Seasonal Forecasting

Innovations in Practice and Institutions

BY ANTS LEETMAA

I'd like to thank the AMS and Columbia University for giving me a chance to reminisce about an exciting time in seasonal forecasting: the intense period from 1997 to 2000, while I was director of the Climate Prediction Center (CPC). The 1997–98 El Niño forecast was a tipping point. Some clear innovations of practices resulted. These didn't just happen, but were the culmination of years of research into thinking about seasonal forecasting and the result of the opportunities that a 100-yr climate event presents. However, we have only paid a short visit to the promised land. We need to start thinking about continued future innovations in institutions and practices in order to fully utilize the benefits inherent in seasonal forecasting.

In short-range forecasting, research has to cross "the valley of death" in order to get into operations. In seasonal forecasting, there was no such divide. In reality, in 1997 there wasn't much of an operational capability to make El Niño-based forecasts, let alone forecast impacts associated with a 100-yr event. During this period we "made up" tools in preparation for the upcoming seasonal forecasts (for lead times of several seasons this is possible—but not recommended). Even though the forecast products needed development, these were grounded in previous and ongoing research. A transition occurred in the way we did seasonal forecasting by basing them on the physics of climate variability, numerical experimentation, and statistics based on physical understanding. A measure of the success of this approach was the unprecedented high forecast skill attained during 1997–2000. One outcome of the forecasts and research during this period was the NWS changing the coupling of short-range forecasts and climate forecasts. This led to the "seamless suite of forecast products," which recognizes that weather regimes are linked to those of climate.

AFFILIATION: LEETMAA—Geophysical Fluid Dynamics Laboratory, NOAA/OAR, Princeton, New Jersey
E-mail: Ants.Leetmaa@noaa.gov

The CPC did try some innovations in outreach and in the entrainment of other institutions in the delivery of climate information. Our focus at that time was disaster mitigation (e.g., bad things can happen during a 100-yr event). However, as others have pointed out, good things can also happen. The challenge in the future is to look at the both the good and bad opportunities that seasonal forecasts enable.

A transition at CPC in the practice of seasonal forecasting took place in 1997/98. In the 20 years before that, forecasts were based on statistics and the idea that precursors lay primarily in middle latitudes. Forecasters were not specifically focused on trying to understand the physics of major climate anomalies, especially on impacts arising from tropical interactions. Of course, the 1997/98 forecast was not the first successful El Niño forecast. The credit for those goes to Steve Zebiak and Jim O'Brien, who are in the audience, and others, such as Mark Cane and Tim Barnett. Their successful forecasts in 1987/88 took place almost 10 years before this event. So there had been a rich history of making seasonal forecasts.

Nevertheless, starting with the 1997/98 event, a couple of significant changes took place. The CPC switched from low confidence/skill forecasts to ones with much higher levels of confidence and skill. A link was made between year-to-year variations in storminess and climate, and this information was used in discussing the forecasts. This resulted from working with the user community and recognizing their need for not only season-mean information, but also information about changes in the likelihood of weather extremes. This led to new NWS products for disaster mitigation and derivation of economic benefits. Currently we anguish about developing the infrastructure for delivery of climate services. During this period, the NWS stepped up to fill a major part of this need. The field and regional offices did a tremendous job in working with local decision makers and in educating the public about the impacts of El Niño and interpretation of the forecasts. The country already has a rudimentary delivery system for climate information; this needs to be enhanced.

Seasonal forecasts are made typically in two steps. Since El Niño is a major source of climate variability, the first step is a forecast for El Niño. The second step forecasts the impacts of El Niño and other factors in the United States (or elsewhere). The research community had a successful history of making El Niño forecasts; this was also true at the CPC. So early in 1997, the CPC had reasonable confidence in its ENSO forecast capabilities. In late 1996, forecasts started to indicate the transition from the La Niña of the previous two years to an El Niño. By mid-April, the CPC publicly announced that this transition was likely. By late May, both the observations and the forecasts showed that a very strong event was likely. However, this confidence was lacking at higher levels in NWS and NOAA. At the press conference in late May announcing the likelihood of a major event, the only two NOAA participants were Mike Hall, who had sponsored most of the ENSO research, and myself. By contrast, after the event got underway in early 1998, the press conferences frequently included Secretary of Commerce Daley; Jim Baker, the head of NOAA; and, toward the end, Vice President Al Gore.

In mid 1997, the CPC was ill-prepared to forecast the impacts of this event. The existing statistical tools showed—with low confidence—that only small areas of the United States would be affected. Fortunately, extensive numerical experimentation showed that the nature and regionality of the impacts depended on the strength of the El Niño. For strong events, much of the West Coast, especially California, would experience above-normal rainfall; for moderate events, this was not the case. The studies also indicated that the stronger the El Niño, the higher the likelihood of these impacts. In California and Florida, the models suggested that there was almost a 90% chance that rainfall totals would lie in the upper third of the amounts historically received.

We needed a simple way to communicate the probabilistic nature of the forecasts. CPC seasonal forecasts are for changes in the likelihood of rainfall or temperature in the upper, middle, or lower third of the climatological distributions. Under normal conditions, each category is equally likely (each will occur one-third of the time). However, climate variability alters those probabilities, rather than completely eliminating categories. So even a 90% probability of above-normal conditions indicates a 10% chance of below- normal or normal conditions. The United States is blessed with having good historical climate data sets. These allowed us to estimate, by climate division, how the probabilities would change because of El Niño (or La Niña), and to display these shifts in a simple bar graph for every state. These graphics were used in California and elsewhere to illustrate the probabilistic nature of the forecasts.

A major concern in California in 1997 was flooding. Nature had not been kind to California in the 1990s. Floods, droughts, and major fires had been common. Also, the economy was weak because of the end of the Cold War. During the winter of 1996/97, devastating floods in northern and central California had breached most of the levee systems and caused extensive damage. Politically, there was tremendous interest in helping California. The administration held a major press event hosted by the Federal Emergency Management Agency (FEMA) in Santa Monica, California, in mid-October of 1997. Vice President Al Gore spoke, as did James Lee Witt, the FEMA Director. I presented the CPC forecast: the El Niño was going to peak in the winter, be comparable in amplitude to the 1982/83 occurrence, and weaken in the spring. I also gave a forecast for a more typical El Niño to give some sense of the range of rainfall that might be expected. The California rainfall forecast was given probabilistically, and we indicated that, although we couldn't be sure, the winter likely would not be a repeat of the previous one (i.e., when the extensive flooding took place).

The CPC seasonal forecasts for 1997/98, and for the two following La Niña years (especially for the cold part of the year), were remarkably good—so much so that in talking with Commerce Secretary Daley during 1998, he commented that we wouldn't need any new resources because the forecast had been so skillful. However, for all these years, we underforecast the extent of the anomalous warming. This was especially evident for the La Niña-based forecasts. More was driving U.S. climate than ENSO. Throughout this period, the administration emphasized the likely role of global warming. After a while, it was easier to get the message out on the seasonal forecasts by getting out of Washington and working directly in the NWS regions with the constituents and the press.

In mid-1997, climate was an orphan in the NWS. With ongoing budget crunches the main issue, getting out of climate came up at least once. A challenge was how to integrate seasonal forecasting into the NWS suite of products. I worked with Susan Zevin, the deputy assistant administrator for operations of

CLIMATE INFORMATION IN THE TWENTY-FIRST CENTURY

The development of reliable seasonal forecasts and successful responses to climate variations, including those of El Niño and La Niña, requires a full understanding of evolving climate conditions. This is made possible by a wide array of in situ and remote observing systems providing real-time measurements. Significant advancements in observations and monitoring have been made during the last two decades, most notably in observing developing El Niño–Southern Oscillation (ENSO) episodes. The inability to detect significant climate events, such as the very strong 1982/83 El Niño episode, before they fully develop, is now a relic of the past.

Improvements in observing systems have been complemented by the development of high-quality long-term datasets. These historical records now provide the basis for understanding how evolving conditions compare to those of the past and are an important source of information for understanding developing trends and future possibilities. Because historical observations were often made with instruments and observing practices that differ from those of today, artificial effects introduced by these changes can often interfere with interpretation of the trends. They need to be removed from climate time series records. The design of homogeneity adjustment algorithms and techniques is the cornerstone of today's improved climate databases.

Although observing systems and monitoring techniques have improved dramatically in the past 10–20 years, observational deficiencies continue to be recognized and addressed. While the TAO/TRITON moored buoy array has greatly aided in forecasting developing ENSO episodes, the realization that year-to-year climate variations are also affected by ocean-related phenomena in other regions of the world has led to a greater focus on monitoring the oceans. As such, improving the global network of ocean observing systems is a continuing focus in NOAA. One such example is the effort to increase the number of Argo observing floats on the world's oceans from 700 to 3000. These submersible buoys are designed to systematically measure the physical state of the upper ocean in near–real-time, providing temperature, salinity and current measurements during 10- to 14-day cycles.

Improvements in land surface observing systems are also needed and are being addressed in several ways. A new U.S. monitoring network is currently being developed by NOAA. This network will provide the highest quality measurements possible at locations with stable environments, equipment, and observational practices. When completed, the U.S. Climate Reference Network will consist of about 300 stations nationwide, providing observations that will ensure a consistent record of the nation's climate, free from artificial biases caused by factors unrelated to climate.

Other efforts to improve monitoring and access to meteorological observations include a new NWS program to modernize the Cooperative Observing Network. This modernization will involve a transition from manual observing equipment to automated observing systems, which will transmit observations in real time to NOAA and other users of weather information. Efforts are also underway in the NWS to improve the existing Automated Surface Observing System (ASOS).

A renewed emphasis by other countries throughout the world on developing observing networks that adhere to sound observing principles, while also committing to making their meteorological data freely available, is greatly needed. The recent Earth Observation Summit reinforced this requirement. Increased implementation of the Global Climate Observing System (GCOS) climate monitoring principles will go a long way toward ensuring the availability of reliable global climate observations.

These improvements in observations and monitoring are complemented by efforts to recover historical instrumental records stored in archives largely forgotten until recent years. NCDC's Climate Data Modernization Program (CDMP) was established to recover these historical records and transfer them from paper records and microfiche to digital databases. Nearly 40 million records have been rescued and made available online. This effort is nearing a stage where important sources of historic climate information will, for the first time, be available for analysis. These data will help provide new perspectives on how newly evolving climate patterns compare to those of the past.

—Thomas R. Karl and Jay Lawrimore (NOAA's National Climatic Data Center) the NWS at that time, to come up with the concept of a seamless suite of forecast products, where applications would extend from the protection of life and property for short-range forecasts to climate forecasts for economic benefit and disaster mitigation at climate timescales. I think this concept resonated with Susan because, by training, she was a hydrologist and open to new ideas. The critical idea was that there existed a link between climate and weather.

Another innovation for the NWS was the generation of new products in addition to the standard seasonal forecasts. Late in 1997, the "threats assessment" was introduced. The idea was that the seasonal forecast combined with knowledge of pre-existing conditions—for instance, ground that is already saturated—provides additional planning information to emergency managers. The seasonal forecast, existing environmental conditions, and other NWS products (from daily out to monthly forecasts) would enable emergency managers to better manage their resources over an extended period of time (such as a whole winter). This product was Web-based and utilized teleconferencing with emergency managers, NWS field personnel, etc., on a regular weekly basis. Over the years, the threats were extended to other extremes, such as cold, wind, heat, and drought. In 1997, the CPC also started making seasonal hurricane forecasts, extending the work that Bill Gray of Colorado State had started much earlier.

Our philosophy at that time was to develop products that addressed current major climate extremes, or those extremes that the seasonal forecasts implied might take place. A significant product in this category was the U.S. Drought Monitor and seasonal drought forecast. The monitor represents a new way of doing business in the federal government. It is an interagency partnership between NOAA, the United States Department of Agriculture (USDA), and the Drought Mitigation Center of the University of Nebraska. The U.S. Geological Survey is also a major contributor by making their streamflow products available online in real time. In the future, as products become increasingly interdisciplinary (e.g., air and water quality and ecosystem forecasts) and occur in areas that are not clearly the purview of NOAA, interagency partnerships should be the preferred mode of operation.

The 1997/98 events gave the CPC tremendous visibility, with access to the White House and regular stories on the major television networks. We briefed upper and middle management in many of the federal agencies, such as the Department of the Interior, the USDA, FEMA, and the Department of Housing and Urban Development. However, one gets the sense that not much remains of that education process. There probably are lots of reasons for this. A major issue was that as a climate community, we did not stay on message; throughout this period climate variability and global warming were confounded. I suspect this was one reason the forecast successes did not translate into further budgetary or programmatic successes. Interestingly, the current political situation appears to be more favorable in looking at climate variability and change in an integrated fashion.

In 1997/98, natural disaster mitigation was high on the agenda for many federal agencies. We focused on the bad things that happened during a 100-yr event and also put considerable effort into working with the insurance and reinsurance industries to assess their needs and requirements. Through our collective experiences it became obvious that there exists a strong seasonality and regionality to the extreme impacts of weather. This led to the seasonal suite of products and press activity addressing this "calendar of extremes." Throughout this period, much of the focus was on seasonal forecasting as a new tool in risk management in natural disaster mitigation. We jokingly suggested to James Lee Witt that he change the name of FEMA to the Federal Risk Management Association.

However, as others have pointed out, good things also can happen during anomalous seasons. The challenge in the future is to look at the both the good and bad opportunities that seasonal forecasts enable. It was already clear in 1997/98 that the forecasts could be used for economic benefits. Jack Kelly, the head of the NWS, and I developed a briefing package for Secretary Daley proposing to engage the other Bureaus in Commerce in utilization of the seasonal forecasts for such activities. Our thinking was to develop a capability for forecasting economic indices for weather-sensitive sectors, and to develop partnerships with the private sector to encourage utilization of climate forecasts for economic competitiveness in the United States and abroad. For reasons that I don't fully understand, we never got access to Secretary Daley to give the briefing (which on recent perusal, still seems timely).

We did have success in engaging the energy sector through the developing weather derivatives community. The interest was high in this because for several seasons energy demand had been overestimated.

This resulted in significant economic losses, and, because of the deregulation of the energy sector at the same time, their bottom line became much more important.

In retrospect, a few lessons stand out. Research should still remain an integral part of the forecast process. Seasonal forecasting is still not yet mature enough to be a turnkey operation. ENSO is only one factor producing the seasonal impacts felt in the United States. Decadal trends are also important, as are other types of climate variability, such as the annular modes. Until we have a better physical understanding of these, the forecasts need to be done on a case-by-case basis.

Success was no guarantee of enhanced resources. Climate research did not get any budget increases as a result of the enhanced publicity and the good forecasts. Perhaps as a media event we were too successful, but not successful enough in translating what

CLIMATE FORECAST USAGE BY AGRIBUSINESS AND UTILITIES

Studies of the use of seasonal climate forecasts in agribusinesses and utilities over the past 23 years reveal an increase in usage, improved value of usage, and a greater understanding among users as to how to employ forecasts in specific decisions. However, there is still considerable potential for improving usage.

Some decision makers have used sensitivity analyses to determine how much their organization is at risk for variations in seasonal climate. With this knowledge, decision makers are more likely to be proactive in their risk management or hedging decisions, and thus integrate seasonal forecasts prior to a specific season. A good example of proactive usage of seasonal forecasts occurred in the autumn of 1997, prior to the El Niño winter of 1997/98, by certain utility decision makers in the midwestern and southwestern United States. The economic value associated with these prewinter decisions varied from $200,000 to $3 million. Many decision makers, however, are still *re*active in terms of usage and will not make decisions until they are already impacted by a seasonal climate anomaly. Often these reactive decisions come too late and are generally not associated with economic benefits.

For long-term use it is essential that users have decision models that can incorporate probabilistic forecasts. Some firms have decision models that can incorporate uncertain climate information and forecasts. However, the decision process is complex and dynamic (always in flux), and often nonclimate factors, such as trends in the unit cost of natural gas or the price of corn, may be much more important in a decision to buy or sell than the future climate. It appears that the most important factor in increased usage is the ability of users to integrate climate information when needed, and have available economic models that can provide a range of outcomes based on different seasonal climate scenarios.

Another factor limiting use for many is the major gap between the types of climate-related information that are being provided by the government and what is needed by many in the private sectors. One could argue that this gap could be filled by private companies involved in weather and climate forecasting. One reason for the gap is that many middle and upper-level managers have limited knowledge of weather and climate, and hence they remain uncertain about employing such information in their decisions. Decision makers in agribusiness and utilities are keenly aware of the influence of weather on their sectors. However, when questioned, many are unaware of how variable seasonal climate is in their particular region of the country. Many agribusiness decision makers will remember certain weather or climate events such as the 1988 drought in the midwestern United States or the flood of 1993. However, when asked to describe the range in climate parameters (e.g., seasonal average temperatures or total precipitation) for a particular place, many don't have the climate information to respond. When utility officials are asked to describe a "cold" winter in their region, many will recall a recent winter they perceive was "colder than average." However, their perception is often incorrect. Many weather-sensitive decision makers interviewed who do not use climate predictions base their decisions on weather conditions of the last year or the average of the past two-to-five years. The government, working in concert with private forecast firms, should improve educational outreach to illustrate successful uses of climate information. Testimony by users who have benefited from the information is essential.

—David Changnon (Northern Illinois University) and Stanley A. Changnon (University of Illinois, Urbana–Champaign) these forecasts meant to the political issues of the day. From my subsequent experiences in working in NOAA on new climate initiatives, the window seemed to close on getting additional resources into seasonal forecasting per se. The problem, the science, and the impacts need to be rephrased in terms of relevance to the broader underlying political themes that are current now (e.g., possibly global change, the environment, globalization, and global security).

It will be interesting to see if natural-disaster mitigation will rise again to be a theme of importance to Capitol Hill and the administration. As less and less of our shrinking discretionary budget goes to bail people out after natural disasters, this may or may not be the vehicle that provides additional resources. The recent multiyear drought was not sufficient to produce an environment for enhanced funding. Nevertheless, across many sectors there clearly remains tremendous potential for risk management based on the ability to foresee what future seasons might hold. Somehow this message needs to get out.

To realize this probably requires increasing the skill of the forecasts. Climate variations during the past few years have not been kind to CPC's skill scores. Some would argue that we lack the resources for adequate product development and service delivery; however, recent history has shown that brainpower cannot be replaced by money. In my own mind, I think we probably are overselling the forecasts, given current levels of skill. The links between opportunities and climate variations are becoming clearer, but we still need to be able to forecast these variations to realize the benefits (and have credibility). In the future, skill levels and possible applications of the forecasts at those levels need to be better defined. Not all climate variability is predictable.

We also need to start thinking about future institutional issues. NWS is the appropriate home for looking at the weather–climate–natural disaster link. However, 97% or more of their resources go into short-range forecasts for protection of life and property. Climate needs to be treated as more than just an extension of weather forecasting. As we move ahead to more interdisciplinary applications, what institutions and agencies in the United States or internationally will step up to do this? Perhaps it's a shared responsibility, like the Drought Monitor. The understanding and predicting of climate variability can be essential for adaptive management for climate change. How will this be done? With the administration's interest in climate and with broad support on Capitol Hill, the future can be bright. It isn't 1997/98, but an equal opportunity exists; it only remains for us to seize it.