the points raised in these sessions were then clustered under one of these key themes and put into narrative form. The key themes were identified and further subdivided into sub-themes (which are not necessarily mutually exclusive categories) as follows:

1. ***The ENSO Forecast***

   Uncertainty issues, forecast-focus issues, marketing the ENSO forecast

2. ***Users***

   ENSO info users, potential users, assessing the value of ENSO info, use and uncertainty, user needs, the role of the media

3. ***Institutional Aspects***

   Government agencies, applications centers

4. ***Teleconnections***

   North American teleconnections, teleconnection graphics

5. ***ENSO Definition Problems***

6. ***Science Issues***

Data needs, modeling, La Niña, biological indicators, the Quasi-Biennial Oscillation, science and politics

7. ***General Comments***

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Great care was taken to include in the summary almost all of the issues raised by the participants in the discussions held throughout the workshop. This section does not summarize the information presented in the discussion papers and the formal presentations but is meant to supplement them. The summary, however, does identify recurrent concerns raised by participants during the workshop and therefore should receive special attention.

1. THE ENSO FORECAST

...Chance favors only the
mind that is prepared

—Louis Pasteur, 1927

Uncertainty issues

What has been going on in the forecast community with regard to the ENSO event(s) that has (have) taken place since the beginning of 1991 has proven to be very interesting. Some researchers correctly forecast the event, while others missed it. Its original decay was expected for the autumn of 1992. *Science* reporter Richard Kerr (1992) wrote about the success of that particular forecast. A few months later he reported that scientists' expectations that ENSO would soon decay were not realized because slightly warm sea surface temperatures in the central Pacific persisted into 1993. There was a repeat of this situation

later in 1993 and into 1994. There has been some contradiction among the views of various researchers as to whether that particular event was one long ENSO, the longest in recent history, or was a set of a few shorter ones, or was a traditional one in 1991-92 followed by years of persistent, slightly warmer, sea surface temperatures in the central Pacific.

To its credit, the US National Weather Service's Climate Analysis Center noted the difficulty in dealing with the latest variations in sea surface temperatures in the Pacific:

> *The statistical and numerical model predictions of tropical SST have not done well during the last two years. . . . All techniques have large error bars for the longer lead forecasts initiated at this time of year, so caution is urged when considering predictions for periods greater than six months* (CAC, ENSO Advisory, 10 February 1995).

The point of all of this is that, while we have been in the midst of an ENSO event (or events) for the past few years; both scientists and the public appear to have had difficulty understanding what has been happening. What is clear is that not all forecasters or researchers agree on forecasts of any particular ENSO event, perhaps because they focus on different sets of indicators, or perhaps because they interpret the same set of indicators differently, resulting in differing assessments of how current conditions might evolve in the future. Nevertheless, forecasts of ENSO's onset do exhibit some degree of skill. We must identify where that skill is reproduced from one event to another. We must also identify the linkages between ENSO and local and regional climate forcing factors that would serve to modify the local effects of ENSO. As part of these efforts of scientists to enhance existing ENSO forecast skill, we must evaluate the various ENSO models and methods of assessment to identify those that appear to be providing the best (i.e., most reliable) forecasts.

There will likely never be a perfect forecast that tracks each and every ENSO cycle, even though there has been considerable advancement, as a result of the TOGA program's decade-long activities, in the scientific understanding of how to forecast an ENSO. Forecasts are probabilistic assessments; they do not come with guarantees or warranties. They are likely to improve as our scientific understanding of atmospheric/oceanic phenomena

improves. Because it is a probability statement, the forecast must be presented in readily understandable, user-friendly terms, as public and private decision makers often have difficulty with probabilistic information. To enhance the value of ENSO forecasts to the public, the public must be taught to deal with probabilities as they relate to forecasts of El Niño and of its possible teleconnections.

With regard to ENSO teleconnection forecasts for North America, until the scientific output of the teleconnection research community improves markedly, they will likely be provided in general terms (e.g., higher than average precipitation for a particular region), and not with much specific local detail, such as the occurrence of particular storm events).

It is important that the forecasters make it explicit to the users of ENSO forecasts that the forecasts are based on the best available scientific information and interpretation. Forecasters must present their forecast skill levels and capabilities to users in realistic terms, suggesting that an ENSO forecast should include a statement about the level of uncertainty that surrounds it.

Many tend to view an ENSO forecast as a yes/no projection; that is, there will be an El Niño or there won't be one. However, it is much more than that. While a go/no-go forecast may capture the attention of potential users, information on changes in an event's development requires continual updating. The USDA, for example, continually updates its agricultural projections, using in part updated ENSO projections, as new information about changes in the equatorial Pacific becomes available. Such a use of frequently updated ENSO forecasts has enabled USDA decision makers in the USDA to identify more realistically the possible impacts of ENSO events on successive stages in a crop's growth and development. However, it is also important to remind members of the user community that the conditions for an ENSO event could be present up to a certain point but could then dissipate.

Incorrect forecasts are to be expected by the user community, just as they are expected by all kinds of weather- and climate-related forecasters and researchers. Because ENSO

forecasts are less frequent than, for example, daily weather forecasts, it will likely take the forecast community a relatively long time to establish a track record of reliable and credible forecasts. In the meantime forecasters need to develop ways to generate credibility among potential users of the value of ENSO forecasts.

Users would like to know, for example, when does corroborating evidence appear following an initial ENSO forecast? It is true, as some scientists suggest, that at some point in the evolution of an ENSO event, it can be said to have "locked in" and, as a result, would be expected with a high level of certainty to continue to grow, mature, and decay over a 12- to 18-month period?

The scientific community's ability to predict the amplitude of ENSO is improving. Researchers acknowledge that it is relatively easier to forecast teleconnections (defined as linkages between ENSO events and climate anomalies worldwide) in the tropics than in the extra-tropics. For each region of the globe, there are normal climatic patterns and variations of those patterns; these must be taken into consideration when seeking to assess the impacts of teleconnections. For example, to project North American teleconnections, there is a need to consider the Pacific North American pattern at the time of the onset of an ENSO event.

Forecasts and the process that produces them need to undergo some sort of scientific evaluation. The notion of a "science court" was raised with regard to addressing uncertainties in the science of global warming, suggesting that scientists present their evidence for or against the hypothesis of human-induced enhancement of global warming; a jury of their peers then renders a decision based on the strength of the scientific arguments. Might such a science court be used for evaluating the level of reliability of ENSO forecasts issued by a variety of organizations? Or, perhaps there could be a convening of an "ENSO forecast summit," made up of key researchers, including those involved in monitoring sea surface temperatures and the Southern Oscillation (i.e., sea level pressure differences between Darwin, Australia and Tahiti). Such a summit might be similar to the periodoc tactical assessment of ENSO indicators such as the ones held in Australia by scientists and

policymakers whenever an ENSO event appears likely. This process has been captured in the Australian ENSO-related video, "Living in a Sunburnt Country." As a less desirable alternative, the scientific community could plead *"caveat emptor"* (or "ENSO forecast users beware").

Forecast focus issues

It was suggested that the focus of ENSO forecasts should be on extreme events. Because of their intensity, these generate more confidence among researchers in the predictability of alleged major worldwide effects (e.g., teleconnections). However, such extreme ENSO events are relatively infrequent.

The Southern Oscillation is an important single indicator of changes in the equatorial Pacific. There is a long time series, capturing several warm and cold events. Australian forecasters tend to rely heavily on the Southern Oscillation Index (SOI). In addition to the SOI, the research on and development of a forecast of the intensity and duration of ENSO events need to receive a higher priority.

Spatial issues

A common concern about ENSO information, including forecasts, centers on spatial considerations. From a media perspective climate news tends to be regional and local. People want to know what weather- and climate-related impacts to expect in the regions where they live. Decision makers as well as the public want to know what an ENSO occurrence might mean for their activities and well-being. Thus, they want ENSO information to be location-specific. This may be beyond the present capabilities of the research and forecast community.

Timing aspects

With regard to the forecasting of certain climate anomalies in North America, ENSO is the one of the few processes that might provide lead time of more than a few months in advance. Scientists suggest that they can provide reliable forecasts up to a year in advance. The National Weather Service is presently issuing a set of monthly forecasts up to a year in advance, to be updated each month.

There is a tendency to over-focus on forecasting the onset of ENSO. Yet, forecasting its other phases (growth, maturity and decay) are equally important to many sectors of the user community. Typically, ENSO goes through a life cycle, running from 12 to 18 months. There is considerable potential for forecasting teleconnections, once an vent has begun. The forecasting of teleconnection anomalies are most reliable for the winter season. Being able to forecast the development aspects of ENSO can be quite valuable.

Marketing the ENSO forecasts

Scientists must look at their ENSO research output as a product worth marketing to decision makers in the public and private sectors. It is important that the "messenger" of the ENSO forecast has a reputation for credibility and presents the forecast in user-friendly terms. However, the way that daily weather forecasts are presented may provide a poor model for marketing ENSO forecasts. TV forecasters present forecasts in less than serious ways. Furthermore, weather information is non-controversial and in that regard may be more appealing to potential advertisers.

However, it takes time to build confidence among potential users in an newly developed forecast system. Thus, ENSO forecast accuracy and reliability should not be prematurely oversold to the user community. The premature development and marketing of ENSO products to the public could backfire when the forecasts fail. The way that a forecast

is "packaged" can be as important as the forecast itself. Therefore, ENSO information and forecasts must be presented with appropriate caveats.

During the 1980s and early 1990s, there was considerable talk about privatizing parts of the US National Weather Service. A two-part ENSO information system was suggested: some information would be free to users, while a fee would be charged for certain kinds of information. In this regard, workshop participants felt that ENSO forecasts should be viewed as a public good, as researchers have identified several anomalous regional climate teleconnections associated with ENSO events. Some felt that information derived from monitoring ENSO (that is, nowcasts of the event as it develops) would be of value to the user community and should be available to the public. Of course, ENSO is just one piece of climate-related information available to the public; users will likely combine it with other information, when making weather- or climate-sensitive decisions.

2. USERS

It is important to those concerned with demonstrating the value to society of ENSO forecasts specifically and ENSO information in general to distinguish between actual and potential users. ENSO information must be marketed differently to different users. For potential users (decision makers, policymakers, specific economic sectors, the public, the media), we must generate interest in this information. For those who already use ENSO information, we need to assist them in fine-tuning it to their specific needs. For example, following the recent South African drought in 1991-92, interest in ENSO has sharply increased in that country but its use has yet to be tailored to the needs of various ENSO-sensitive sectors of South Africa.

Because of the most recent ENSO episode(s) between 1991 and 1995, public and private awareness has greatly increased about the phenomenon. ENSO forecasts (e.g., forecasts, advisories, warnings, etc.) have become more available to the public and to

potential users. Potential users are showing increased interest in understanding how they might use ENSO information.

ENSO info users

The use of ENSO information is more widespread in North American society than we may think. A survey of popular and business magazines identified several references to ENSO: restaurant magazines, commodities reports, brokerage newsletters, and so forth. Unfortunately, descriptions of the physical aspects of ENSO in these reports are frequently either incomplete or incorrect. Nevertheless, these articles and news items generate awareness as well as educate various segments of society. Thus, at the level of "wholesaling" (i.e., broadcasting) ENSO information to the public, they are very valuable.

One way for scientists to demonstrate that they can provide useful information would be to identify uses and misuses of ENSO information. Some countries already use ENSO information in managing their weather- and climate-sensitive activities. Drought-prone northeast Brazil is often cited as a successful example of the use of ENSO information for policymakers. Australia provides another positive example. Australian researchers have produced a video, "Living in a Sunburnt Country," to explain ENSO and to market ENSO forecasts to the Australian agricultural and livestock sectors. It is also used to educate the general public. Several of those involved in Peruvian agriculture and fisheries activities also use ENSO information to their advantage. As noted throughout this workshop, Canadian decisionmakers concerned with agricultural production activities in the Canadian Prairies also believe that ENSO affects their agricultural productivity and that a judicious use of ENSO forecasts and regional meteorological information can provide them with long-range planning options.

In addition to success stories, it would be useful to identify situations in which ENSO information had been available but was not used in decision making. Yet another set of

examples could focus on the misuse of reliable ENSO information, e.g., situations in which decisions were inappropriately made based on ENSO information. One example might be the treatment of probabilistic information as if it were certain. Another example might be using an ENSO forecast to identify unsubstantiated teleconnections to a particular geographic or economic sector. Examples of the use, misuse and non-use of ENSO information, presented together, could highlight to potential users the value of ENSO information.

USDA

Most agricultural users would require detailed information about ENSO as it progresses, so that they can relate it to potential impacts at various stages of crop growth and development. One participant noted the need to convert an ENSO forecast into specific crop impact forecasts. The USDA has been interested in ENSO for about 15 years. It appears that USDA personnel at the higher levels of decision making increase their agency's monitoring efforts once they have been alerted to the possibility of an ENSO; they update ENSO forecasts as the growing season progresses. It may be that the USDA could provide an example of the successful use of ENSO information in high-level decision making, it is not clear how well the rank and file North American farmers and industries have been made aware of its potential value. Most likely, agricultural users need to be further convinced about ENSO and its potential regional consequences (positive and adverse) for the agricultural sector in the US and elsewhere around the globe.

Potential users

Most people talk about ENSO info in general terms. Often, such talk is based on a belief that ENSO information must be useful. Seldom, however, does it provide specific detail about whether, or how, it is actually used. In other words, it is usable in theory, but is it being used in practice? Other concerns related to usability need to be addressed: What does it mean to "use" information? What does it mean to be a user? What do we mean by

the user community? We need to develop a clearer understanding of what is meant by usable science, as this phrase has become a key aspect for the evaluation of the US Global Change Research Program, a primary sponsor of ENSO research.

Which users are ready to deal with today's uncertain ENSO forecasts? Are we energizing the user community too soon by focusing attention primarily on forecasting the onset of ENSO and suggesting that we can now deliver a reliable forecast product on an operational basis? Clearly, some users are ready to deal with imperfect information, despite the surrounding scientific uncertainties. At the same time, there is potentially valuable information about ENSO. It is available, but it is not being used.

In North America there is widespread and growing interest in ENSO, even if much of it is just a general interest. Converting that interest into use, however, requires efforts by the researcher, the forecaster, the user, and an intermediary who can translate scientific research output into usable information and who can tailor ENSO information to the specific needs of various users. Those needs must be identified.

For example, we do not know which government agencies in Washington, DC are using what pieces of ENSO information in support of their missions. It would be valuable to undertake an ENSO information "audit," that is, a review of what decision makers in these agencies know about ENSO, whether they use any ENSO information at all, and if so, how they use it. This would provide the ENSO forecast and impacts community with a baseline assessment, identifying agencies and groups within these agencies that could or should make effective use of ENSO information. A prototype ENSO info assessment would help to determine whether a more comprehensive assessment involving several agencies would yield the anticipated beneficial insights.

Some of the many potential users that have been identified as benefitting from information derived from ENSO forecasts would include fire managers, the insurance industry, fisheries managers and such government agencies as FEMA. Commodities

brokerages often hire private meteorologists to keep them informed of weather- and climate-related problems. Many Third World government agencies could greatly benefit from forecasts of ENSO teleconnections. Yet, not everyone whom we think ought to be interested in using ENSO information is aware of its availability or is interested in or predisposed toward using it.

Corporations are major consumers of information if they believe that it can help them in their daily business. However, they are in competition with each other. As a result, they are often reluctant to share with outsiders what they know. While they might be willing to work closely with the forecast community up to a certain point, beyond that point they are less likely to do so, because they prefer to treat certain information as proprietary.

Perhaps an effective initial step to identify as well as cultivate regional ENSO users would be to identify a "champion" or a "true believer" in the value to society of the enhanced use of ENSO information, including forecasts. By focusing on those who are predisposed to the use of ENSO information, the researcher, user, and the intermediary can focus on practical actions rather than on a need to win over less convinced potential users of ENSO info. A demonstration of utility may be the best way to activate many of the potential but hesitant users.

Assessing value of ENSO info

To get at the true value of ENSO forecasts, it will be necessary to assess an ensemble of such forecasts, not just a single forecast. It will also involve undertaking assessments of the actual use of ENSO and teleconnection forecasts by decision makers. However, forecasts can be seen as "value added" information to existing historical ENSO information. Once scientists *confirm* that an ENSO has begun, the likelihood of its continuance is high. There is considerable value in that information to many users, especially those who are risk-averse.

Thus, the research community should not over-focus just on the value of an ENSO forecast. There is value in what one might call the "climatology of the ENSO process."

It is useful to note that some decisionmakers who have tried to use ENSO forecasts have given them mixed reviews. Water managers in California, for example, do not believe it provides (as yet) information that they can use to help them prepare to cope with ENSO teleconnections in their region. Those specific teleconnections are still surrounded by high levels of uncertainty. Should we, then, encourage decision makers in California to make more use of ENSO forecasts? At present it seems that all we can say is that in California ENSO events are associated with "severe weather" -- either floods or droughts.

The strength of ENSO teleconnections and confidence in our understanding of them varies markedly from one region to the next. Although teleconnections in California are uncertain, we have some confidence in ENSO teleconnections in the southeastern US, along the Gulf coast from Texas to Florida, for example, where ENSO tends to be associated with cool, wet weather in the springtime.

Use and uncertainty

Not every forecast will be correct. Therefore, users must be able to deal with the uncertain nature of ENSO forecasts, and to understand the consequences. Users can adapt to the use of incomplete and imperfect information associated with ENSO. Users must realize that the benefits of a judicious use of ENSO information will accrue over time and not necessarily from any single forecast. People constantly make decisions with incomplete and imperfect information.

It is the a forecaster's "job" to make forecasts, even though they know their forecasts are not guaranteed. Thus, an ENSO forecast is a "buyer beware" product. Nevertheless, many sectors of society, such as the fishmeal sector in Peru, or those concerned with US

disaster preparedness need the information provided by those forecasts, uncertainties and all. Many decision makers are not risk-takers, even if they were to be provided with perfect information. They would usually combine ENSO info with information from other groups with different, often competing, objectives. Many users *can* learn how to "handle" probability statements that accompany ENSO forecasts. An optimal decision from the standpoint of human safety will likely be suboptimal from the standpoints of other sectoral interests.

With regard to changes in probabilities, it appears that ENSO events are associated with years of fewer and less severe hurricanes along the East Coast of the United States. This teleconnection has gained credibility among policymakers, although there are scientists who argue that the association is not reliable. Hurricane specialists now remind us that North America has just gone through a 25-year period of relatively benign hurricane activity and that the next few decades could witness a return to fewer ENSOs and, therefore, to a more active hurricane regime. Making matters worse, there have been major demographic changes along the Gulf of Mexico and Atlantic coasts. Thus, hurricanes of similar intensity, landing in the same locations as before, are likely to bring more damage and to have more costly impacts than they had decades ago, because of higher population densities and supporting infrastructural development in coastal areas. It is important to remember that uncertainties on the scientific aspects of ENSO are accompanied by uncertainties on the societal side as well.

User needs

Tailoring information

A recurrent issue throughout the workshop was that ENSO information has to be tailored to the needs of specific users. ENSO forecasters must take into consideration the general as well as specific needs of the user community. But. . . what makes scientific information usable? While physical scientists might consider usability to mean that scientific research output must be credible and that the information might be needed to resolve societal

problems (at least in theory), social scientists involved in scientific issues tend to put more emphasis on more practical concerns: (1) societal awareness of the use of scientific information and (2) the "user-friendliness" of scientific information to potential users.

Not all potential users require the same level of skill, detail or reliability in a forecast. Requirements of the users will depend on the activities for which they might need forecast information. So, just how much ENSO-related information do we need to supply to users? How much detail? Should we make raw ENSO info (such as sea surface temperature maps or SOI charts) available to users to do their own analyses and to make their own assessments? For some users the forecast of the onset of ENSO might be sufficient; for others detailed information about the evolving event is of critical value (e.g., for USDA or for FEMA). As noted earlier (and often), many potential users of ENSO want local information and local forecasts. Hence, ENSO forecasts and, more generally, ENSO info need to be tailored to the needs of specific users; a "retailing" of ENSO information.

On larger geographic scales different needs of users will also emerge; for example, North American needs will likely differ from South American needs which, in turn, will differ from Australian ones, and so forth. Thus, forecasters and researchers must also be aware of divergent interests in the ENSO phenomenon among countries and regions within countries and among government agencies within countries as well.

Need for a "bridge"

Bridges are needed between the researchers and forecasters of ENSO on the one hand, and the various segments of the user community on the other. Traditionally, the research and forecast community developed information products largely independent of input from the user community. In recent years, the public and policymakers have called on the research community to show more relevance of their scientific research by addressing societal needs more explicitly and more directly. In the case of ENSO research and forecasts, the use and

value of research products is not always clear. Therefore, to demonstrate benefits and to maximize use, a "bridging" community needs to work closely with the research and user communities so as to serve to educate users about ENSO science and to educate ENSO researchers about the various user communities.

Because the use of scientific research is not always obvious and straightforward, the scientific community needs to convince potential users about the usability of ENSO research. To do so, it needs to better identify and understand the types of information that are needed by different users. Building a community of interests takes time: credibility has to be cultivated in the forecasts and in the ability of the scientific community to deliver reliable projections during the evolution of an ENSO event. One approach would be to encourage users to get involved in the early stages of the development of a forecast, and, perhaps, even in the design phase of the research projects leading to an enhanced forecast capability. This could build trust and lead to a mutual understanding of interests between forecasters and users. For their part, industry, too, has a responsibility to understand the potential value that ENSO research can offer and to communicate that understanding to the research community.

Multidisciplinary workshops on the usability of ENSO information that involve scientists, policymakers, and users is one way to "reach out" to the user community. These could also be held for the media, especially science writers. Workshops provide a way either to "wholesale" or to "retail" ENSO information.

Need for "translators"

Scientists require translators in order to make scientific information such as that related to ENSO directly useful to a particular sector or interest. It is not enough for scientists to believe that their research is useful to society.

ENSO forecasters and researchers are in need of "translators" who can actively engage in translating science into terms that specific users can understand. This is an important task,

because, without it, much of the existing pool of scientific information may not be of immediate and direct value to users.

Translators could summarize modeling, forecast and general information about ENSO events and their teleconnections in the context of a particular user's needs, determining in the process the appropriate level of detail required by the particular needs of specific users. Many potential users of ENSO info are most likely not familiar with the science of ENSO and rely on the popular media for intermittent news reports about it. The media, however, become interested only when an ENSO event has been forecast.

An increasing number of examples appearing in the popular literature strongly suggest that people *are* being made aware of ENSO, but they may not really understand its processes or socioeconomic impacts. For example, an article in a restaurant business magazine referred to El Niño as a hurricane. Translators could assist in correcting misimpressions of the phenomenon.

The insurance industry is beginning to show interest in the phenomenon; FEMA and the Office of Foreign Disaster Assistance (which is within US AID) are showing increased interest in using ENSO information. Still, many potential users are unaware of how ENSO affects their activities either directly or indirectly. People are often comfortable with the sources of information that they are currently using. Thus, new information has to be shown to be of value before it will be incorporated into decision processes. In addition, decisionmakers and the public do not deal well with issues that are ambiguous, controversial, or uncertain. And ENSO forecasts, while recently claimed to be operational, are still surrounded by ambiguity, controversy, and uncertainty. Translators can identify the value of ENSO information at the regional level and can identify the most appropriate formats for presentation.

The role of the media

It is very important to educate the media, from the science of ENSO to its societal impacts. The media are potential educators of users about ENSO information. They are also creators of users, as well as users themselves. A user-friendly "manual" about ENSO would benefit the media, noting that there are different media with different interests in and needs from the scientific community. Science writers can get adequate space in their papers to treat the subject of climate well. The media and the publics they serve could benefit from user-friendly ENSO-related information.

However, there are problems for the media with respect to reporting on ENSO. The science of ENSO, and therefore its forecasts, are still surrounded by considerable uncertainty. Reporters acknowledge that natural variability of climate is not particularly newsworthy, but that extreme aspects of that variability are. As a result, the media tends to focus on either the forecast of an upcoming event or on the extreme impacts around the globe, once an event has begun. Some reporters tend to seek out opposing (or extreme) views, searching until someone they interview says "Yes, it's an El Niño," in reaction to a dominant view that it isn't; or "Yes, this flood or drought is definitely related to El Niño." Conflicting views in the media on ENSO and its socioeconomic impacts often confuse the public. Scientists are not necessarily the best communicators to the public of their own research findings. The media would like to report that the ENSO researchers have reached a new level of understanding or consensus, but they do not yet feel they can do so on many aspects of ENSO and its North American teleconnections.

The media could provide better reports on ENSO if they focused on peer-reviewed reports and articles rather than on controversies. But is the "best" science really important to some segments of the media? For example, TV weathercasters often use weather information to entertain as much as to educate the public. Can they be used to present descriptions and analyses of ENSO? They, too, like newspaper reporters tend to focus on the worse effects of ENSO events — droughts and floods.

3. INSTITUTIONAL ASPECTS

Does a government agency that supports ENSO research have a responsibility to encourage other government agencies (and industries) to use that information as it relates to their areas of concern? There is an opportunity, if not a responsibility, to do so. For example, there should be a mechanism in NOAA that enables it to demonstrate to federal agencies, e.g., FEMA, the value of using ENSO-related information in their short- as well as long-term planning activities. Yet, there are several obstacles, such as institutional (and bureaucratic jurisdictional) borders, that tend to block the flow and processing of ENSO information.

Social science researchers need to know what and how scientific information is being used by decisionmakers in the planning process. They need to assess the uses of ENSO-related information within government agencies. This assessment was referred to earlier as an "ENSO information audit," that is, an assessment of policymakers' use, non-use and possible misuse of ENSO-related information in their decision making. A problem with such assessments is that some groups within national and state government agencies may consider this information as proprietary. For example, the USDA treats it as "intelligence," and do not share such information with their counterparts in other nations because they export agricultural products that might compete with ours in the global marketplace. Likewise, the information used by the Canadian Wheat Board to make timely decisions are not open to public scrutiny.

Another institutional problem arises when data needed by the international research community on ENSO and its impacts do exist in some countries, but those governments treat them as proprietary. They see the data as having either strategic value (fearing that they might be providing competitors with information that could be used against them) or monetary value. Brazil and Malaysia were cited as examples of the former; China and India have been suggested as examples of the latter.

Applications Centers

Regional applications centers have been proposed to focus on interannual forecasts, with a strong focus on ENSO to inform policymakers on ENSO-related policy issues. There is convincing evidence that, while certain socioeconomic activities are clearly affected by ENSO events, there is little awareness within those affected areas about the potential value of ENSO information. FEMA, for example, could benefit from an improved understanding of ENSO; also, ENSO appears to be absent from the reports of the International Decade on Natural Disaster Reduction (IDNDR). The insurance community, too, has been unaware of the specific uses it could make of ENSO-related information.

Regional applications centers in North America could foster cooperation among government agencies, as well as among groups within these agencies, many of which appear to compete with each other. Such centers could foster multidisciplinary cooperation as well. They could also summarize information from various sources predictions about ENSO's North American teleconnections.

There is a strong need to bring users and impacts researchers into the process to create and develop such regional applications centers. This would challenge the "habit" of viewing ENSO experts as being only those scientists who come from out of town. They can be instrumental in converting global science into region-specific information and enhance its local use by policymakers and the public.

4. TELECONNECTIONS

North American teleconnections

Users interested in North American ENSO teleconnections want forecast information that has more subregional detail. Some regions around the globe have strong, robust teleconnections. It is important to identify ENSO information used in those countries where teleconnections are strong (e.g., Australia, Peru), then for North America, where teleconnections are less robust, use the lessons learned from these places. While there are consequences of ENSO events in North America, it is usually during the strongest events that they become more evident. Canadians are particularly interested in the teleconnections associated with La Niña (anomalously cold sea surface temperature events in the equatorial Pacific) for the Canadian Prairie Provinces. They also noted the importance of the interactions of ENSO/La Niña occurrences with the PNA pattern. The PNA is a powerful factor in forecasting North American teleconnections. Thus, ENSO-related information must be viewed in the context of regional climates.

It was suggested that we focus only on those areas in North America with a relatively high probability of ENSO teleconnections. For example, the June to August precipitation during warm events shows a tendency toward wetter than normal conditions in about 80% of the Midwest. It was also noted that we need seasonal information related to the ENSO in the Northern Hemisphere winter.

Despite scientific uncertainties, *there are* a few regions in North America where there is emerging confidence that ENSO events can be linked to agricultural impacts. For example, some argue that there is a good statistical correlation between Pacific sea surface temperature anomalies and corn yields in North America. Users, however, need to know probabilities of such teleconnections in order to better assess the value of the information provided by the

forecast. They also need to know the timing of the various stages of the ENSO evolution and of its impact on agriculture (e.g., timing relative to crop growth cycles).

There was considerable discussion about the linkages between ENSO events and extreme weather in California. ENSO-related forecasts of rainfall in California lack reliability. Some ENSO events have been associated with droughts and others with floods. What seems to be agreed to is the general view that ENSO is associated with extreme weather in California. The location where anomalous sea surface temperatures occur in the equatorial Pacific Ocean appears to be an important determinant of the type of ENSO-related impacts in California.

Teleconnections graphics

Do the maps used to depict the location of North American teleconnections provide a useful way to convey information to users or are they misleading — suggesting, for example, more certainty than really exists? Such maps do provide a first step toward generating discussion about ENSO impacts between scientists and users. The months during which the teleconnections might occur could be highlighted as well as the probabilities of occurrence. Clearly, the reliability of the information shown on such maps has to be high. The maps would have to be user-friendly, showing appropriate information and requiring little additional explanation. Credibility is not a useful factor, because information can be believable but may still not be reliable.

Researchers now suggest that teleconnections for warm events are generally opposite those that occur during cold events. For example, heavy rains in a region during an El Niño might convert into sparse rainfall during La Niña. Thus, maps depicting teleconnections related to cold events need to be developed.

5. ENSO DEFINITION PROBLEMS

Thanks to the scientific community and the media, the public has become familiar with the term El Niño. It appears in science reports, in newspapers and on television. There is a mystique that tends to surround El Niño as a natural phenomenon. However, the term ENSO is preferred by the scientific research community. While ENSO is more correct, it would require too much explanation within each news story. Thus, it will require considerable effort to shift awareness from El Niño to ENSO in the minds of the public and policymakers. While the public may have name recognition of El Niño (and to a much lesser extent of ENSO) they may not really understand the phenomenon or how it works.

Conflicting definitions generate confusion. Clarity will emerge in time, as interest in and understanding of the phenomenon increase. For now, however, we must be more careful when interacting with the public on how we use the terms El Niño and ENSO.

Following the 1982-83 event, which was unlike the typical (i.e., canonical) ENSO model that had been developed in early 1982, researchers suggested that no two ENSO events were alike. The notion of a canonical ENSO as a predictive tool for societal and environmental impact assessment is not very useful for any given event. From a societal impacts perspective, there are likely to be types of ENSO events that have a certain set of characteristics and there are regional factors that help to generate similar teleconnection anomalies. As yet, there is no taxonomy of ENSO events.

Scientists as well as the public tend to consider several kinds of sea surface temperature (SST) anomalies in the Pacific as ENSO events. The scientific community has yet to distinguish among these different types of SST anomalies. We must convey to potential users that there are types of ENSO events, depending on various subsets of characteristics chosen to define the phenomenon. Users are interested in having more information about the intensity of an event and its teleconnections, i.e., weak, moderate, strong and very strong, as well as its duration.

6. SCIENCE ISSUES

Data needs

Discussion about ENSO-related data centered on the reliability of past data, the quality of present data, and access to data. Several participants questioned the reliability of historical data and information on ENSO and associated teleconnections. For example, there is a tendency to link all extreme weather impacts to an ENSO, such as the 1988 drought in the US Midwest, linked by some observers to La Niña, or the devastating floods in the Midwest in the summer of 1993. However, there are other forcing factors that could produce similar climate anomalies in various regions.

Quinn and his colleagues reconstructed the history of ENSO events and the intensity of each event for the past few centuries. Yet, are the data reliable enough to make such fine distinctions among ENSO events? Are such data reliable enough to identify robust distant teleconnected anomalies? For example, we have been closely monitoring an ENSO event(s) since early 1991. Yet, for the last 3-4 years we have not been able to formulate a clear picture of this event(s): Is it one long event? Are they multiple warm events? Is it a strong event? Is it strong in terms of sea surface temperature anomalies or in terms of its societal impacts?

Those interested in ENSO are aware of data needs such as long time series that can be used to trace the development of the warm event/cold event interannual cycle which is embedded in a multidecadal scale global climate fluctuation. The information that we have (the most recent events based on observations and earlier ones based on a reliance on various proxies) must be calibrated to determine its degree of reliability. This is important, because the quality of data being produced today is under question. Statements such as "credible data is limited," "the data is getting worse," "while ocean data is improving, precipitation data is becoming less continuous and of questionable reliability in many parts of the globe," "wind

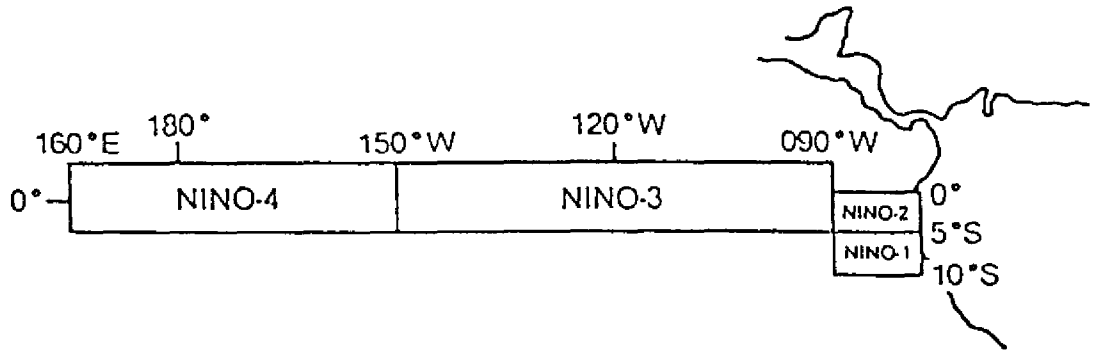
data is inadequate," are on the increase. There are, however, some more favorable comments on data: "data do exist but we cannot get it out to others," and that "data and observations will improve in the future."

Both industrialized and developing country governments have shown a reluctance to maintain monitoring networks, especially as competition increases for a dwindling national revenue. In this regard, it is important to note that there has been a shift in emphasis toward an increasing dependence on monitoring environmental changes from space. Space observations can provide continuity of data over long periods of time, a continuity that is difficult to maintain for ground observations as a result of constant financial pressures.

From the users' perspective, different users need to know what an ENSO occurrence means in terms of temperature, precipitation, wind, humidity, and so forth in those subregions in North America and for those economic sectors with which they are concerned.

Modeling

Models related to ENSO and its teleconnections are useful as heuristic devices and for developing forecasts. To date, modeling efforts have tended to focus on the region in the central Pacific referred to as NINO3, shown in the following map. Modeling activities will encompass more than the NINO3 region.



Schematic depicting NINO1,2,3,4 regions

There is a lack of consensus about the robustness of ENSO modeling results. Workshop participants suggested that it would be useful to convene a meeting of ENSO researchers, including modelers, to discuss the strengths and weaknesses of both models and observations. It was noted that there have been ENSO forecast summits for modelers of ENSO.

La Niña

For some regions of the world, forecasts of La Niña (cold events) may be more important than ENSO (warm events). For example, Canadian agricultural researchers believe that La Niña events, in combination with other regional atmospheric phenomena (e.g., the Pacific-North American [PNA] pattern), strongly influence precipitation patterns in their agricultural heartland, the Prairie Provinces. Now that ENSO seems to have captured the attention of researchers in North America, there is a need for greater scientific scrutiny of cold events. We also need to improve our understanding of La Niña teleconnections. It is important to note that in either extreme SST anomaly situation (warm or cold event), the alleged teleconnections cannot be expected to recur in a specific location with each successive event; there is, however, a probability of recurrence in the same region.

Biological indicators

Biological indicators can be used to improve our understanding of ENSO events and their impacts. However, for the most part, biological data is not being considered, let alone used, by ENSO researchers and forecasters today. There has been a tendency to ignore bioindicators because they are less clear. Such indicators include, for example, the fat content of certain fish species, and fish size. Marine species also shift in space and time related to ENSO events. Also, a gonadic index, compiled in Peru and in Chile by marine researchers, could provide some insight into changes in the marine environment in advance of an ENSO

onset. Biological signals may prove to be precursors of ENSO events, and they can also be used to confirm that an ENSO-related anomalous change in the marine environment has taken place.

Quasi-Biennial Oscillation (QBO)

Research on the QBO is not well understood and its possible linkages to ENSO remain unclear. It could improve our understanding of the life cycle of ENSO. The QBO could be considered as a possible forcing factor in the generation of warm events. Those involved in ENSO research, however, have suggested that they are not yet ready to incorporate consideration of the QBO in their ENSO research efforts.

Science and politics

Scientists need to become more aware of the political process and should improve their understanding of the political context in which they carry out their research. They can do so without getting involved in the political aspects of science. They need to "market" their research programs and their research results to the public. This view reinforces the belief that the scientific community can benefit from the support of social scientists who research the socioeconomic aspects of ENSO forecasts and impacts, some of whom can fill the role of translators.

7. GENERAL COMMENTS

Changes in social and economic systems can either enhance or diminish a society's ability to cope with anomalous climatic conditions. For example, fires across the southern US from the Pacific to the Atlantic coast have been associated with ENSO events. The

environmental movement, in its desire to reduce controlled burns in forested areas, has unwittingly abetted the intensity and frequency of fires. One can also cite examples where human activities benefit from ENSO, such as in the case of corn production in the US corn belt. Thus, improving our understanding of ENSO will not be a panacea for all climate-related societal ills. It can, however, provide society with usable research output. While it is generally believed that technological advancements buffer large segments of American society from the worst effects of weather and climate extremes, demographic changes increase the risks to society from extreme weather events, some of which might be attributable to ENSO or La Niña.

Highlights: Action

- ENSO forecast accuracy and reliability should not be oversold to the user community, decision makers, policymakers, specific economic sectors, the public, the media, especially before the science matures.

- ENSO research results must be "marketed" to potential users in different ways to take into account the various needs of different users.

- We must build confidence among potential users in an ENSO forecast system.

- Most users require updated detailed region-specific information on ENSO teleconnections. We need to provide assistance to fine-tune the current use of ENSO information in various regions of the country and sectors of society.

- To accurately identify the value of ENSO forecasts, assess the actual use of forecasts by decision makers.

- "Translators" are needed by the ENSO community (forecasters, researchers and users) to summarize scientific information about ENSO, and to determine the appropriate level of detail required by the particular needs of the different users.

- It is extremely important to educate the media about the science of ENSO and its socioeconomic impacts. They are potential educators of the public, creators of potential users, and users of ENSO info themselves. Produce a "manual" about the ENSO phenomenon specifically for the media. Focused regional workshops on the usability of ENSO information could be held for the media.

- Increase research efforts on the socioeconomic impacts of La Niña (cold) events.

- To better assess the benefits of ENSO research, undertake an ENSO information review of what decision makers in government agencies know about ENSO, whether they use any ENSO information, and how they use it.

Highlights: Information

- The benefits of the use of ENSO information will accrue over time and will not necessarily result from the use of information about any single ENSO forecast.

- A government agency that supports research has an opportunity and a responsibility to encourage other government agencies (and industries) to use that information.

- Users want information with greater subregional specificity about North American ENSO teleconnections.

- Biological indicators may prove to be precursors of ENSO events and can also be used to confirm that an ENSO-related anomalous changes have taken place.

- Ongoing changes in social and economic systems can either enhance or diminish a society's ability to cope with anomalous climatic conditions.

- A video of specific North American teleconnections to ENSO would be an important educational tool to convert potential users to actual users.