A POLICY FORUM: IMPROVING RESPONSES TO CLIMATE PREDICTIONS

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ATMOSPHERIC POLICY PROGRAM
AMERICAN METEOROLOGICAL SOCIETY

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Panel 2

Progress In The Development Of Decisions On Regional And Sub-Regional Strategies To Respond To Information On Seasonal Variations In Climate

POSITION PAPERS

Assessment Of Issues Related To Usage Of Climate Predictions In The U.S. Agribusiness And Utility Industry

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Overview:

For the past 20+ years, we have been involved in a series of studies assessing usage of climate predictions in agribusinesses, electric-gas utilities, and water resource management. We pursued these studies with funding from NSF, NOAA, and the private sector, and we sought to establish values of usage, reasons for usage and non-usage, and activities needed to improve usage. Many of these findings have been published in the refereed scientific literature, and repeated assessments over time have allowed us to measure change in the usage and the reasons for changes. We also have served as consultants to individual firms and focused on climate predictions. Today, we will present key findings derived from our assessments of usage in agribusiness and utilities, which are among the nation's most weather-sensitive industries, and conclude with answers to the four focus questions posed for this panel.

In most instances data collection was done through extensive interviews done with company staff having weather-sensitive responsibilities including planning, shipping, operations, and maintenance. The agriculture sampling included eight sectors of companies (seed firms, insurance, food producers, chemical producers, etc.), and the utility sampling included electric and natural gas utilities with staff involved in load forecasting, power trading, fuel acquisition, system maintenance, and daily-monthly operational planning. Other projects and consulting endeavors involved close interactions with company staff over a period of time, often coupled with product development.

Major Findings: Agribusiness

Six studies concerning the use of seasonal climate forecasts in agribusinesses have been conducted over the past 23 years. The results reveal a temporal increase in the amount of usage, improved value of their usage, and a greater understanding among users as to how to employ forecasts in specific decisions.

The major factors identified as improving usage and the value of use are listed in Table1. Major improvements in the formats of forecasts made by CPC in January 1995 were an important factor. The highly successful El Niño based forecasts of 1997-1998 that engendered huge national media attention was another factor enhancing usage. Forecasts based on El Niño and La Niña conditions bring a new dimension of skill and opportunity for use of forecasts. The development of new technologies, and new public institutions and private firms providing climate services have made accessing forecasts and expertise much easier in 2001 than in 1981. The search for information to provide corporate advantages in the highly competitive world of agribusiness has also led more firms to use forecasts more often.

Table 1. Major factors affecting the growth of the use of climate forecasts in agriculture.

- National economic growth and increasing international competition creating pressures within weather-sensitive industries to use forecasts
- Rapid improvements in the ease of accessing climate data, information, and expertise.
- Improvements in accuracy of climate forecasts
- Improved formats and allied information in forecasts
- Increasing number of atmospheric scientists employed within agribusinesses

However, recent studies show there is still considerable potential for improving usage. Many agricultural firms do not have a useful measure to determine the potential value from using uncertain climate forecast information, as revealed by two decision experiments we conducted. Many firms lack decision-oriented economic models that assess the use of probabilistic weather information. There are also ways that climate forecasts can be improved by furnishing additional information based on analysis of historical information. The failed spring 2000 drought forecast for the Midwest represents a setback in usage in that region. *Credibility in the value of climate forecasts is hard to develop but easy to lose.*

Another factor limiting use for many is the major gap between the types of climate-related information that are being provided by the government and what is needed by many in the private agricultural sectors. One could argue that this gap could be filled by private companies involved in weather and climate forecasting. One reason for the gap is the limited knowledge of weather and climate in many middle and upper level managers in agribusiness, and hence, they remain uncertain about employing such information in their decisions. Providing a near perfect forecast does not guarantee wise or beneficial usage, and educational interactions between user and potential provider are needed.

Major Findings: Utilities

Sampling of 56 weather-sensitive decision makers in power utilities during 1993 revealed only 3 (7%) used forecasts. A second sampling study in 1996 found usage had grown to 35% and the primary reasons were 1) de-regulation/merger economic pressures, and 2) improved forecast formats from CPC. Users reported nominal values from usage, ranging from $20,000 to $100,000 per year. Several users of the accurate 1997-98 winter forecasts issued based on El Niño made large economic gains for their firms, and widespread awareness of these gains affected future usage, now estimated as 50% of all U.S. firms. Utility usage of predictions remains less than in the agribusiness sector. Reasons for continued non-usage of seasonal forecasts by utility decision makers are generally similar to those found in agribusiness and include 1) lack of an appropriate decision model that can integrate and assess uncertain climate information, 2) the potential *losses* resulting from climate-related decisions are too great, and 3) confusion associated with differing forecasts put out by multiple forecasting groups.

Summary:

Successful use of climate forecasts is a two-way street involving both the producer of the forecast and the user of the forecast. They must interact and understand each other to achieve successful usage. Assessment of agribusiness and utility users reveal 60% get products from private meteorological firms, and 25% have in-house expertise.

The two agribusiness decision experiments conducted in recent years concerning use of climate forecasts at existing accuracy levels of forecasts (50% to 60%, as opposed to 33% by chance) revealed that what is available can provide sizable benefits, particularly to firms that make decisions involving hedging around weather variations. Users have estimated economic benefits of moderate levels, but most lack any real measure of value.

Many limitations to usage have been cited, but most can be eliminated by the actions listed in Table 2.

Table 2. Actions needed to enhance usage and benefits in agriculture and utilities.

- Private weather-sensitive firms need to use or develop decision models that assess the value of probabilistic weather information.
- Forecasts need to include information, often of a statistical climatological nature, related to the forecast conditions.
- The government should improve educational outreach, working in concert with private forecast firms, to illustrate successes from usage. Testimony by users with benefits is essential.
- Successful usage is a two-way street involving interactions between the user and provider of the forecast, and the role of the private forecast sector is key in order to provide company-specific information.

Focus Questions:

<u>Question One.</u>

Decision makers in agribusiness and utilities are keenly aware of the influence of weather on their sectors. However, when questioned, many are unaware of how variable seasonal climate is in their particular region of the country. Many agribusiness decision makers will remember certain weather or climate events such as the Midwest U.S. drought of 1988 or the flood of 1993. However, when asked to describe the range in climate parameters (e.g. seasonal average temperatures or total precipitation) for a particular place many don't have the climate information to answer. When utility officials are asked to describe a 'cold' winter in their region many will recall a recent winter they perceive was 'colder than average.' However, when those data are examined, their perception is often incorrect. Many weather-sensitive decision makers interviewed who do not use climate predictions base their decisions on weather conditions of the last year or the average of the past two to five years.

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

Question Two.

Usage of seasonal climate forecasts is greatly limited by a misperception of “accuracy” by decision makers. The fact that seasonal forecasts will always carry some amount of uncertainty is important for the provider and user groups to understand. This uncertainty must be communicated to the decision makers in a way that they understand. For example, a greater probability of a warmer winter does not mean a cold winter can’t occur. Beyond obtaining probabilistic forecast information, many users would like to understand whether the computed probabilities are related to the forecaster’s confidence in a specific forecast (e.g. warmer or colder than average). Uncertainty measures that have been identified in our studies and need to be clearly stated to decision makers and the public include:

- Probabilities of <u>all</u> levels of the condition (above, near, and below average)
- Confidence level of forecaster in the forecast (high, moderate, or low)
- Correctness (accuracy) of recent forecasts (track record)
- Conditional relationships of outcomes based on similar historical conditions
- General physical reason behind the forecast

Many users want to understand what a specific seasonal forecast is based on (e.g. ENSO phase, other teleconnections, etc.). Furthermore, they are interested in the recent (last five years) track record of the forecast group when making a seasonal (e.g. winter temperature) forecast for a location such as Chicago. In other words, how frequently have the forecasts been reasonably correct (forecast warmer than average and verified warm) and incorrect (forecast warm and verified colder than average). These issues not only get to the accuracy issues facing many decision makers but also help them understand the uncertainty that comes with this decision tool. Much of the information users want is qualitative in nature and their decisions are often based on their perception. It is important that the provider of seasonal forecasts understand the limitations under which the user works.

For long-term use it is essential that users have decision models that can incorporate probabilistic forecasts. Some firms have decision models that can incorporate uncertain climate information and forecasts. However, the decision “process” that users work under is complex and dynamic (always in flux), and often non climate factors such as trends in the unit cost of natural gas or the price of corn may be much more important in a decision to “buy” or “sell” than the future climate. Furthermore, decisions made by decision makers in the Midwest are influenced by what is going on across the rest of the country, if not the world, both in terms of climate and non climate factors. It appears that the most important key to increased usage is the ability for users to integrate climate information when needed, and have available economic models that can provide a range of outcomes based on different seasonal climate scenarios.

<u>Question Three.</u>

Currently, the Climate Prediction Center of the National Weather Service prepares and disseminates seasonal climate outlooks for three-month periods out to a year. These outlooks incorporate probabilistic information and a great deal of information explaining these probabilistic values. In most cases, users understand these probabilities. Unfortunately, those in the atmospheric sciences who are asked to interpret these probabilities for the media often are misquoted, which can alter how "uncertain" the forecast is viewed and lead to potential confusion for the user. The providers, media, and users need to be educated on how to convey and use probabilistic forecasts. For example, the spring 2000 drought forecast presented by government officials never included any discussion of uncertainty, which led to decision makers in agribusiness and the general public to view that the drought would occur when in reality it didn't.

We feel that the CPC forecasts are as detailed as generalized national-regional climate forecasts can and should be. However, in most instances, the information needs of decision makers in agribusiness or utilities is much greater than CPC provides. The added information needed must be developed either by corporate atmospheric staff or by private climate firms.

<u>Question Four.</u>

The forecast providers and users must meet regularly and develop an understanding of the needs and potential products. Although many applied atmospheric scientists in the United States are working toward this collaborative activity, successes in wise use of climate forecasts is limited.

Should developing countries strive to use the U.S. model that has yet to show significant success? We suggest that developing countries begin the process with joint meetings between users (utilities, agribusiness, and water resources) and government, academic, and private sector climatologists where discussions can identify where and how users can integrate available climate information and forecasts into specific weather-related planning and operational activities. One model would have the government set aside funding so that climatologists can work directly with users to develop useful decision models. These tools should be operated under different climate scenarios so that the users can understand the direct economic value from using climate information. This partnership, where outreach and education can continue in an ongoing fashion, would seem to be the best way to develop a successful transfer of climate knowledge into weather-sensitive decisions.

Connecting Water Management and Climate Information

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1. How do decision makers at present manage responses to climate variability?

There is a broad range of potential responses to climate variability, depending on the decision-making context, the type of decision-maker, the scale of the decision, the magnitude of the perceived threat, etc. (In other words, this question is a bit too general). Most managers respond to relatively short-term forecasts (weather reports) and are skeptical of the accuracy of longer-term projections. However, there have been some documented cases in which longer-term forecasts, particularly those associated with El Nino, have been used by a wide variety of decision makers, including water managers and emergency managers. The responses of utility managers, water managers and emergency managers in California to the 1998-99 El Nino are a good example.

Many water managers are unaware of the trends that have developed over the past century, and are operating under the assumption that the climate regime is stationary. Use of historical data to develop operating procedures without assessing trends or looking at new information on longer-term records of flooding and drought is the norm in surface water management. It is difficult to introduce new information paradigms and forecasting techniques in the context of water management, though progress is being made.

2. What climate prediction uncertainty measures are critical to response decision makers in the US?

Again, the measures that are "critical" in one region, application or geographic scale may have little relevance in other contexts, so this question is a bit difficult to respond to. Most managers are much more concerned with responding to extreme events than to longer term trends. However, in the longer term, responding to long-term changing conditions (such as sea level rise or rise in ET due to temperature increases) may be more expensive and politically difficult.

In order to provide some more specific response to the question, I will assume the decision maker is a water manager. Sources of uncertainty include regulatory uncertainty (such as the recent concerns of the Salt River Project about the Southwestern Willow Flycatcher moving into a major reservoir area when it was dry, resulting in the potential for an ESA violation for filling the reservoir); inability to predict regional implications of climate trends (the scale of the forecasts is not the same as the scale of the decision); and not knowing the degree of accuracy of forecasts. Inability of forecasts to take into account topographic changes is of particular concern in the southwest. Snowpack extent, snow water equivalent and forecasts of melt times are main inputs to the reservoir management process. Because some water management operations are more sophisticated and large-scale, they have access to highly trained specialists who can help them integrate climate information into reservoir management decisions. But for smaller entities, a large source of uncertainty comes from lack of access to information, inability to find information that is relevant to their specific application, and lack of knowledge about how to use new kinds of information.

There are also uncertainties on the interpretive side, since many researchers may not understand the context of decision-making and understand what motivates particular responses to information. For example, researchers at the University of Arizona have found that a key uncertainty for water managers who depend on groundwater is predicting lighting strikes, since that commonly will result in pump outages.

3. How well is the information on the probabilistic nature of climate forecasts and uncertainties communicated to response decision makers and the general public?

The perception of uncertainty is probably the most important impediment to the use of climate information. Probabilistic forecasts are not currently communicated well, many potential users are not getting the correct message from the "% difference from normal" approach. Better ways of communicating than those developed by CPC need to be developed. The IRI ENSO Quick Look is a good example of an approach that communicates well to decision-makers, who want easily accessed, concise, value-added information without having to do a lot of interpretation themselves. Providing a verbal explanation of a graphic, as well as a key, on the same page as the graphic could result in much-improved utility for decision makers.

Multiple researchers have shown that uncertainty in and of itself should not be a reason not to use information—in any case, virtually all decisions are made in the context of uncertainty. The issue of communication of climate forecasts has been extensively evaluated by Hartmann and Pagano, et. al. (BAMS Volume 83, No. 5). They found that there are multiple ways of improving communication of uncertainty, and that uncertain information can be used effectively by decision makers if they understand the nature and sources of the uncertainty. It has also been shown that effective communication of uncertainty also increases the credibility of forecasts. Ways to improve communication of climate information are currently being tested through the EndInsight program of CLIMAS (funded by NOAA at the University of Arizona).

Problems may also arise due to political and economic forces; for example, when subsidies and assistance levels are tied to particular drought triggers, there may be pressure to use climate forecasts and other information in inappropriate ways (eg, over-interpret what is actually presented), or even to influence the making of forecast to include/exclude areas important to particular constituents or interests."

4. In what ways can the experience be utilized in developing countries?

Acknowledging the importance of the context of decision-making, improving the credibility of information through appropriate and clearly articulated discussions of the uncertainty and encouraging the appropriate use of information in the context of uncertainty seem entirely transferable to developing countries. However, the key in most developing countries is capacity building to enable use of new sources of data and predictive tools in the local and regional context.

(These responses were prepared with the assistance of Barbara Morehouse and Greg Garfin of the CLIMAS project at the University of Arizona).

Water Resource Management

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No paper submitted at time of printing.

IMPROVING DECISION SUPPORT TOOLS FOR EMERGENCY MANAGEMENT AS RELATED TO WEATHER

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Each year, U.S. industry suffers approximately $34.5 billion in losses related to severe weather. The key industrial sectors affected are agriculture, commercial aviation, construction, communications, electric utilities, manufacturing, and transportation. A study funded by the National Weather Service (NWS) Modernization Program has determined that $14.5 billion of those losses could have been prevented if emergency response managers, operations managers, disaster mitigation teams, and other key decision-makers had tools in place to accurately determine and forecast the effects of severe weather on their specific assets or geographic areas of responsibility.

Every year, inclement or severe weather dramatically affects both government and industry, causing a tremendous amount of damage to both lives and property. Because weather prediction is an inexact science, determining the impact of weather on lives, property, and business is always a challenge.

With over 25 years in the Emergency Management business I was delighted to serve on the U.S. National Weather Service (NWS) Modernization Transition Committee. NWS modernized its technology by integrating data from multiple sources, including weather satellites, Doppler radar, surface observations, and sophisticated map-based computer modeling techniques. This modernization provided improved weather forecasts and more accurate and timely warnings to support management, command, and control personnel. However, improving forecasts is only half the battle. Personnel responsible for predicting the impact of weather on critical assets-such as roads, bridges, generators, substations, emergency response teams, utility work crews, etc.- need to base their critical decisions on more than a forecast.

Shortly after the NWS modernization one of the highlights was the creation of the WCM (Warning Coordination Meteorologist) position that worked directly with the local emergency manager to assist in translating and understanding the warning message. With existing technology, decision-makers must assimilate forecast data and "mentally" superimpose it on their maps, assets, or GIS infrastructure data. With the weather data that is currently available - television-based weather channel information - provides a much broader picture than is helpful in evaluating how specific assets will be affected by current or impending weather. For precise and timely analysis and subsequent decisions, WMC’s understand that decision-makers need a much smaller view of their world, a view made possible by a system that alerts them to conditions that are about to invade a specific, predetermined "buffer zone" around particular assets. To complete the decision process, personnel must be notified and mitigation activities must be triggered.

The Future of Weather-related Decision Support

The Advanced Weather Interactive Processing System (AWIPS), a network of 2,500 computers located at 135 geographic locations throughout the 50 states, Puerto Rico, and Guam. High-resolution weather data is incorporated from the GOES weather satellites, NEXRAD Doppler radar, NCEP super-computer forecast models, and ASOS surface observations all combine to offer exciting opportunities for the future of weather related decision support tools.

These tools partnering with the many value added private sector partners can generate accurate and timely reports and alerts for a wide range of weather events that impact operations. Reports such as, lightning strikes; extreme temperature; high winds; heavy rains and flash floods; severe thunderstorms; snow, sleet, hail, and ice; and other critical weather conditions.

Mid- and long-term forecast data, gridded weather data models, as well as complete 3D visualization and simulation which are capabilities critical for mission planning and rehearsal are also exciting opportunities for the future. In the monitoring phase, users define which weather events are monitored and what actions are triggered by the occurrence of a weather event that meets the specified criteria. Decision-makers define an area of interest for the weather event. This might be a county, a rectangular area that spans all assets of interest, or a buffer zone around a particular asset, for example, a three-mile buffer around an airport refueling zone. The weather criteria are then set for the selected area of interest. This involves specifying the type of weather event (such as issued warnings or weather observations, or the occurrence of lightning) and configuring the criteria for that event type. Examples of weather event criteria include:

- Severe thunderstorm warnings
- Flash flood watches
- Temperatures less than 32 degrees Fahrenheit and winds greater than 20 mph from the northwest with freezing rain.

Users also specify the notifications that could occur when an event meets the criteria. With the current high use of PDA’s, pagers, cell phones, etc., this could also include such actions as paging a supervisor, faxing the field office, or e-mailing the dispatchers. Users also specify the notifications that should occur when an event meets the criteria.

During the preparation phase of the decision support cycle, the decision-maker can use the GIS data to help determine the best response to prepare for the weather event.

Standard GIS analysis tools can also support the assessment and restoration phases of the cycle by allowing weather-specific data to be combined with GIS information. The combination of a data window and the GIS data originally used allows quick capture of information related to the extent of the damage. Of course, throughout the other phases of the cycle, monitoring the defined weather events continues so that additional weather impact can also be mitigated.

During the 1997 El Nino many state and local emergency preparedness organizations were able to incorporate activities in all phases of emergency management because of getting the right information at the right time.

Additional actions Completed for Emergency Preparedness:

The Governor's Office of Emergency Services (OES) and local emergency management agencies conducted Alerting and Warning workshops to ensure that emergency information is conveyed to the public in a timely and effective manner.

Developed Evacuation Guidelines that identify authorities and responsibilities for flood evacuations that will assist local governments in emergency response.

Conducted flood awareness and preparedness workshops throughout the communities with levee maintaining agencies and local governments.

OES expanded the Response Information Management System (RIMS). OES has connected 15 State agencies, 52 counties, FEMA Region IX, the American Red Cross HQ in Long Beach and the United States Coast Guard HQ in Alameda. This tool was the predecessor to the web-based tools used today.

OES is continuing to improve its ability to deploy Geographic Information System (GIS) teams to support incident command posts and many jurisdictions, including, Los Angeles have incorporated GIS in the planning/preparedness as well as the response phase of the program.

We are all looking to developing written guidance that identifies emergency response and recovery costs that are generally reimbursable and marring this with the current emergency information management tools that we currently use.

Other agencies that we work with on a daily basis contributed to the effort of the 1997 El Nino.

CalTrans cleaned more than 30,000 storm drains statewide and completed more than $200 million repairing storm damage from the winter of 1996/1997.

CalTrans, in conjunction with the Department of Conservation, identified potential slide locations on Route 50. Forty locations were identified for stabilization of slide material, armoring of the riverbank, replacement and upgrading of drainage facilities and roadway paving.

CalTrans installed slide-monitoring equipment at potential slide locations. Response protocol for landslide activity was established through a 24-hour dispatch location.

CalTrans coordinated with county Office of Emergency Service (OES) offices and other emergency service providers to provide emergency response to floods and slides, and the department updated its emergency response plans internally and with local response agencies.

Cal Trans, in conjunction with the California Highway Patrol and OES, developed communications and decision- making protocols in the event that parts of the state highway system are closed or used to manage a storm-related emergency.

The Public Utilities Commission (PUC) required and reviewed emergency plans for electric and water utilities, covering internal and external communications, use of utility-wide resources, mutual aid agreements with other utilities and consumer and press information centers. Without the partnership with NWS these activities would have preceded much slower.

The PUC tightened tree-trimming requirements, to minimize outages due to contact between trees and electric transmission lines and established standards for inspection, record-keeping, and repair of electric utility distribution systems, to assure that they are well-maintained and ready for severe weather.

DIMENSIONS OF UNCERTAINTY

Recent advances in the conceptualization and the measurement of uncertainty clearly demonstrate that, despite the predominance of the probabilistic interpretation of uncertainty, uncertainty should be understood as a multi-dimensional concept. Depending on the mathematical framework employed, uncertainty may be measured in terms of one or more of the five complementary characteristics (Figure below):

- Entropy (conflict),
- Dissonance (pure conflict),
- Confusion (pure and potential conflict),
- Nonspecificity (lack of informativness), and
- Fuzziness (vagueness).

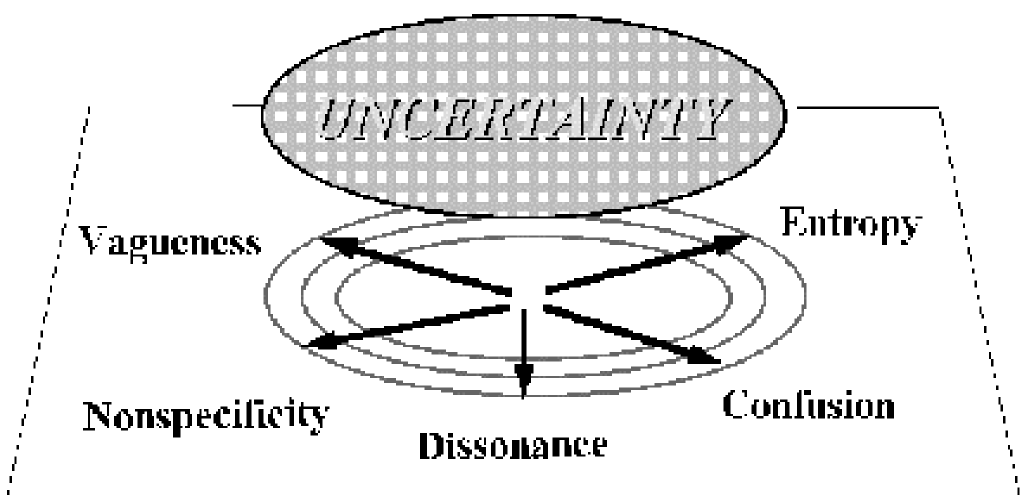

Figure: Dimensions of uncertainty

These dimensions of uncertainty are often complicated by the systems or lack thereof of systems to receive information and then disseminate it. Many Emergency Management agencies are still wrestling with the incorporation of the appropriate tools to support decision making.

Americans live in the most severe weather-prone country on Earth. Each year, we cope with an average of 10,000 thunderstorms, 2,500 floods, 1,000 tornadoes, as well as an average of 6 deadly hurricanes. Potentially deadly weather impacts every American. Communities can now rely on the National Weather Service's StormReady program to help them guard against the ravages of Mother Nature.

Some 90% of all presidentially declared disasters are weather related, leading to around 500 deaths per year and nearly $14 billion in damage. StormReady, a program started in 1999 in Tulsa, OK, helps arm America's communities with the communication and safety skills needed to save lives and property– before and during the event. StormReady helps community leaders and emergency managers strengthen local safety programs.

With some of the proposed legislation being introduced by the 108th congress there will certainly be opportunities to enhance the existing relationships and tools as assure we take advantage of current technologies. Legislation such as S. 118, to develop and coordinate a national emergency warning system will do a lot to address some of the issues related to decision making.

The truth is that even with the considerable progress in atmospheric science there remains considerable room for improvement in the accuracy of public warning. But even if we had perfect knowledge of the process of weather disturbances inadequate atmospheric sampling and measurements would still prevent warning accuracy from ever reaching 100 percent.

Stewart (2000) states the problem succinctly:

> Every prediction contains an element of irreducible uncertainty… actions that are based on predictions leads to two kinds of errors. One is when and event that is predicted does not occur, i.e., a false alarm. The second is when an event occurs but is not predicted, i.e., a surprise. There is an inevitable tradeoff between the two kinds of errors; steps taken to reduce one will increase the other.

There has been substantial progress in public severe storm warnings since the 1950's. The Critical Success Index (AMS, 2000) is used as a combined measurement of the accuracy of storm warnings and includes both surprises and false alarms as defined above.