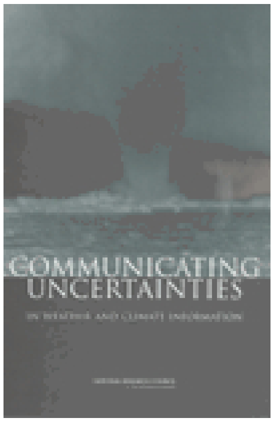

Communicating Uncertainties in Weather and Climate Information: A Workshop Summary

Elbert W. Friday, Jr., Rapporteur, National Research Council

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A Workshop Summary

Communicating Uncertainties in Weather and Climate Information

Elbert W. Friday, Jr., Rapporteur

Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

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Preface

Each year, typically in the summer, the Board on Atmospheric Sciences and Climate selects a topic for special study (often called our "summer study"). Our goal is to organize an informal workshop where scientists and agency staff can share information about current issues in the atmospheric sciences, meteorology, and climate. These events are a forum for frank discussions and creative interaction, and sometimes lead us to develop more in-depth activities.

Based on a suggestion from the Federal Committee for Meteorological Services and Supporting Research, a committee chaired by the Administrator of the National Oceanic and Atmospheric Administration (NOAA) whose members include senior policy executives of the 14 federal agencies that are producers or users of weather and climate information, the topic selected for the August 2001 summer study was the growing concern for the proper communication of uncertainties in weather and climate information. We elected to use a series of case studies to look at actual examples of the communication of weather information and to see if these examples could provide insights that might lead, in time, to new ideas and approaches.

This report is the product of the workshop held at the J. Erik Jonsson Woods Hole Center in Woods Hole, Massachusetts, August 7-11, 2001, and was sponsored by the U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, and National Science Foundation. The agenda for the workshop is presented in Appendix A and workshop participants are identified in Appendix B. As the product of a workshop, this report does not contain findings or recommendations but instead represents an overview of discussions that occurred during the workshop. Each case study does contain a section, "Remaining Challenges," that summarizes what the workshop participants saw as critical next steps. In addition, a new National Research Council report on public-private partnerships in weather and climate services (expected mid 2003) will provide detailed discussion of the relationships among the key participants in weather forecasting (i.e., the public, private, and academic sectors).

The National Academies and the Board on Atmospheric Sciences and Climate wish to thank the speakers and participants who contributed their time and energy to this workshop. This kind of activity is an important mechanism for focusing discussion on issues and highlighting opportunities for future work.

Chris Elfring
Director, BASC

Acknowledgment of Reviewers

This workshop summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published summary as sound as possible and to ensure that the summary meets institutional standards for objectivity, evidence, and responsiveness to the workshop charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this summary: Lance Bosart, State University of New York, Albany; Stanley Changnon, Illinois State Water Survey; Robert Ryan, WRC-TV, Washington, D.C.; and Jack Williams, *USA Today*.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations from the speakers nor did they see the final draft of the summary before its release. The review of this summary was overseen by Marvin Geller, State University of New York, Stony Brook. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the author and the institution.

Contents

1

Background

When a major East Coast snowstorm was forecast during the winter of 2001, people began preparing—both the public and the decision makers responsible for public services. There was an air of urgency, heightened because just the previous year the region had been hit hard by a storm of unpredicted strength. But this time the storm never materialized for the major metropolitan areas of the mid-Atlantic. The missing storm of 2001 left many people wondering what went wrong with the weather forecast. But did anything go wrong or did forecasters just fail to communicate their information in an effective way—a way that conveyed some real sense of the likelihood of the event and kept people up to date as information changed?

There is uncertainty in all forecasts, and weather and climate forecasts are no exception.[1] Traditional weather forecasting uses numerical models and statistical techniques to project likely future scenarios, and these techniques have some level of definable errors. Newer forecasting techniques use more sophisticated ensemble methods that provide a more quantitative measure of uncertainty under certain conditions. Deterministic or categorical forecasts issued by the National Weather Service (NWS), private meteorological firms, and the media can, in some cases, lead the user to misjudge or ignore forecast uncertainty and as a

[1]There are two terms used in this report to describe predictions of future events: *forecast* and *outlook*. Forecasts are predictions with more specific information, usually for the relatively short term. Outlooks, on the other hand, are predictions, usually of a more general nature and of a longer ranged projection. One generally thinks of "weather forecasts" and "climate predictions." As the range of weather forecasts is extended and the seasonal climate projections improve, a blurring of the distinction in these terms is occurring.

result make preventable errors in the decision process. More sophisticated users of weather and climate information, particularly those in the commercial markets, usually do take uncertainty into consideration in the decision-making process. These users generally receive products and services from the meteorological community that highlight and, in many cases, quantify uncertainty associated with a forecast. However, in the general public market there are occasions when improper statements or lack of explanations of uncertainty can result in inadequate or inappropriate action or missed opportunities. These actions range from the public not taking necessary precautions in a life-threatening severe weather situation to governments and businesses missing opportunities to respond to or mitigate potential long-term impacts of climate variability and change.

As sources for weather and climate information have increased, especially given the many sources of information now available on the Web, the issue of confidence in the information has become more important. Communication of accuracy, reliability, and forecaster confidence is made even more complex when issues of climate forecasting are added to the mix.

THE CASES SELECTED FOR STUDY

Recent history provides a rich record of case studies that can be used to describe the strengths and weaknesses in the communication of weather and climate information to decision makers. This workshop explored five cases representing a range of time scales and issues. They address the forecasting of weather events, seasonal outlooks, and projections of climate change, and include cases in which the forecasts were of high quality and cases in which the forecasts or projections were of uncertain or unknown quality. In each case the impacts were largely dependent on the way the information was communicated. In particular, the workshop focused on the issue of communicating uncertainties. The cases presented are as follows:

Red River of the North Flood, Grand Forks, April 1997 (presented by Lee Anderson, Susan Avery, and Roger Pielke, Jr.). This major, record-breaking flood, its forecasts, and the public response illustrate the need for complete information, including a well-defined understanding of uncertainties by the emergency management community.

East Coast Winter Storm, March 2001 (presented by Raymond Ban, George Frederick, James Hoke, and Robert Ryan). This case looks at the complicated relationships that link the forecasting community, the media, the public, and decision makers. It also examines the competitive pressures faced by the media when a forecast of a major storm is a headline news story. The case shows how a forecast can be successful from a technical perspective (i.e., provides a relatively sound forecast) but have its usefulness compromised by problems communicating the uncertainty associated with that forecast, resulting in poor decisions being made by the public, government, and industry leaders.

Oklahoma-Kansas Tornado Outbreak, May 3, 1999 (presented by Howard Bluestein, James Lee, and Margaret LeMone). This record-breaking severe weather outbreak illustrates the complexity of communicating weather information in a rapidly evolving, short-time-frame situation and the importance of doing so to save lives. It illustrates the benefit of effective partnerships among the public, private (especially the media), and emergency management communities.

El Niño 1997-1998 (presented by Stanley Changnon, Steven Clifford, James Laver, and Robert Weller). The 1997-1998 El Niño was the first major seasonal climate event to occur after the state of the science provided the weather and climate community with sufficient capability to provide a forecast. The case examines methods of presentation of the forecasts, presentation to and reception by certain government and user groups such as the emergency management community in Southern California, and the public's perception of the event. It illustrates several aspects of the communication of climate information and the confusion that can occur between *climate* and *weather*.

Climate Change Science: An Analysis of Some Key Questions, June 2001 (presented by Eric Barron, William Randel, and Vaughan Turekian). This discussion summarizes a report produced by the National Research Council at the request of the White House that attempted to provide the administration with answers to questions of climate science related to greenhouse gases and global warming. It illustrates the importance of preparing for public communication when designing a study.

Although any number of examples could have been selected for study, these five were chosen because of the breadth of the time scales of the events, the degree to which they have been documented, and the interest and involvement of the workshop participants.

To ensure that each case study focused on communication of meteorological information, the presenters were asked to use a standard framework and describe each of the cases in terms of

- Who?
- Said what?
- When?
- To whom?
- How? and
- With what effect?

The presenters provided an initial assessment of these factors that were modified by the ensuing discussion at the workshop. The workshop participants then looked across all the cases for unifying themes, and the final chapter looks at common features of the cases.

2

Case Studies

RED RIVER OF THE NORTH FLOOD GRAND FORKS, APRIL 1997[1]

Description

Flooding is a common problem during the spring in many of the western U.S. river basins. The Red River of the North Basin, located in North Dakota and Minnesota in the United States and southern Manitoba in Canada, routinely experiences various levels of floods. The Red River flows north into Canada through Winnipeg and empties into the Hudson Bay. The region is exceptionally flat and consequently prone to flooding. Conditions that contribute to the region's flooding include soil moisture, snow cover, water equivalent, depth of frost, rate and timing of snow cover melt, spring precipitation, river ice conditions, and base hydrologic flows.

During 1997 almost all of these categories were above average, setting the stage for severe flooding. Winter records for snowfall were recorded, and the rate of melt was erratic beginning in late March. Flooding began in the southern part of the basin in March, and following a brief hiatus during a freeze, proceeded northward. Grand Forks, North Dakota, and East Grand Forks, Minnesota, which had experienced a major flood in 1979 with a river crest of 48.8 feet, prepared for the flood by raising dikes, seeking to survive a possible crest of 52 feet. Those dikes broke through on April 18, and the two cities suffered catastrophic damage.

[1]This case is documented in the National Weather Service's document *Service Assessment and Hydraulic Analysis: Red River of the North 1997 Floods* (NWS 1998).

In East Grand Forks the crest was 54.4 feet on April 22. Total estimated damages were approximately $4 billion with $3.6 billion in losses in Grand Forks and East Grand Forks alone. These losses were the greatest per capita in U.S. history. Nearly 90 percent of the area was flooded and three neighborhoods were completely destroyed. Eleven buildings in downtown Grand Forks were destroyed by water and fire. In a region of 5,000 homes, fewer than 20 escaped damage. Widespread evacuation occurred and potable water was unavailable. Fortunately no deaths were attributed to the flood in the Grand Forks area.

By February 1997 the National Weather Service (NWS) knew of the potential for record flooding in this region and disseminated information through the standard suite of products that included weather data and forecasts, hydrology data, hydrology outlooks (narrative and numerical), hydrology forecasts (at least twice a day), and flood statements and warnings. Leading up to the event, the NWS was the main voice speaking with the communities. After the event, during a post-analysis (NWS 1998), two other potential sources were identified that could have provided information that would have been beneficial leading up to the flooding. Following the disaster, considerable finger-pointing by the public and elected officials focused on the role of NWS flood predictions (see Figure 2-1). (Detailed timelines for this weather event are given in Appendix C.)

FIGURE 2-1 An example of the public reaction to the flood event. SOURCE: Barry Reichenbaugh, National Weather Service.

Communication Summary

Because this region has had considerable experience dealing with floods, and many residents remembered a major 1979 flood, communication channels were well established. This context helped set the expectations of the public. Below is a summary of the communication process.

Who? Leading up to the event, the NWS's North Central River Forecast Center and the Grand Forks Weather Forecast Office were the primary voices providing information about river levels. The media was a secondary voice. A representative of the NWS held a press conference in Washington, D.C., that was covered on national network news.

Said what? The message was one of potential for severe record-breaking flooding for the spring season. On February 28 the NWS issued a quantitative outlook with two potential river crest levels: one for 47.5 feet, which did not take into account future precipitation, and the other for 49 feet under average precipitation conditions. As the flood progressed, the NWS issued flood crest forecasts of 50 feet, 52 feet, and 54 feet on April 14, 17, and 18, respectively. None of the forecasts provided any numerical measure of uncertainty, although some general words indicating uncertainty and severity were used. The NWS headquarters press conference included a qualitative statement indicating that the level of flooding would be "more water than you've ever seen before."

When? The North Central River Forecast Center and the Grand Forks Weather Forecast Office issued narrative and numerical outlooks periodically from February 14 to March 28, 1997, for the entire river basin. Deterministic operational hydrology forecasts for the Grand Forks area were made twice a day after April 14, 1997. There was plenty of lead time to develop mitigation and adaptation strategies for handling the flood. The NWS press conference in Washington, D.C., was held on March 18, 1997.

To whom? The primary communication was between the NWS and emergency managers in the region and to local officials responsible for flood preparedness. The secondary communication was made through the media to the general public.

How? The dissemination of the information was done through regular media outlets, including television, radio, and print. Information was also conveyed through the National Oceanic and Atmospheric Administration (NOAA) weather radio, wire services, Internet, emergency manager weather information network, weather hotline phone, and amateur radio.

With what effect? Based on available information, city officials decided to prepare the city for a 52-foot river crest. This level was chosen based on the 49-foot forecast and adding a 3-foot buffer. But in reality the forecast was not meant to be taken with such certainty. The NWS thought it was conveying real urgency by using the 49-foot measure because this was above the past instrumented flood record in 1979. Instead, the message received was one of perceived certainty, in part due to the experience of the 1979 flood when the NWS forecast a flood crest of 49 feet, a forecast that came within two-tenths of a foot of the actual flood level. The effect was misplaced certainty in the outlook/forecast product.

At another level, however, the communication to the public was effective. After the press conference held by the NWS representative in Washington, D.C., there was a dramatic increase in the purchase of residential Federal Emergency Management Agency (FEMA) flood insurance policies. The fact that there was a spike in flood insurance sales after the remarkably clear statement "more water than you've ever seen before" was made indicates that many people were paying attention to the forecasts, the warning was communicated effectively, and people understood the implication of the warning and took action to protect themselves. Better follow-on information would have helped local officials to evaluate the specifics of the developing situation and plan more sufficient protective action. The forecasts were accurate, better than in many previous flooding situations, but the uncertainties were neither communicated nor understood.

Analysis of the Case

The magnitude of the disaster prompted the NWS to conduct a detailed analysis of the event (NWS 1998). This report identified problems in the scientific information that was disseminated, in institutional arrangements, and in communication.

The first problem was that the scientific information did not contain uncertainty information. The hydrologic models did not produce probabilistic information. In part this lack of information was due to "guessing" how to extend the rating curve on the hydrograph beyond the 48.8-foot limit of the instrumental record. In reality there are multiple methods to extend a rating curve. After the event it was learned that the U.S. Army Corps of Engineers had been using a rating curve different from the one the NWS forecast offices were using, and in hindsight the Corps of Engineers' method gave a more accurate estimate of the flood crest. Although making precise predictions of the Red River at these extreme levels may not be possible, better information about the uncertainty of the forecast could have been useful to the decision makers.

Quantification of the uncertainty could also have been done empirically by analyzing the success of historical forecasts and events. For example, records indicate that earlier floods at East Grand Forks had a 10-percent error (5 feet for the 1997 flood). From a forecast verification perspective, the Red River flood forecast was good, with only about an error of 5 feet between predicted and actual river crest. To the public, however, this was a greater error than the 1979 flood because the dikes were overtopped and real damage ensued.

Another problem was the lack of new observational information that would lead to updated river predictions. The 49-foot forecast was reiterated several times by the NWS even though no new information had been assimilated into the forecast. The forecast given immediately after an early April blizzard did not incorporate any of the blizzard's effects. The timing of this reiterated forecast could have led to the belief that the precipitation from the blizzard had no effect on the river crest value, and in the public's mind it reinforced the certainty of the 49-foot level.

The 1998 NWS assessment also found that institutional arrangements and delineation of responsibilities were a problem. The river forecast office and the weather forecast office were not coordinated. Responsibilities between officials in Grand Forks and the forecast offices were unclear.

While Grand Forks officials wanted a single number for the predicted crest, a single number was simply not justified by the state of the science. There were plenty of data and folklore to indicate river crests had high variability. Ignoring this variability and not quantifying uncertainty caused decision makers to misjudge how to handle the flood and led to a de facto handing off of responsibility from the city officials to the weather service. As an example of mitigation alternatives, the city of Fargo sacrificed certain streets to save other parts of the city. Grand Forks and East Grand Forks made the decision to try to save all of the city and neighborhoods.

Communication was the final problem area. While almost everyone in the community was aware of the 49-foot forecast, very few knew how to interpret it in the context of flood-fighting decisions. Errors in interpretation were obvious in the media, yet the forecast offices did not correct the misinterpretation that was in the print/news media. Psychologically the public had a previous context in which to "anchor" this flood, that of 1979. Communication in terms of this experiential knowledge would have gone a long way in helping to understand the potential severity of the flood.

Lessons Learned

During the workshop, participants suggested several lessons learned from this case:

- Understanding the uncertainty inherent in the scientific products that are being delivered is essential to delivering an accurate message to decision makers and the public.
- Uncertainty measures of scientific products are needed. These measures can be of multiple forms, including probabilistic model outcomes, empirical

verification of outlook/forecast performance, and narrative language that conveys the correct meaning of the uncertainty. Visualized presentation of the uncertainty would complement text presentation of uncertainty.

- A clear understanding of the roles and responsibilities of forecasters and decision makers is essential for an effective communication process. Forecasters need to convey full information to the decision makers. Maintaining the credibility of the science for the decision maker is essential. Forecasters may require training to recognize that their role is not to make decisions for decision makers or to provide prognostications that go beyond what the science can support.
- An understanding of the decision process by those handling weather service outreach is invaluable in determining the strategic information that needs to be disseminated. This understanding is needed in order to know where the science has the most impact and what products would be most effective. Development of new products may be a part of this process. Developing a dialog between forecasters and decision makers would be more useful than briefings.
- Coordination among the agencies well before any event is essential, and synthesized scientific knowledge (stream flow and precipitation) is key to preparing accurate products for decision makers.
- When communicating with the public, the context of the upcoming event relative to past experiential evidence of the people helps to convey the potential severity of the hazard. A personalized narrative is important and can have beneficial impact.
- Misinterpretation of scientific information by the media can be expected. After all, they are not scientific experts. Therefore, it is imperative that errors be corrected quickly to avoid public confusion.

Follow-up Improvements

The *Service Assessment and Hydraulic Analysis* report (NWS 1998) provided guidance for improvements, and suggestions for improvements were also provided by user communities. Several actions have been taken since the disaster in order to avoid a repeat of this experience (Anderson 2001):

- The North Central River Forecast Office and the Grand Forks Weather Forecast Office implemented new products under the Advanced Hydrologic Prediction Service (AHPS) capturing uncertainty and probability of a given crest level. The uncertainty is characterized by 40 years of precipitation data that are used to determine a historical probability function for precipitation. Future climate outlooks are taken from monthly Climate Prediction Center (CPC) outlooks that are then used to weight the probability density function. The information is incorporated into a new hydrology model that has been improved from a channel hydraulics model to a soil moisture/terrain model. AHPS now produces a number of different products and is experimenting with different forms of graphical presentation.

- Probability products are being tested with users, and feedback is being received and incorporated to improve products and services.
- Narrative outlooks are now more descriptive, contain more information, discuss uncertainty, and encourage users to contact the weather office for continual updates of meteorological conditions. Statements of how hydrologic projections are made are now included, and these projections include the current observed state of stream flow, soil moisture, and snow pack, and are coupled with future precipitation and temperature patterns and anticipated hydrologic changes due to reservoir and canal releases.
- Product delivery is now enhanced through an expanded outreach program and Internet and wireless delivery systems.
- The media and decision makers have shown a greater sophistication in the use and interpretation of outlook/forecast information, as evidenced in the tone of articles in printed and broadcast venues.

Remaining Challenges

Although significant improvements have been made, the workshop participants identified some challenges still to be addressed in the forecast/decision-making process:

- Although probabilistic information is now being produced, understanding of the different types of measures of uncertainty is still limited. In particular, regular use of empirical performance of NWS outlook and forecast products could be used to augment probabilistic outlooks/forecasts. This additional information would provide a level of calibration of the historical accuracy of particular prediction products.
- Given the public response to personalized narrative, this approach could be developed to help convey and interpret the products. It will be a challenge to develop appropriate language that conveys experiential meaning to the public.
- Reconciliation of user wants and user needs with science capabilities is important. Inherent and irreducible uncertainty cannot be ignored by the NWS even though users seek certainty because such uncertainty clearly affects the alternatives that might be available in the decision-making process.

EAST COAST WINTER STORM
MARCH 2001

Description

In March 2001 a major winter storm brought precipitation along the East Coast from the mid-Atlantic states to the Northeast. Heavy snow (primarily inland and in New England), high winds, and coastal flooding occurred in the eastern United States. Snowfall in excess of 10 inches was commonplace from

West Virginia to Maine, with 40 inches recorded in southeastern New Hampshire near Manchester. Figure 2-2 shows snowfall amounts and the track of the storm.

The storm had major impacts: Schools were closed; many activities were canceled; and transportation was disrupted, first in anticipation of the storm and then as a result of its effects (see Figure 2-3). Air traffic was significantly disrupted in the northeast corridor as airlines canceled flights and moved aircraft out of the storm's path days before any storm had actually formed. During the storm, downed power lines left tens of thousands without electricity, primarily in the interior of New York and New England. There were at least eight fatalities attributed directly or indirectly to the storm. Before and during the storm, a state of emergency was declared in Massachusetts and Connecticut. After the storm, Maine and New Hampshire filed for disaster relief assistance.

Although this was a major storm with many impacts, it illustrates another side to the communications issue: In this case, private sector and media meteorologists and weathercasters in major metropolitan areas from New York City to Washington, D.C., criticized the NWS for over-estimating in its forecasts when,

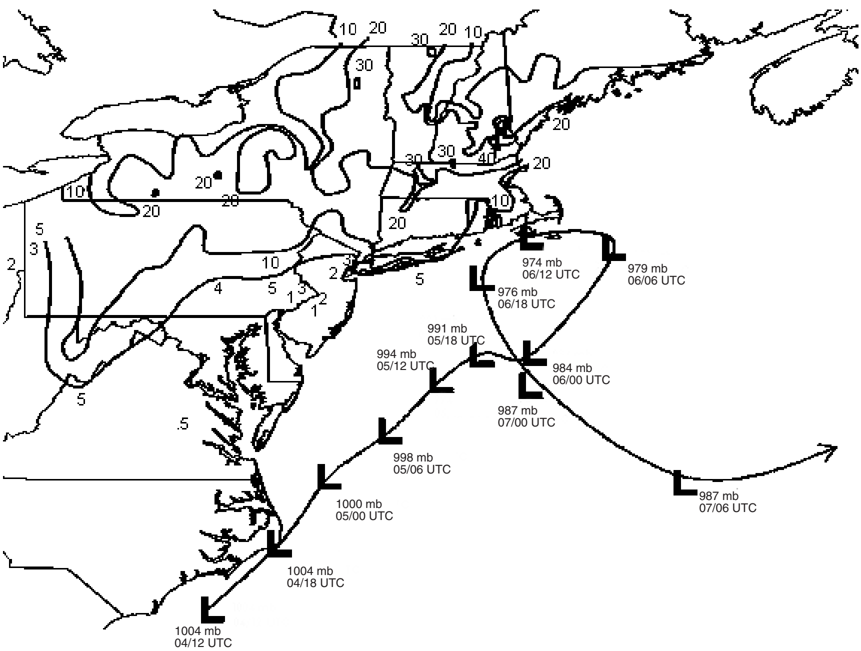

FIGURE 2-2 Snowfall total amounts (in inches) and track of the storm, March 4-7, 2001. SOURCE: National Weather Service.

FIGURE 2-3 Snow was piled deep in many New England areas. SOURCE: National Weather Service.

in fact, the storm never had the major impact on the East Coast megalopolis that it had on many inland and New England areas. One potential explanation for this over-estimation was that both media and government officials remembered the "surprise" snowstorm of January 2000, which was not well anticipated and had significant impacts on the public, and consequently they took pains to ensure against another unforecast storm. (Detailed timelines for this weather event are given in Appendix C.)

Communication Summary

Who? Communication of information was shared among NWS through the National Centers for Environmental Prediction's Hydrometeorological Prediction Center (NCEP/HPC), NOAA, weather forecast offices (WFOs), private forecasting services and companies, and national and local media.

Said what? NWS/HPC provided medium range forecast (MRF) computer-generated outlooks and hand drawn guidance indicating a potential developing

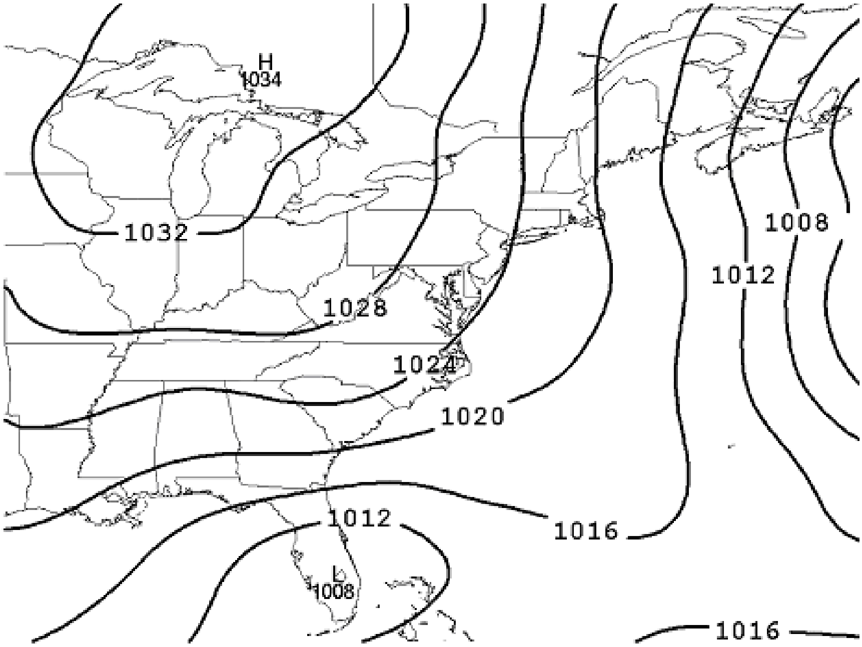

FIGURE 2-4 MRF surface pressure forecast made at 0000Z, February 26, and valid at 1200Z, March 4. SOURCE: National Weather Service.

major storm off the East Coast of the United States 7 days in advance of actual cyclogenesis. Figures 2-4 and 2-5 provide illustrations of 156 hour (made at 0000Z[2] on Monday, February 26) and 108 hour (made at 0000Z on Wednesday, February 28) MRF model forecasts, both valid at 1200Z on March 4. Figure 2-6 is the verifying surface analysis for that time. These forecasts showed the potential development of a significant storm that, if verified, would have a major impact on the East Coast. Local and national media and private forecasting organizations began discussing the possibility of an East Coast storm for the weekend of March 3-4 as early as Monday, February 26. On Wednesday, February 28, a TV weathercaster in Philadelphia issued a statement predicting a possible 16 to 20 inches of snow for the Philadelphia metropolitan area beginning on Monday, March 5.

[2]In meteorological discussions, times of data analyses and computer model valid times are usually referred to in "Z", or Coordinated Universal Time (UTC). These times are expressed in two or four digits (e.g., 0000Z or 00Z). Conventional time designations are used for press releases, etc.

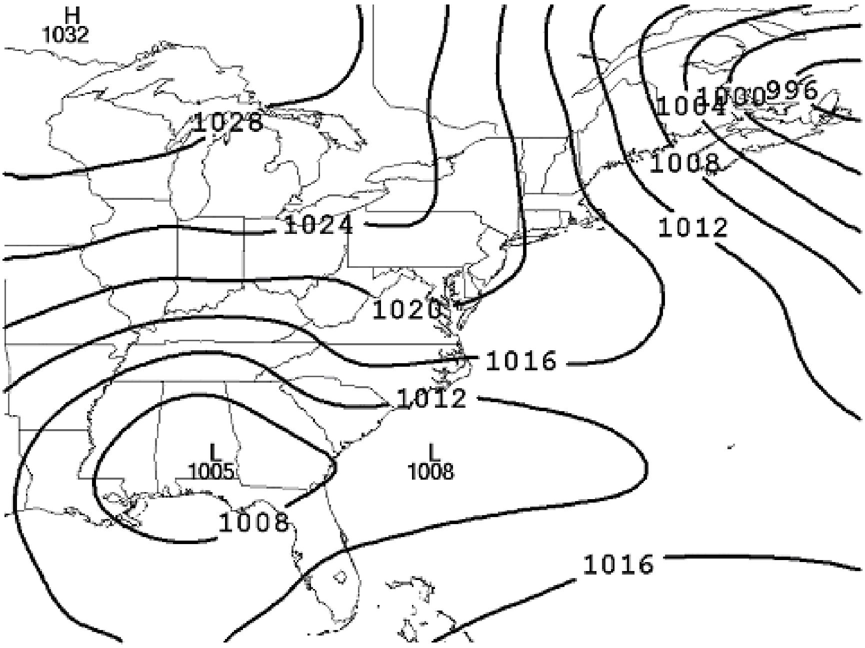

FIGURE 2-5 MRF surface pressure forecast made at 0000Z, February 28, and valid at 1200Z, March 4. SOURCE: National Weather Service.

Other local and national media soon became aware of other deterministic forecasts being made 4 to 5 days in advance of the potential storm and came under increasingly competitive pressure to make some deterministic forecasts even though the timing was well in advance of what most agree is the current state of the science. By Thursday, March 1, many private weather services and local and national media began making deterministic forecasts and statements of snow amounts. On Friday, March 2, NWS/HPC hosted a storm conference call at 11:00 A.M. (See Figure 2-7 for the AVN[3] model forecast made at 1200Z on March 2 and valid at 0000Z on Monday evening, March 5. This forecast indicated a major storm that would bring significant amounts of snow to the Northeast.) This conference call included all affected WFOs and NWS/HPC meteorologists. Many NWS WFOs on the call conveyed that they were feeling increasing pressure

[3]The AVN is one of the major numerical weather prediction models run at NCEP. The model was originally designed to support the needs of the aviation community, hence the name AVN for aviation.

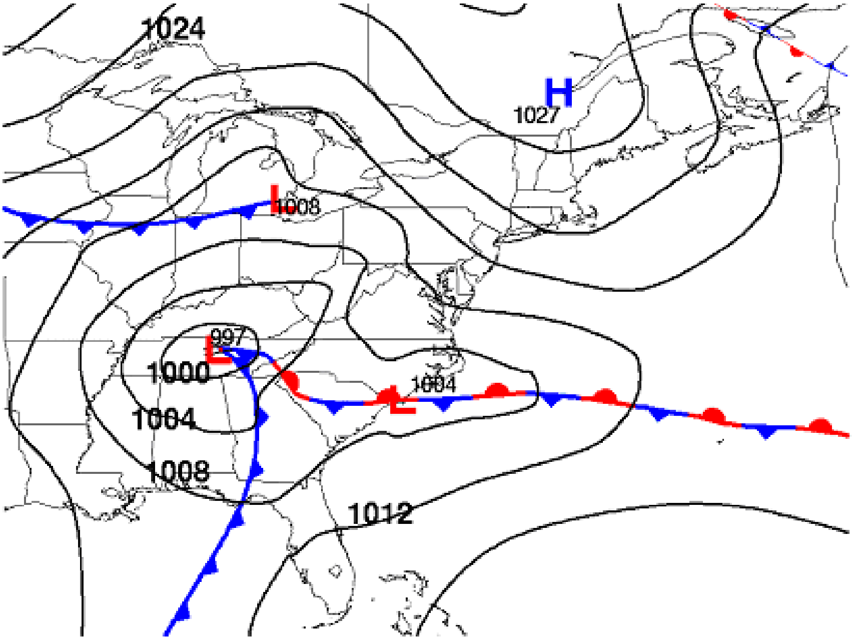

FIGURE 2-6 HPC surface analysis valid at 1200Z, March 4. SOURCE: National Weather Service.

from local emergency managers who needed to plan snow removal operations for the upcoming weekend. That afternoon, shortly after 3:30 P.M., an internal guidance discussion was issued by the NWS/HPC extended outlook forecaster that included specific language discussing the potential historic nature of the coming storm. WFOs along the East Coast began issuing winter storm watches for the upcoming weekend. At 4:00 P.M. NOAA issued a press release warning of a potentially significant East Coast storm. (See Box 2-1.)

As a result of the press release, NBC Nightly News made the upcoming storm its lead story at 6:30 P.M. Friday evening. Other major network news agencies included stories about the storm at the same time. A NOAA press conference on Saturday, March 3, attended by high-level NOAA/NWS officials, continued to highlight the historic aspect of the coming storm. WFOs in the mid-Atlantic area were still issuing only winter storm watches; winter storm warnings were issued for the Sunday-Monday period for metropolitan areas from Philadelphia northward. By Sunday, March 4, the storm had finally become well organized and with much of the coastal areas receiving rain, watches and warnings were changed to advisories for Monday. Winter storm warnings were maintained in the interior and most of New England, where heavy snow did fall.

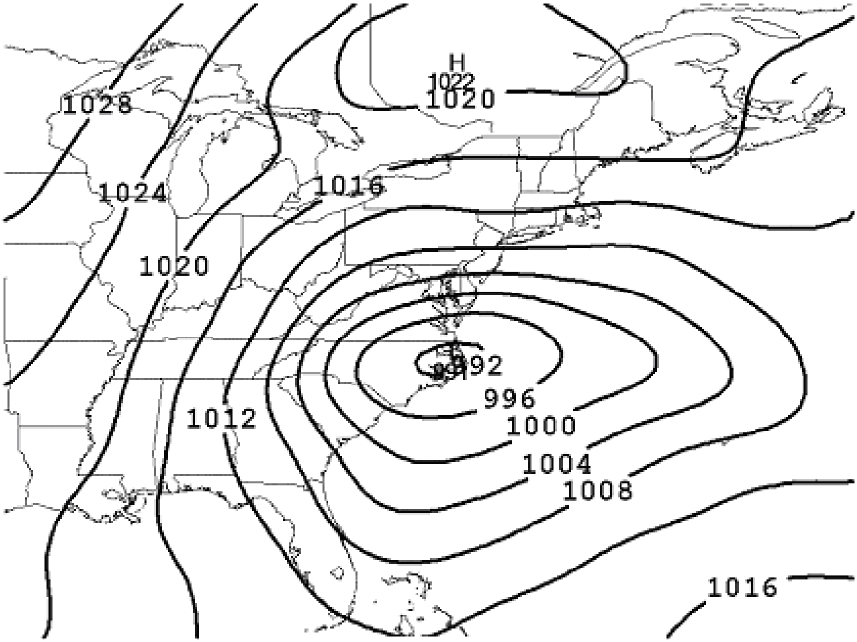

FIGURE 2-7 AVN model surface pressure forecast made at 1200Z, March 2, and valid at 0000Z, March 5. SOURCE: National Weather Service.

When? Initial outlook graphic products, based primarily on the MRF and European Center for Medium Range Weather Forecasts (ECMWF) models and interpretative discussion, from NWS/HPC indicated a potential East Coast storm 7 days before the storm even formed. Local and national media began discussing a possible storm coincident with these HPC outlooks. Specific language indicating a storm of possibly historic proportions was conveyed to forecasters and the media 3 days in advance. A teleconference was held and a press release and guidance documents were available 2 to 3 days in advance. Deterministic snow amount forecasts were issued 2 to 4 days in advance and as much as 5 days in advance by some media in Philadelphia and other private sector meteorologists/weathercasters. A NOAA press conference 1 day in advance still highlighted the potentially historic nature of the storm.

To whom? Communication at this point flowed from NOAA/NWS to and then among WFOs, emergency managers, local and national government officials, private sector clients, the media, and the general public.

BOX 2-1
NOAA Press Release, March 2, 2001

FOR IMMEDIATE RELEASE

NOAA ANNOUNCES THE POTENTIAL OF A MAJOR NOR'EASTER FOR THE MID-ATLANTIC AND NORTHEAST SUNDAY INTO MONDAY

There is a possibility that a major winter storm could impact the mid-Atlantic region beginning Sunday afternoon and spread northeast into Pennsylvania, New Jersey and New York Sunday evening. This storm system would likely bring major rains to Alabama, Georgia, South Carolina and southern Virginia over the next few days providing some relief of drought conditions. This heavy rain could also be accompanied by the threat of severe weather.

From southern Virginia, to eastern New York, many National Weather Service field offices have issued Winter Weather Outlooks, which are used to alert the public of potential significant winter weather conditions beyond 36 hours.

National Weather Service numerical weather predictions are converging on the development of this major Nor'easter, however, the exact track of the storm will determine how much snow might fall along the East Coast. National Weather Service meteorologists will refine this forecast as the event gets closer. The potential for coastal flooding from the mid-Atlantic into the Northeast is also significant with this developing storm.

Marine interests should pay special attention to this developing storm system over the weekend. Mariners should be alerted that high winds and waves will exist and persist as this storm develops Sunday evening. This storm, once it begins to develop, may move only slightly Monday into Tuesday and be just off the mid-Atlantic coast. Please stay alert to warnings and watches over the coastal areas and into the high seas.

After this storm system passes, there will be extreme cold, and there is a possibility of blizzard-like conditions in the mid-Atlantic and Northeast. This is a dynamic and developing weather situation.

How? Dissemination of the information was done through forecast products, guidance documents, press releases, press conferences, teleconferences, the Internet, cable, television, radio, print, and other mass communications media.

With what effect? Correct general synoptic scale information of East Coast cyclogenesis was generated 7 days in advance and mesoscale and regional models and forecasts were of varying accuracy 12 to18 hours before actual development. However, there was a building awareness and anticipation by the public and other decision makers in major East Coast population centers that created a sense of urgency in the public's mind. Internal communications, such as the HPC guidance document, may have been misinterpreted by some as deterministic forecasts as opposed to forecaster guidance. Some of the language used created a building sense of inevitability about the event. There was an over-anticipation by the public that the storm would hit the major metropolitan areas, and when it failed to materialize, the public and media were very critical of the forecasts and of forecasters.

Analysis of the Case

By February 26, nearly a week before the first precipitation fell, NWS forecasters recognized the potential for an East Coast storm. Confidence was not high 6 to 7 days out, however, as there was significant disagreement among the medium-range forecast models. By March 1, a number of forecasters were indicating increasing confidence in the possibility of a major East Coast storm. By the afternoon of March 2, the medium- and short-range models (MRF, ETA,[4] AVN) were coming into much better agreement, which was reflected in forecast discussions of high confidence of a major East Coast event. On Saturday, March 3, even though the storm had yet to form and new guidance indicated that it would be slower to develop than had been indicated 24 to 48 hours earlier and perhaps be more of a rain event rather than a snow event, there was still widespread action by public and private sectors in many major East Coast cities to prepare for an impending snowstorm all along the East Coast from Virginia to New England. Confidence of a major snowstorm was lowered even further later that day because warmer air was holding along the coastal plain. On Sunday, March 4, predictions were continually refined as the storm slowly intensified. By Sunday afternoon there was increasing expectation within the forecasting community that the storm would primarily bring rain rather than snow from Washington, D.C., to New York.

Lessons Learned

During the workshop, participants suggested several lessons learned from this case.

- It is possible to overstate the implied accuracy of longer range forecasts, even though the synoptic scale outlooks of the storm reflected the state of the science for a forecast 2 to 7 days in advance.

[4]The ETA model is a mesoscale numerical weather prediction model run at NCEP. Its name derives from the eta coordinate system mathematical formulation used in the model.

- Short-term (1 to 2 days) meso and synoptic forecasts based on continental and regional short-range models were of varying accuracy. Major mid-Atlantic and northeast cities' snow amounts were over forecast or incorrectly predicted precipitation timing. Interior and New England forecasts were quite accurate. The entire event in meteorological terms was indeed a major East Coast storm.
- The temporal and physical uncertainty associated with an event of this magnitude was not adequately communicated to forecast users by the meteorological sector. The slow development of the storm was not adequately communicated, and this information would have helped forecast users know they had more time before decisions had to be made.
- Two to 4 days before the storm, repeated communications from local media, local and national NWS/NOAA public statements, and increased national news coverage created a sense of urgency in the public's mind. In hindsight this urgency was unwarranted. The high level of NWS and media attention to the potential storm, coupled with experiences with similar events in recent winters, contributed to a sense of a deterministic event rather than a probabilistic event. Uncertainty was not adequately discussed with the public in statements, forecasts, press releases, press conferences, and media presentations.
- Significant competitive pressures exist for broadcast meteorologists and weathercasters, and this contributes to deterministic forecasts and statements being made by these information providers.

Follow-up Improvements

- The uncertainty inherent in the science associated with forecasting winter storms is not adequately understood by the public and decision makers or communicated by many in the government, media, and private sector forecast community. Both providers and users should view uncertainty in forecasting as an integral part of the decision-making process.
- Uncertainty information needs to be updated regularly, along with forecasts.
- The media and other value-added providers should be careful to convey the limitations of forecasting science when presenting life- and property-threatening information, even in an increasingly competitive marketplace.

Remaining Challenges

- Improve the understanding of the accuracy of deterministic models.
- Improve the understanding of the subliminal effects of peer pressure within the forecast community, which appears to reduce the communication of uncertainty in forecasts.
- Identify the appropriate role of the public and private sector in conveying information and the timing of statements forecasting major storms.

Concluding Thoughts

Workshop participants noted that the American Meteorological Society (AMS), as the professional society of meteorologists and through its TV Seal program,[5] might establish professional guidelines that Seal holders agree to abide by in the dissemination of NWS warnings and statements. Also, the AMS might help raise understanding within the forecasting community of the importance of discussing uncertainty in forecasts, especially forecasts that are likely to spark public action such as the March 2001 example. Station managers probably also bear some responsibility in controlling program content and reducing unnecessary hype during extreme weather situations.

OKLAHOMA-KANSAS TORNADO OUTBREAK MAY 3, 1999

Description

A major outbreak of nearly 70 tornadoes spawned in 11 supercell storms was responsible for 48 deaths and over $1 billion in property damage in Oklahoma and southern Kansas during the late afternoon and evening of May 3, 1999 (see Figure 2-8). Some of the tornadoes were of F4 and F5 intensity (wind speeds in excess of 260 mph); the most intense and longest-lived tornado passed through the southern part of the Oklahoma City metropolitan area. Another violent tornado passed through parts of suburban Wichita. At times a number of supercells co-existed. Each of these produced tornadoes, some of which were on the ground at the same time. (Detailed timelines for this weather event are given in Appendix C.)

Communication Summary

Because the nature of the activities changed as the tornado outbreak unfolded, the discussion of communication issues is divided into three parts: the preparation phase, the event, and the aftermath.

[5]The AMS established the Seal program in 1960 to upgrade radio and television weather programs. The growth of television and radio was accompanied by an increasing impact on the public; therefore, the need for professional weathercasting was recognized by the AMS. To date, over 1,000 Television and 150 Radio Seals of Approval have been awarded. The stated goal of the program is to ensure that meteorologists who hold the Seal of Approval exhibit scientific competence and effective communication skills in their weather forecasts.

FIGURE 2-8 Damage in Moore, Oklahoma, from the May 3, 1999, tornado. Copyright by Howard B. Bluestein.

Preparation Phase

Who? Tornado awareness materials were presented to the public by the NWS, local television and radio weathercasters, print and other media, and city officials.

Said what? The presentations included information on how to identify tornadoes; how all involved parties (the public, the NWS, ham radio operators, police forces, television and radio stations) should prepare for tornadoes; and how government agencies and television and radio stations should coordinate their efforts.

When? The preparation phase was ongoing, occurring months to years before the tornado outbreak.

How? Several groups in the Oklahoma City area had formal tornado preparedness programs. For example, the NWS trained spotters and conducted internal drills. The local television stations customized storm-tracking software to include detailed city backgrounds, broadcast tornado preparedness segments on news programs, presented 30-minute specials, and had weathercasters give live presentations at schools and other venues. Several cities (e.g., Moore, Oklahoma) sent out fliers on storm preparedness with utility bills. The staff of the

Weather Forecast Office (WFO) in Norman gave public presentations and had numerous meetings with public officials and emergency managers, and worked closely with the ham radio community to set up a network to relay spotter reports. Tornado preparedness drills were conducted in area schools and some businesses.

With what effect? As a result of these activities, a more effective network was built to coordinate storm spotter reports and relay warnings so that people knew what to do when a severe weather or tornado warning was issued. The NWS, media, and emergency managers (e.g., city officials, Highway Patrol) were able to work together effectively.

The Event

Who? During the event, the NWS, television stations and cable outlets, radio stations, NOAA weather radio, ham radio operators, severe-weather spotters, and the Highway Patrol, local police, and fire departments played important roles in saving the lives of people in the paths of the tornadoes.

Said what? From as early as a day before the outbreak, the NWS recognized the possibility for severe weather. However, the outlook from the Storm Prediction Center (SPC) as of 6:00 A.M. local time on May 3 called for only a slight risk of severe weather. By 11:15 A.M., the SPC upgraded its outlook to a moderate risk, based on its analysis of the morning data from soundings and wind profilers and numerical model forecasts. It was not until 3:00 P.M., only 1 1/2 hours before the beginning of the outbreak, that the SPC recognized the full potential severity of the event and upgraded its outlook for the potential of severe weather to "high." The SPC issued a tornado watch at 4:30 P.M., effective at 4:45 P.M., just 2 minutes before the Norman WFO issued the first tornado warning. Ham radio operators immediately started to relay tornado sightings to the NWS. As tornadoes were being reported by spotters and detected by NWS Doppler radars, the local television and radio stations and cable outlets relayed warnings, showed radar images (sometimes superimposed on street maps), live images of tornadoes and their projected paths, and tornado damage. Local radio stations also relayed warnings and in many instances rebroadcast the audio portion of the live television broadcasts. In addition, the NOAA weather radio broadcast warnings. The Highway Patrol and local police also relayed warnings, kept Interstate 44 clear ahead of a tornado, and routed people around damaged areas.

When? Forecasts of the event began 1 day before the outbreak and continued throughout the event.

How? Forecasts and warnings were issued by the NWS to commercial outlets and the public via commercial television and radio broadcasts, private sector weather-related companies, and NOAA weather radio broadcasts, and warnings were given by police on the road.

With what effect? Because of extensive preparation and timely, coordinated warnings, relatively few people lost their lives in an area of over one million people. It has been estimated that as many as 700 people might have been killed had warnings not been issued (Brooks and Doswell 2002).

Aftermath

Who? Follow-on information to the public came from the NWS, the media, insurance representatives, and emergency service organizations.

Said what? After the event, the NWS, the media, insurance representatives, and emergency service organizations played prominent roles in helping tornado victims and in documenting the storm damage. The NWS sent out damage survey teams to confirm and define the locations of tornado damage paths and estimated tornado intensity based on the damage (Speheger et al. 2002); this information was made available within days. The media interviewed both operational and research meteorologists as well as tornado victims. Some were interviewed on television and radio live, some were taped for broadcast later, and others were interviewed by newspaper and magazine reporters. Insurance representatives promptly arrived on the scene to provide assistance, while representatives from the American Red Cross and the Salvation Army converged from several states to provide assistance to the tornado victims.

When? Analysis of the storm and its impacts began just after the event and continued until months after the event.

How? Information collected included ground and aerial surveys and interviews of victims and meteorologists.

With what effect? Assistance was provided to the tornado victims.

Analysis of the Case

There was significant forecast uncertainty as little as 6 to 12 hours before the first tornado (Edwards et al. 2002). Although morning soundings showed adequate vertical wind shear and convective available potential energy for supercell storms, which are the most prolific producers of major tornadoes, the synoptic scale forcing was weak and there were no localized zones of surface convergence. In addition, numerical model products were not indicating precipitation in the region where the tornado outbreak actually occurred. It was subsequently determined that the models' failure to predict the event may have been in large part due to the lack of resolution and initial data over northern Mexico and off the west coast of California (Roebber et al. 2002). On the basis of later soundings, wind profiler data, model runs, and visible satellite imagery, the forecast uncertainty decreased with time, enabling the SPC to upgrade their outlook to moderate by 11:15 A.M. and high by 3:00 P.M. The forecast effort is considered excellent in spite of the small time elapsed between the first tornado watch and the first tornado warning. Careful scrutiny of the current data and trends in the data enabled forecasters to foresee the event in spite of ambiguous numerical guidance. The first storms in Oklahoma prompted a tornado watch, and the first tornado warning was issued shortly thereafter.

Once the storms began, uncertainty was less important; warnings were based on tracking the events by Doppler radar and spotter reports. The ham radio network proved essential for communication; moreover, it was the *only* means of communication when the telephone system and power failed. The many drills at the WFOs eased the warning process and enabled forecasters to overcome unexpected equipment failure. For example, when the Wichita Doppler radar failed, images from the Doppler radar at Vance Air Force Base were quickly brought in as backup. Also, periodic failure of the automated voice system for the NOAA weather radio could be overridden rapidly. Division of forecast responsibility at the Norman office enabled forecasters to concentrate on subregions within the forecast area. Better display software enabled forecasters to quickly locate the tornado track with respect to towns and cities. The efforts of the WFO employees were particularly impressive, in view of the fact that several had families in the tornadoes' paths. The median warning time was 23 minutes (Andra et al. 2002), enabling the public to respond effectively.

The combined efforts of the ham radio network, live broadcasts by the network television stations received directly and via cable, rebroadcasts of the audio portion of television reports on cable and several radio stations, and law enforcement personnel helped to minimize loss of lives. The competition of the media in the Oklahoma City area led to outstanding coverage of the tornadoes. Many lives were saved because the television stations broadcast live video and eyewitness descriptions of the large Oklahoma City/Moore tornado, graphically highlighting the seriousness of the event. Radar images of the storms and the projected paths of the tornadoes superimposed on street maps enabled the public to know whether they were directly in the path of the tornado. The urban Oklahoma City and Wichita areas tend to get more attention from the large-market television and radio stations than do outlying areas; however, the warnings for the regions outside the metropolitan areas were prominently displayed on television and repeated frequently on audio for rebroadcast on the radio. The Oklahoma public is accustomed to dealing with sophisticated graphics and display tools because they have been shown on local television stations for many years. This case provided an excellent example of cooperation between the NWS and radio and television stations. The Highway Patrol and local police departments warned many people out of contact with radio or television. In spite of this excellent effort, there were still people who never received warnings.

Tornado preparedness drills at schools and businesses saved lives. Because the event occurred during daylight hours after school, work, and the evening commute for most of the population, most people were able to receive and respond to warnings from the media. The public's familiarity with tornadoes and preparedness procedures in the Oklahoma and Kansas areas facilitated the response.

The warnings issued in the Oklahoma City and Wichita metropolitan areas were outstanding in view of the large number of tornadoes and the relatively limited loss of life, in spite of the large population density. The response of the public to this effort was uniformly positive. The NOAA service assessment report (NOAA 1999) noted that the public was "well served" by both the Norman and Wichita WFOs. The efforts of the NWS Forecast Office in Norman; the Oklahoma Department of Public Safety; KFOR, Channel 4; KOCO, Channel 5; KWTV, Channel 9; the Southwest Independent Repeater Association; and the Oklahoma Climatological Survey were recognized with a special award from the American Meteorological Society at its annual meeting in 2001 "for outstanding and well-coordinated actions before, during and after the historic 3 May 1999 tornado outbreak in central Oklahoma, which prevented untold deaths and minimized the impact of the devastating storms" (AMS 2001).

Some newspaper articles concerning the event unfortunately perpetuated some myths about the nature of tornadoes and severe thunderstorms. For example, explanations about the formation of severe thunderstorms in terms of colliding warm and cold air masses were common, even though the air masses on May 3, 1999, were relatively uniform.

Lessons Learned

- Adequate preparation by both forecasters and the public is indispensable for major severe weather events, even if there is only a small possibility of severe weather (e.g., when all the parameters for a classic tornado outbreak are not discernible).
- Advance coordination among NOAA, spotter networks, ham radio operators, emergency managers, and the media was key in making the warning and response successful. Advance planning could be considered for other WFOs. Practicing severe weather drills helped both those responsible for providing warnings and those receiving the warnings. Educational outreach in schools is thought to have significantly decreased deaths in families with school-age children.
- Spreading the warnings in different ways and through different media was very effective in reaching diverse parts of the population. Feeding the television audio to radios helped reach those who were not watching television, spreading the best information broadly. Live broadcasts of the tornado in multiple ways

(radar, track, actual funnel, voice description) provided a clear message of the tornadoes' severity as well as current and projected locations. The Oklahoma public has experience with tornadoes and the sophisticated graphics and display tools used, and this experience led to effective warnings and response. Transferring these highly successful strategies to other communities around the country will be a challenge.

• The degree of confidence in a forecast can affect the appropriate response. Although people are usually told not to outrun a tornado, the media advised people to do so in this case because the locations of the tornadoes and their projected paths were so well known in advance. Although this strategy worked in the Oklahoma City area, it is not clear whether it would be appropriate elsewhere and in other circumstances.

• In dealing with the print media, it is imperative that experts who are interviewed provide feedback to the journalists in advance of publication. After events, experts should avoid speculating about scientific results that have not yet been adequately analyzed.

EL NIÑO 1997-1998

Description

The 1997-1998 El Niño was one of the strongest on record. It also was the first major El Niño/Southern Oscillation (ENSO) to occur while there was an operational ENSO observing system and diverse ENSO prediction and impact prediction efforts. In 1997-1998, ENSO-based weather predictions and predictions of impacts received major media coverage. Public awareness of climate variability and of its predictability was increased, and there was considerable scientific agreement that the predictions based on the 1997-1998 ENSO were a success. This case study examines the lessons to be learned about communicating these ENSO predictions and their accompanying uncertainties. (See Figure 2-9.)

Communication Summary

Who? Various government agencies (e.g., CPC, NASA's Jet Propulsion Laboratory), various academic groups (e.g., Scripps Institution of Oceanography, University of Maryland, and Columbia University), and several private sector companies provided forecasts of ENSO-based weather and climate outcomes and of environmental and socioeconomic impacts. Media (radio, television, press) provided ENSO coverage to the public. Private firms (e.g., meteorological, agricultural, economic) provided guidance to decision makers.

Said what? Predictions of the ENSO event describing ocean changes in sea surface temperature (SST) and coupled ocean-atmosphere variability were pri-

Weather uncertainties loom

WARM NORTH ATLANTIC WATERS MAY HELP MAKE THIS EL NINO EVEN SNOWIER IN THE EASTERN STATES - ONE OF THE BIG DIFFERENCES THIS YEAR FROM 1982/83

Hot year for 1998

Warm El Nino winter could mean early spring planting

We're hearing plenty of hype about the strong weather phenomenon known as El Nino that could bring flood, droughts and hurricanes around the world.

In Illinois, it's likely to bring less snowfall and milder winter temperatures, notes Steve Hollinger, with the Illinois State Water Survey. There is a very high probabil- we should be in pretty good shape through March, says Hollinger.

"Illinois farmers may be able to get crops in a little earlier than normal in the spring," says Hollinger. Farmers who planted this year's crops in June would welcome an early start to the 1998 growing season. "Overall this can be rather positive for

Value of El Nino forecasts gets mixed reviews

■ Scientists seek refined effort

La Nina turmoil likely to continue through June

By Shannon Tangonan
USA TODAY

Blame La Nina, El Nino's de-

Weather effects o
La Nina, cooler-than-normal sea-surfac

Meteorologist sees weather woes ahead

STUDY BY NOAA SCIENTISTS COULD LEAD TO BETTER PREDICTIONS OF EL NIÑO, COMMERCE AGENCY SAYS

Experts hedge El Nino forecast

Special Report
Science struggling to predict El Niño devastation

WEATHER: Rainfall this winter could be three or four times the normal amount, or not.

Pesky El Niño is singing its swan song, forecasters say

The Fury Of El Nino

TIME

Suddenly nobody's calling it El No-Show anymore. What have we learned from the climate event of the century?

Only a few months ago, El Nino was starting to look like the most overhyped story of the decade. The periodic warming of Pacific

FIGURE 2-9 Headlines illustrating the variety of forecasts available to the public. SOURCE: Changnon (2000). Used by permission of Oxford University Press, Inc.

marily addressed initially to the scientific community. After a short period of time, however, ENSO predictions, as well as predictions of impacts of ENSO, were addressed to users and the public.

Points about this case:

• This was the largest and warmest El Niño to develop in the Pacific Ocean during the past 100 years.

• The news media gave great attention to this El Niño, and it received more attention at all levels than any previous climate event.

• Scientists were able to use El Niño conditions to successfully predict weather conditions for the winter 6 months in advance over most of the United States.

• The direct impacts of the ENSO-generated weather during October 1997-April 1998 included: (1) flooding and wind damages in California, (2) increased tornadic activity in the South, (3) heavy rain events in Texas and Florida, (4) unusual winter storms in the High Plains in early fall and severe winter weather in Canada and New England in January, (5) few winter storms, above normal temperatures, and little snow over most of the northern United States, (6) no Atlantic hurricanes striking the United States, and (7) Pacific hurricanes that hit Mexico and California.

• The net effect of the El Niño-influenced weather on the United States was an economic benefit, after early fears and predictions of great damages. Some areas, including California and Florida, suffered major losses, but many areas, including the northern United States, realized sizable economic and health-related benefits.

When? NOAA issued official, scientific-based weather forecasts for the fall, winter, and spring from July 1997 through December 1997. The various weather impact predictions were issued by government agencies such as the Federal Emergency Management Agency (FEMA) and the U.S. Geological Survey (USGS) and by numerous private sector organizations during the fall and winter of 1997-1998.

To whom? The forecasts were issued to the ocean/atmosphere community, the prediction centers, relevant federal and state government agencies, the media, the public, and managers of, for example, agriculture, water, power, emergency preparedness, transportation, and insurance.

How? Official NOAA predictions were disseminated through press conferences, news releases, Internet releases, and interagency memorandums. In turn, this information was interpreted by numerous government agencies, individual scientists, and the media and distributed to the public.

With what effect? Many decisions makers took steps toward mitigating the potential impacts of the El Niño in such areas as utility operations and power purchases, agricultural planning, and water management. The media coverage created high penetration into the public consciousness of climate variability and of potential for greater skill in seasonal to interannual forecasting. The success of the forecasts improved climate forecast credibility. Awareness of the climate-weather connection was raised. One possible negative impact was an over-simplification of the complexities of climate variability resulting from a view of ENSO as sole driver. Some levels of confusion and skepticism resulted from different forecasts coming from multiple institutions.

The predictive successes brought new credibility to the science of long-range prediction and, in general, acted to increase the public's understanding of the weather-climate connection and the utility of long-term forecasts. The intensity of the 1997-1998 El Niño brought forth claims that the phenomenon was the result of anthropogenic global warming. This possibility added to the scientific-policy debates.

Analysis of the Case

There were notable differences in how weather-sensitive decision makers reacted to the predictions—some used them for gain, while others, fearing failure, did not. There was a progression in the media coverage. First came science stories by science writers, which included discussion of uncertainty. Then came stories with mass appeal, not always by science writers, which emphasized causality and downplayed uncertainty.

The ENSO-based weather predictions were received with little debate or skepticism by the media and the public. There also was a readiness to accept predictions of impacts, although this created confusion in some regions. At some point the 1997-1998 ENSO achieved a sort of folklore status and even became the subject of jokes making it responsible for all problems. The media and the public were fascinated with El Niño, and it became a household word throughout the country. (See Figure 2-10.)

It is not yet clear that the 1997-1998 ENSO created a lasting change in public perception and media treatment.

The 1997-1998 ENSO was the strongest on record, and its clear secondary impacts on regional weather created opportunities to affect perceptions. There was opportunity for NOAA to take advantage of the high visibility to illustrate its capabilities and for private sector firms to produce marketable ENSO and ENSO impact products.

There were shortcomings in the predictions. The rapid development of the El Niño was not predicted successfully. Basing predictions on the 1982-1983 ENSO produced poor results in some parts of the world. However, in terms of human lives and dollars saved, winners exceeded losers in the United States.

El Nino gave blizzard much of its strength

By Maria Puente, Debbie Howlett and Patrick O'Driscoll
USA TODAY

The blizzard that blasted the Rockies and Plains this weekend moved on to Canada on Monday, leaving many wondering: Was El Nino to blame?

El Nino gets the blame

El Nino-fueled storm socks it to California

'El Meaño' responsible for disasters, benefits in world's weather

Storms batter California, Florida

Wind, rain, surf now... coasts

Can't blame it on El Nino

By MARCELLA S. KREITER United Press International

El Nino has been taking the blame for a lot of storms this winter but a forecaster at the National Weather Service says Monday's snows in the Midwest, tornadoes in Florida and heavy rains in the Northeast cannot be blamed on the weather phenomenon.

FOR IMMEDIATE RELEASE

El Niño Does Not Increase Risk of Large Storms over Great Lakes

CALIFORNIA
Twister leaves ...h of damage ...ng Beach

Is El Niño to blame for every weather problem this year?

And Exactly What Isn't El Nino's Fault?

El Nino Was Major Factor In Tornadoes
Effects Have Become Stronger During February

By Curt Suplee
Washington Post Staff Writer
Tuesday, February 24, 1998; Page A14

El Nino likely propelled the lethal tornado rampage in Florida, and probably will continue to set records for rainfall, storm ferocity and other unusual types of weather across the nation through the spring, federal weather officials said yesterday.

USA TODAY
05/01/98- Updated 06:...

El Niño unlikely to affect twister paths

news

El Niño is innocent for once

FIGURE 2-10 Diverse forecasts together with uncertainty gave rise to the tendency to ascribe many events to the El Niño. SOURCE: Changnon (2000). Used by permission of Oxford University Press, Inc.

Highly accurate seasonal climate forecasts were based on our understanding of El Niño, and mitigation actions produced large and measurable savings.

Lessons Learned

- The 1997-1998 ENSO brought beneficial scientific outcomes: Climate research paid off with quality predictions, and as a result, the science of climate-weather links was strengthened. Mitigation efforts paid off (e.g., California performed major maintenance on flood control systems). Although climate research was important to the success of the predictions, there were shortcomings such as linking ENSO to other scales of variability.
- Differing forecasts from multiple sources create a problem for users. Coordinating the forecasts or providing discussion of the various forecasts with an explanation of the uncertainty could reduce confusion in the future. There may be value in labeling some forecasts as official to show official expertise as opposed to research-based experimental forecasts.
- Classic ENSO patterns and impacts can be unreliable as a guide for predictions of impact of new ENSO events. The 1997-1998 ENSO event was not a repeat of the 1982-1983 ENSO event.
- Local experts may not be prepared to interpret regional scale events and often provide differing views.
- Forecasters and media should attempt to provide information on both negative and positive outcomes. Forecasts from the Climate Prediction Center mentioned the possible "good" effects of El Niño, such as lower heating bills across the North, but this perspective was often overlooked. Dire warnings hurt credibility when different outcomes occur.
- A skillful forecast does not directly lead to value. The decision environment plays a critical factor in the value achieved. The expectations of decision makers can be guided by the careful predictions of forecasters. It is easy to oversell climate forecasts.
- If the media and the public fail to understand El Niño, then chances are decreased that even skillful forecasts will have value to decision makers.

Follow-up Improvements

- The entire weather community has worked to improve coordination of forecast releases.
- The National Weather Service has vetted a Web site for information and graphics to accompany forecasts.
- Ongoing communication of interannual to decadal modes of variability (Pacific Decadal Oscillation, Arctic Oscillation, North Atlantic Oscillation) as well as ENSO would raise the level of understanding of climate variability and thus of uncertainties related to ENSO and ENSO impact predictions.

• Study of the 1997-1998 ENSO leads to understanding of why it was not more similar to the 1982-1983 event and to the building of quantification of uncertainty in both ENSO and ENSO impact predictions.

Remaining Challenges

• There is a need to adequately inform the media and provide them with the type of information they can understand, including names of experts they can contact. Properly managing the public and media interest to achieve education and over the long term improve understanding of uncertainty in predictions remains a significant challenge.

• Developing skill at seasonal prediction is needed to separate seasonal changes that are a result of extreme events from those that are a result of normal variability.

• Explaining complexity of seasonal to interannual prediction and impact prediction will lead to better understanding of the forecasts.

• It is important to respond to users and adjust forecast products to their needs. If they turn out to be largely accurate, uncertain predictions will become fact if the event's conditions agree with the prediction. But this can inflate expectations and lead to problems if future predictions are less accurate.

• Seasonal forecasts can be made more useful by including more information on existing and past forecast accuracy and comparing current and past outcomes; current probabilistic information about forecast conditions; and "climate profiles" of weather conditions during a warm, cold, wet, or dry season.

• Agencies in the business of issuing forecasts and warnings may have to deal with unintended consequences of success, including inflated expectations of the public and other users in the future. There is an opportunity for forecasters to improve communication of probabilistic information to decision makers.

CLIMATE CHANGE SCIENCE AN ANALYSIS OF SOME KEY QUESTIONS JUNE 2001

Description

The importance of anthropogenic greenhouse gases as a potential mechanism for causing future climate change has been a topic of scientific investigation, political debate, and media discussion for several decades. Much of the debate focuses on the level of uncertainty associated with projections of future climate change and whether the risk warrants action to minimize potential adverse effects. President Clinton endorsed an international treaty, the Kyoto Protocol, as a mechanism for reducing U.S. and world greenhouse gas emissions as a first step in addressing the global warming problem. The election of President George W.

Bush resulted in a review of U.S. climate change policy and a decision not to endorse the Kyoto Protocol. Review of climate change policy continued amid international criticism of U.S. rejection of the protocol and the lack of an alternative action proposed by the White House.

During this review of U.S. policy options, the Intergovermental Panel on Climate Change (IPCC) released its Third Assessment, a comprehensive summary of climate change findings written by a broad spectrum of international scientists (IPCC 2001). Seventeen international scientific societies then endorsed the IPCC report and used its findings as a call for action on the Kyoto Treaty. Because President Bush was scheduled to discuss global warming with leaders from 15 European nations in June 2001, the White House requested a fast-track study by the National Research Council (NRC) to help inform the Administration's ongoing review of the U.S. climate change policy by identifying the greatest certainties and uncertainties in the science of climate change and answering 14 key questions on climate change science. There were initial discussions within the National Academies as to whether the study should be done and whether the questions were appropriate for an NRC study. Since the original purpose of the National Academies was to provide sound scientific advice to the government, the study was accepted. The NRC completed this study in less than one month, releasing its report on June 6.

Communication Summary

Who? The U.S. National Academy of Sciences (NAS) communicated the findings of a special study on climate change science. The NAS committee that conducted the study was composed of 11 members chosen for their special competences and with regard for appropriate balance (and with minimal involvement in the IPCC Third Assessment report), 7 of whom were also members of the NAS. The NAS not only selected a larger than usual representation of Academy members, but (recognizing its 1863 charter to respond to government requests) it also chose to support the committee work with its own funds rather than with the more usual agency contributions.

Said what? The NAS released its final report, *Climate Change Science: An Analysis of Some Key Questions*, on June 6, 2001. This report was based on the committee's critical assessment of certainties and uncertainties in climate change, the accuracy and consistency of the recent IPCC assessments, and answers to 14 key questions on climate change science. The committee of U.S. senior scientists reached consensus that, among other things,

- Temperatures are, in fact, rising. The changes observed over the last several decades are likely due mostly to human activities, but we cannot rule out that some significant part of these changes are also a reflection of natural variability.

- The committee generally agrees with the assessment of human-caused climate change presented in the IPCC Working Group I scientific report.

A warming of 3°C by the end of the twenty-first century was deemed consistent with current understanding of climate change. However, considerable uncertainties in this forecast were noted to be associated with natural variations and reactions to anthropogenic influences.

Of note was that the NAS committee did not communicate any policy recommendations regarding what to do about global warming, which it viewed not to be part of its charge and not possible in the time frame.

When? At 4:00 P.M. on Wednesday, June 6, the NAS posted a final draft of the report on its Web site and the NAS media officer issued a press release.

To whom? The White House was the official recipient of the information in the report, but the communication was intended also for

- The U.S. Congress. Climate change was a topic of debate in the U.S. presidential election 6 months prior to the White House request. During the campaign, then-candidate Bush pledged to reduce CO_2 emissions from U.S. power plants. Following the election and the President's subsequent reversal (in March) of his campaign decision, Drs. Hansen and Linzden (both members of the NAS committee) testified to Congress (on April 30, 2002) on this topic.
- Foreign academies. Seventeen foreign academies of sciences requested that the NAS co-sign a statement supporting the Kyoto Protocol. In his letter declining the U.S. signature, NAS member and then foreign secretary Sherwood Roland noted that the NAS believes that it "can be of the most value in conducting its work on this topic through the Research Council committee process using a highly expert group of scientists; that report is expected to be issued this summer."
- International policy makers and the IPCC. Despite the findings of the IPCC Third Assessment report and pressure from European and other governments, the United States had not endorsed the 1997 U.N. Kyoto treaty to restrict the emissions of CO_2.
- The scientific community, both U.S. and international.
- The media, which had followed and reported climate change news for a number of decades, and with whom the scientific community had established considerable working connections.
- The American public. The 14 questions were typical of public enquiry of global change issues and underscored the public quest for answers. Europeans

had protested President Bush's reversal of his campaign promise to reduce CO_2 emissions from power plants.

How? A short (24-page) peer-reviewed NAS report was the source of the information that was communicated. The NAS produced this report in fast-track mode, producing a final report within 1 month of receiving the official White House request. A key aspect of communicating the report's findings was the active involvement of an NAS media officer with the committee throughout the entire process. The media officer issued a press release, and in the following weeks, NAS personnel and committee members briefed the White House, Administration officials, Congress, and the media. Another key aspect of how the report was communicated was its release on the web, making the key information available simultaneously to all recipients.

With what effect? The immediate effect of the communication was a speech by President Bush on June 11 (just prior to his European trip) acknowledging the report and thanking the NAS. The President, who had said in March that he was unsure that global warming was a real phenomenon, now suggested several ways to address the problem, including more basic climate change research and advanced computer modeling, technological innovation to help reduce CO_2 emissions, and improved international cooperation. Subsequently, President Bush's stand on environmental issues became somewhat more visible, with talk of a "new environmentalism."

The clearly received information that anthropogenic climate change was probably occurring and would likely be a significant environmental "event" of the twenty-first century was conveyed to the public by the media. The balance of scientific evidence was recognized as supporting this view, even with the caveat of significant uncertainties. Lacking in the media, for the most part, were the tones of prior reporting in which both sides of the argument were given equal weight. And unlike past media reporting, the event (i.e., real climate change expected by end of the twenty-first century) rather than the uncertainties was the focus.

The recognition by both the NAS and the White House, conveyed more or less faithfully by the media, that climate change was real and likely to be a twenty-first century environmental event helped move climate change (and related research) to the forefront of Administration policy and Congressional legislation, with the challenge of providing a U.S.-based scientifically-justified plan for action. The report helped promote a more bipartisan approach to climate change policy now that the option of "doing nothing" is less viable: Senator Kerry (D-Mass) said, "It increases the imperative for them to take action," and Senator Hagel (R-Neb) said that "the report provides us with a basis to move forward."

An unexpected effect of the communication of the NAS report was a refocusing of attention on prior climate change studies that had already identified key problem areas. Questions were raised about the ability of the United States to address the problem within the current framework of climate change research (disparate groups scattered among various organizations and agencies, with limited coherency or overall vision, and inadequate computer resources). Media reports pointed out that U.S. capability lagged behind that of Europe, especially in the types of effort needed to contribute to the studies on which the IPCC reports were based (implying a reduction of U.S. effectiveness in this process). Both the NRC and the National Assessment had addressed these very issues in prior reports[6] whose findings and recommendations had initially received far less attention, but which now emerged anew. A particular recommendation from prior reports that received favorable attention, in addition to the urgent need for advanced computer resources, was the need for a National Climate Service, analogous to the National Weather Service.

Lessons Learned

• The questions from the White House that became the charge to the committee were very basic in nature; they were perhaps not scientifically valid questions to ask and probably not what scientists would have asked. Nevertheless, they were the types of questions the average person might ask, and they seemed to reflect underlying controversies about whether global warming was real and whether humans were responsible for it. It is important for scientists to consider the public audience at the very beginning of a study. If part of the goal of a scientific endeavor is to communicate the findings to the public and policy makers, then the charge and findings should be written with that audience in mind from the start. Dissemination should not be an afterthought. Executive summaries and press releases are helpful, but lay language should not be confined exclusively to these documents.

• Along the same lines, it was very beneficial to include a "communication" person (in this case an NAS media officer) in committee deliberations. This helped the committee consider aspects of communication as an integral component of the report and resulted in much smoother public relations following the report's release.

• The brevity of the climate change report seemed to play a role in its dissemination. This does not mean everything should be boiled down to a 1-page

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[6]For example, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change* (U.S. Global Change Research Program 2001, Cambridge, U.K.: Cambridge University Press); *Decade-to-Century-Scale Climate Variability and Change: A Science Strategy* (NRC 1998); *The Atmospheric Sciences Entering the Twenty-First Century* (NRC 1998); *Adequacy of Climate Observing Systems* (NRC 1999); *Global Environmental Change: Research Pathways for the Next Decade* (NRC 1999); *Improving the Effectiveness of U.S. Climate Modeling* (NRC 2001); *The Science of Regional and Global Change: Putting Knowledge to Work* (NRC 2001).

press release or a 3-page executive summary. On the other hand, if scientists are concerned about communicating to the public, it would help to keep in mind that reporters have a limited time to write their stories. Likewise, the public is much more inclined to read a 30-page report word for word than they are a 300-page report. The important lesson here is to be cognizant of time limitations, for better or worse, which impact reporters and the general public.

- Regarding the communication of uncertainties in general, certainties are news, while uncertainties rarely are. By making a considerable effort to communicate uncertainties, the certainties were more readily accepted. Most of the media reports acknowledged the uncertainties highlighted in the report, and they were clearly highlighted by the White House. However, the focus was the Academy telling President Bush how certain the NAS was about global temperatures rising, greenhouse gas emissions contributing to this, and future impacts.
- To focus attention on the scientific questions of climate change, the composition of the committee was critical to its integrity. The committee included leading scientists with a wide range of publicly recognized views, who achieved a consensus on the central issues. The process of constructing the report was made intentionally clear and public. Furthermore, by keeping the report to the science of climate change the message was clear and easier to communicate. The extension to climate change impacts and mitigation would have cluttered the message.

When it was decided to release the report earlier than expected on the afternoon of June 6, the NAS was prepared to do so instantaneously by releasing electronic files of the report. Having documents in electronic versions that can be e-mailed and posted on the Academies' Web site is key to disseminating news in today's world of constant news cycles and the instantaneous flow of information. By posting the climate change report to the Web, it was available for anyone to read in its entirety before it could be misrepresented.

3

Lessons Learned from the Case Studies

The case studies presented by the workshop participants yielded a number of lessons about the communication and understanding of information that are of general application regardless of the specific situation. At the conclusion of the presentations, the workshop participants were asked to identify the key lessons. Again, it is important to note that these are the views of the participants in the workshop and do not constitute findings and recommendations of the National Research Council or the Board on Atmospheric Sciences and Climate.

CONSIDERATIONS BEFORE A FORECAST IS ISSUED

Communication and dissemination of information should be integral, ongoing parts of the process, not afterthoughts. Suggestions for forecasters and communicators for improving the overall process included:

- Invest time and effort in communication from the outset, in some cases even prior to the event as in the example of severe weather.
- Make an effort to understand the communication process.
- Make education of the user community a goal of good communication.
- Use multiple modes of communication where appropriate.
- Repeat important messages. A startling warning may not be believed the first time.
- Understand communication as part of a broader process of decision making, and produce useful products that support that process.

Two-way communication and feedback is essential between information providers and users.

- Create understanding between the culture of decision making in forecasting and cultures of decision making in the user communities.
- Understand not only the words used in the forecasts but also the meanings of those words in the user community.

Accurately understand the forecaster's role, place, and responsibility in the decision-making process. The following actions were suggested:

- Know the audience.
- Coordinate across the spectrum from science to decision making to enhance appropriate responses.
- Learn about the decision-making process and "thresholds" in that process as a part of the responsibility of the information provider.

Pressures in a competitive market can result in unwarranted urgent responses to many weather threats. The following factors may affect these situations:

- Forecasts not fully supported by the state of the science may have an enormous impact on decision makers and may reduce the credibility of future forecasts.
- Dissemination of guidelines and case studies and an active role by professional societies could be used to limit the negative effects and user confusion associated with the possible trend toward unwarranted hype and unfounded claims of accuracy of previous forecasts.
- Information providers should understand and nurture the role of the media in educating the users of weather and climate information.
- Heightened interest during and following weather and climate events provides opportunities to educate the public.
- Clear, graphic warnings, which the public can grasp, may increase the chances for intelligent responses to threat.

If part of the goal of a scientific endeavor is to communicate the findings to the public and policy makers, then the charge and findings should be written with that audience in mind. Dissemination should not be an afterthought. Executive summaries and press releases are helpful, but lay language should not be confined exclusively to these documents.

CONSIDERATIONS DURING THE RELEASE OF FORECASTS AND INFORMATION

Understanding, communicating, and explaining uncertainty should be an integral and ongoing part of what weather and climate forecasters do and are essential to delivering accurate and useful information. The following suggestions were made during the workshop to improve information delivery:

- View communicating uncertainty to all information users as a key part of the decision-making process.
- Communicate why information is uncertain, not just the fact that it is uncertain.
- Communicate why information about uncertainty is important.
- Use multiple measures of uncertainty and ways of communicating uncertainty to reach diverse audiences.
- Use both qualitative and quantitative forms to communicate uncertainty.

Effectively communicating uncertainty and its context appropriately shifts the burden and responsibility of decision making to the information user. The following suggestions could improve communications to decision makers:

- The use of context (a tie to a past experience) in the face of complexity and uncertainty frequently makes the meaning of the uncertainty tangible.
- Comprehensively communicate what is known, rather than only what it is thought the decision maker needs to know.

Success or failure of forecasts and the portrayal of forecasts by the media and decision makers guide opinions and help determine the credibility of future forecasts. The following actions were suggested:

- Expect misinterpretation. Make an effort to correct problems as soon as possible. Feedback from users is critical.
- Provide a "measuring stick" to decision makers to guide their evaluation of forecasts and forecast uncertainty.
- Avoid over-selling or over-interpreting the science.
- Provide follow-on information about forecast quality to help ensure the credibility of future communications. This information is particularly important following the forecast of significant events (e.g., when a forecast was successful despite a large uncertainty or when a forecast was highly credible and failure resulted).

Diverse and different forecasts from multiple sources might have considerable value but may also have the potential to create confusion. The following factors may be considered:

- Multiple forecast efforts are of considerable value in the drive to improve future forecasts as well as to understand uncertainty in present forecasts.
- Emphasizing a distinction between "official" operational products and experimental research products may limit confusion.
- A source of compiled information (e.g., a Web page for a particular type of forecast), including diverse products labeled as operational or research, has the potential to achieve two goals: (1) the provision of a measure of uncertainty and (2) an understanding of the varying and multiple sources of information.
- Conflicting forecasts and information in life threatening situations may result in decision errors, including potentially dangerous inaction by users and decision makers. It is important always to include and highlight "official" forecasts in such cases.

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Acronyms and Abbreviations

AHPS	Advanced Hydrologic Prediction Service
AMS	American Meteorological Society
AVN	Aviation model (a numerical weather prediction model used at NCEP)
BASC	Board on Atmospheric Sciences and Climate
CPC	Climate Prediction Center
ENSO	El Niño/Southern Oscillation
ETA	A mesoscale numerical weather prediction model used at NCEP
F1, F2…F5	Tornado intensity designations on the Fujita Scale
FEMA	Federal Emergency Management Agency
HPC	Hydrometeorological Prediction Center, a component of NCEP
IPCC	Intergovernmental Panel on Climate Change
MRF	Medium-range numerical weather prediction model used at NCEP
NAS	National Academy of Sciences (USA)
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
RFC	River Forecast Center
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WFO	Weather Forecast Office

Appendix A

Workshop Agenda

**J. Erik Jonsson Woods Hole Center of the
National Academy of Sciences
314 Quissett Avenue, The Carriage House
Woods Hole, Massachusetts
August 7-11, 2001
Agenda**

Note 1: The agenda as presented is general, with no explicit times allocated for any item. The subjects are listed in the order in which they will be covered in the summer study, but the agenda is flexible to permit in-depth pursuit of an issue if needed or less time devoted to less difficult issues. A study may carry over to the next day if the discussion warrants. All participants are encouraged to actively engage in the discussion items and the presentations.

Note 2: Each day the meeting will begin at 8:30 A.M. and end at approximately 5:00 P.M. On Saturday, August 11, the study will conclude at approximately 1:00 P.M.

Tuesday, August 7

8:30 A.M. ***Welcome and introductions*** (Eric Barron)

Logistics for the meeting (Joe Friday, Diane Gustafson)

Scope of the workshop (Eric Barron)

The workshop will examine methods of communicating uncertainties in the provision of weather and climate information. The workshop will examine several case studies to illuminate the various issues associated with the proper communication of weather and climate forecasts. The workshop will examine the nature of the forecasts, the methods of determining uncertainties, and the communication of those uncertainties. It will also examine the public reaction and response to the events and explore successes and failures of the communication process.

Science Communications Framework for Environment Canada (Presentation by Richard Anthes)

In 1998 Environment Canada's Science and Technology (S&T) Advisory Board focused on science communications as an area for attention and advice to their Deputy Minister. The Advisory Board initiated a lessons-learned analysis of science communications associated with key environmental issues faced by Environment Canada in the past and used this analysis as input for the development of this science communications framework, which also includes recommendations for future action. A working group co-chaired by two Environment Canada Advisory Board members, Peter Calamai and Richard Anthes, was established to oversee the preparation of this document and to formulate key recommendations for discussion by the S&T Advisory Board.

General Considerations in Communications (Discussion led by Robert Ryan)

Over the past 5 to 10 years weather and weather- and climate related stories have become a leading theme and topic for local, national, cable, and other media news sources. Various media surveys of viewers and listeners show that the number one reason people watch local television news programs (at most times), seek information on the Internet, or listen to radio is to get weather forecasts and information.

6:00 P.M. ***Reception hosted by Bob and Susan Gagosian, Woods Hole Oceanographic Institution, Clark Building, Room 507***

Wednesday, August 8

8:30 A.M. ***Case Study 1: The Spring 1997 Grand Forks and Fargo Floods*** (Discussion led by Lee Anderson and Roger Pielke, Jr.)

This case was one of a flood event predicted well in advance through the spring outlook. The subsequent forecasts issued by the NWS were of record floods, but they were perceived by the emergency managers and the public as being misleading and incorrect. The case will examine what lessons were learned from the event and the changes in communications methods made as a result.

Case Study 2: The March 2001 East Coast Storm (Discussion led by Raymond Ban, Robert Ryan, and James Hoke)

This case was one of a scientifically good forecast of a major East Coast winter storm, predicted well in advance. The communications of the event in the Washington, D.C., area were such that the public expected a major snowstorm in the local area, but it did not materialize. The forecast process lost a considerable amount of credibility as a result. The case examines the actual forecast uncertainty, the communication of that uncertainty to the media, and the relay of that information to the public.

5:00 P.M. ***Reception at the Main House***

Thursday, August 9

8:30 A.M. ***Case Study 3: Climate Change Science: An Analysis of Some Key Questions*** (Discussion led by Eric Barron and Vaughan Turekian)

This case will consider the recently completed NRC report that was requested by the White House to inform them of the state of the science in the area of greenhouse warming. The review will examine the process used in the preparation of the report, the response of the administration to the report, and the characterization of the report by the press and various special interest groups.

Case Study 4: The May 3rd Oklahoma Tornado Outbreak (Discussion led by Howard Bluestein and James Lee)

This case deals with rapidly developing situations that literally saturate the communications mechanisms to the public. The requirement for rapid communication of life-saving information with minimal ambiguity will be explored through this example. What worked well and not so well will be explored.

Friday, August 10

8:30 A.M. ***Case Study 5: The 1997–1998 El Niño*** (Discussion led by Stanley Changnon and James Laver)

This case represents the first major forecast of a significant "climate" event. The development of the seasonal to interannual forecasting capability coincided with the onset of the "climate event of the century." The ability to communicate the meaning of this new forecast information, the implications and impacts of the event, the media, and the public reactions will be examined. Future implications for NWS will be discussed.

Saturday, August 11

8:30 A.M. ***Discussion of common themes and lessons learned***

1:00 P.M. ***Meeting adjourns***

APPENDIX B

Workshop Participants

Lee Anderson	*NOAA/National Weather Service*
Richard Anthes	*University Corporation for Atmospheric Research*
Susan Avery	*CIRES, University of Colorado, Boulder*
Raymond Ban	*The Weather Channel, Inc.*
Eric Barron	*Pennsylvania State University*
Howard Bluestein	*University of Oklahoma*
Stanley Changnon	*Illinois State Water Survey*
Steven Clifford	*NOAA/Environmental Technology Laboratory*
George Frederick	*Vaisala, Inc.*
Elbert (Joe) Friday, Jr.	*National Research Council*
John Gaynor	*NOAA/Office of Atmospheric Research*
Thomas Graziano	*NOAA/National Weather Service*
Richard Greenfield	*American Meteorological Society*
Diane Gustafson	*National Research Council*
James Hoke	*NOAA/National Weather Service*
Thomas Karl	*NOAA/National Climatic Data Center*
Aaron Kawczk	*U.S. Navy/Fleet Numerical Meteorology and Oceanography Center*
William Kearney	*National Research Council*
James Laver	*NOAA/National Weather Service*
Judith Lean	*Naval Research Laboratory*
James Lee	*NOAA/National Weather Service*
Margaret LeMone	*National Center for Atmospheric Research*
Lewis Moore	*U.S. Department of the Interior/Bureau of Reclamation*
Sumant Nigam	*National Science Foundation*

Roger Pielke, Jr.	*National Center for Atmospheric Research*
Michael Prather	*University of California, Irvine*
William Randel	*National Center for Atmospheric Research*
Robert Ryan	*WRC-TV, Washington, D.C.*
Robert Schiffer	*National Aeronautics and Space Administration*
Tony Socci	*U.S. Environmental Protection Agency*
Vaughan Turekian	*National Research Council*
John Weatherly	*U.S. Army/Cold Regions Research and Engineering Laboratory*
Robert Weller	*Woods Hole Oceanographic Institution*

APPENDIX C

Weather Event Timelines

RED RIVER OF THE NORTH FLOOD, GRAND FORKS, 1997

February 13. First Snowmelt Outlook issued using data from the airborne snow survey. The potential for spring flooding was characterized as "Severe," defined as levels at or exceeding the previous flood of record.

February 27. Snowmelt Outlook updated. Outlook called for 47.5 feet with no additional precipitation and 49.0 feet with normal additional precipitation. The 49.0-foot forecast exceeded the existing flood of record that occurred on April 26, 1979 (48.8 feet). Record numerical peak forecasts allowed the USACE (U.S. Army Corps of Engineers) to initiate advanced flood protection measures earlier than would otherwise have been possible.

March 18. Press conference was held in Washington, D.C., presenting the Spring Hydrologic Outlook. The situation for the Red River of the North was described as severe, resulting in "more water than you've ever seen before."

March 30. Flood Warning issued for all NWS river forecast points in the Red River of the North Basin.

April 3. Current stage is at 18.1 feet. Forecast to continue to rise. Outlook with normal precipitation is for 49.0 feet. (Note that river model indicates forecast peak may be well below the outlook peak of 49.0 feet, but forecasters were reluctant to lower the guidance.)

April 5-6. Severe blizzard conditions occur throughout the Red River of the North Basin. One to three inches of precipitation falls. Cold, windy, and snowy conditions hampered data collection and flood-fight activities.

April 12. Current stage is 42.3 feet. Outlook crest is for 49.0 feet beginning fourth week of April.

April 13. Current stage is 42.8 feet. Outlook crest is 49.0 feet. This crest will be very broad, occurring as early as April 19 and extending as late as April 21-22.

April 14. Current stage is 43.7 feet. Crest upped to 50.0 feet for April 19-22.

April 16. Current stage is 47.5 feet. Rise to 49.0 to 49.5 feet by April 17, then slow rise to 50.0 feet April 22-23. USACE field construction personnel alerted to raise emergency flood protection by raising top of the levee to a stage of 54.0 feet.

April 17. Current stage is 50.9 feet. Crest 51.5 to 52.0 feet April 18; April 19. Ice effects in the area appear to be causing fluctuations in the rate of rise.

April 18, 9:00 A.M. Current stage is 52.0 feet. Crest 53.0 feet April 18-19. Numerous levee failures occurred on both sides of the river. USACE reported that all levee breeches and over-toppings appear to have occurred between river stages of 51.6 and 53.0 feet.

April 18, 7:00 P.M. Stage is 52.6 feet. Crest forecasted to be near 54.0 feet late on April 19.

April 19, NOON. Stage is 53.1 feet. Rise to near 54.0 feet over the next few days.

April 21. Estimated stage is 54.0 feet. Near crest; remain near this level for several days.

EAST COAST WINTER STORM, MARCH 2001

February 26, Monday. NCEP models began to show a significant storm for March 4. Local and national media and public and private forecasters began to discuss the potential for a significant storm on March 3-4.

February 28, Wednesday. A Philadelphia weathercaster predicted a possible 16 to 20 inches of snow beginning March 5.

March 1, Thursday. Many East Coast weathercasters now making deterministic forecasts for significant snowfall amounts.

March 2, Friday. Pressure builds from the emergency management community to identify how much snow to expect.

11:00 A.M. NWS/NCEP conference call discussing the forecast.

4:00 P.M. NWS press release indicating the potential for a significant storm with blizzard conditions.

6:00 P.M. National news media carry the story of a paralyzing East Coast storm.

March 3, Saturday. NOAA press conference highlights the historic nature of upcoming storm. Winter storm watches issued for all of the mid-Atlantic region. Winter storm warnings issued for Philadelphia north.

March 4, Sunday. Storm became well organized with most of the mid-Atlantic region receiving rain only.

March 5, Monday. Heavy snows fell in the interior and most of New England.

OKLAHOMA-KANSAS TORNADO OUTBREAK, MAY 3, 1999

(All times in Central Daylight Time)

May 2
12:04 P.M. Slight risk of severe storms issued for all of Oklahoma for May 3.

May 3
2:55 A.M. Slight risk of severe storms late this afternoon and tonight issued for most of Oklahoma.

6:30 A.M. Slight risk of severe storms issued for this afternoon and tonight; isolated tornadoes possible.

11:15 A.M. Part of the Slight-risk area upgraded to Moderate risk.

3:49 P.M. Western/central Oklahoma portion of the Moderate risk area upgraded to High risk.

4:47 P.M. First tornado warning of the event issued for Comanche and Caddo counties.

4:51 P.M. Spotters in Comanche County report first tornado of this event (near Interstate 44).

5:41 P.M. Oklahoma City metropolitan area identified as having a potential for tornadoes to move into the area that evening.

6:57 P.M. NWS issued the following statement: ". . . Tornado Emergency in South Oklahoma City Metro Area . . ." Predicts large damaging tornado will enter southwest metro area between 7:15 and 7:30 P.M. "Persons in Moore and south Oklahoma City should take immediate tornado precautions!"

7:11 P.M. First tornado in Cleveland County (immediately south of Oklahoma City). Tornado crossed South Canadian River near S.W. 149th Street.

7:17 P.M. First tornado warning was issued for Oklahoma County valid through 8:00 P.M.

7:25 P.M. Tornado moved through Moore (south of Oklahoma City).

7:30 P.M. First tornado in Oklahoma County (entered southern part of county east of Interstate 35).

7:31 P.M. NWS issued the following statement: ". . . Large Damaging Tornado Moving Through Oklahoma City Metro . . ." Also states, "Persons in southeast Oklahoma City and Midwest City are in danger!"

7:34 P.M. Tornado near Tinker Air Force Base (Midwest City).