3.3 ASSESSING HOW THE U.S. PUBLIC UNDERSTANDS AND USES WEATHER FORECAST UNCERTAINTY INFORMATION

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1. INTRODUCTION AND MOTIVATION

In the past few years, there has been increasing attention within the meteorological community to providing uncertainty information in weather forecasts. For example, in 2002, the American Meteorological Society (AMS) adopted a statement endorsing probability forecasts and recommending that their use be substantially increased (AMS, 2002). Shortly thereafter, the National Research Council (NRC) released a workshop summary that draws several lessons learned from case studies, among them that understanding, communicating, and explaining uncertainty should be an integral and ongoing part of forecasting for conveying accurate and useful information (NRC, 2003). Recently, the NRC completed a study commissioned by the National Weather Service (NWS) that takes a wide-ranging look at estimating and communicating uncertainty information in hydrometeorological[1] forecasts and characterizing users' needs for uncertainty-explicit forecasts (NRC, 2006).

This growing interest is not surprising given the inherent nonlinearity and complexity of the atmosphere, which makes uncertainty an inevitable part of prediction. An often cited reason for providing forecast uncertainty information is the potential benefit to forecast users (c.f., NRC, 1999; AMS, 2002; Mass, 2003; Ryan, 2003; NRC, 2006). Although the meteorological community has a wealth of information about forecast uncertainty available, it currently provides users with primarily deterministic forecast information. Creating and disseminating forecast products that effectively communicate uncertainty could help users make better decisions based on their own circumstances and thresholds for action, resulting in socio-economic benefits. Moreover, Pielke and Carbone (2002) discuss the weather forecast process as consisting of three parallel subprocesses—prediction, dissemination, and use in decision-making. They stress that the common task of the weather forecast process should be viewed as producing good decisions. Although not explicitly called for by Pielke and Carbone, uncertainty-explicit forecasts can play a role in improving this process. Additional reasons for providing weather forecast uncertainty information are to establish and retain user confidence and to avoid misrepresenting the capabilities of weather prediction science.

The confluence of several factors make now an opportune time for a paradigm shift to make uncertainty information an integral and essential component of weather forecasts (c.f., Mass, 2003; Ryan, 2003; NRC, 2006). Among these factors are the meteorological community's increased ability to produce uncertainty guidance, improved public-private-academic sector partnerships within the meteorological community, which are critical to effectively communicating with a broad range of users, and enhanced digital capabilities.

Moving toward this new paradigm will require a solid foundation of research supporting the effective incorporation of uncertainty information into weather forecasts. However, there are many unanswered questions, among them what forecast uncertainty information different types of users need and can use, how users interpret different types of forecast uncertainty information, and how this knowledge can be applied to more effectively communicate forecast uncertainty.

This study takes a step toward answering some of these questions by surveying the U.S. public to assess people's understanding of, uses of, and preferences for weather forecast uncertainty information.

2. RELATED WORK

To provide some context for this study, a few related studies from within and outside the field of meteorology are discussed below.

2.1 *In Meteorology*

One area of weather forecasting in which people's understanding and use of forecast uncertainty information has been assessed is probability of precipitation (PoP) forecasts. PoP is one of the only uncertainty-explicit forecast products that is routinely provided to the public, and it has been provided regularly in the United States since 1965.

Fifteen years after mainstream provision of PoP began, Murphy et al., (1980) surveyed a voluntary-response sample of 79 people to assess the U.S.

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[1] Per the NRC (2006) report, hydrometeorological refers to the combined fields of meteorology and hydrology from the short time scales of weather prediction to inter-seasonal climate forecasting.

public's understanding of and preferences for it. They concluded that most people understand probabilities well, want precipitation information conveyed probabilistically, and prefer receiving numerical expressions of probability to verbal (i.e., non-numerical) information. However, they also concluded that people have difficulty understanding the event of concern in PoP forecasts, in that they confuse area forecasts with point forecasts. More recently, Gigerenzer et al. (2005) extended Murphy et al.'s work by surveying a convenience sample of 750 people in five cities (New York, Amsterdam, Berlin, Milan, and Athens) in five different countries to assess their understanding and use of PoP forecasts. Their results showed that only in New York did a majority of residents select the correct interpretation of PoP from a close-ended question. Gigerenzer et al. ultimately concluded that the reference class to which a single-event probability refers should be specified to reduce confusion associated with uncertainty-explicit forecasts.

Employing a different methodology, Roulston et al. (2006) evaluated how well people can effectively utilize uncertainty information to make decisions that increase their expected rewards and reduce risk. They used an experimental economics approach and a simple hypothetical cost-loss problem. Subjects were divided into three groups, each of which received temperature forecasts with different levels of uncertainty information, and they had to make decisions based on the possibility of the temperature falling below freezing. Roulston et al. found that, compared to subjects who did not have uncertainty information, subjects who were provided with uncertainty information increased their expected profits while decreasing their risk.

In addition to addressing general questions related to the public's understanding of, use of, and preference for uncertainty forecast information, the study discussed here follows up on the Murphy et al., Gigerenzer et al., and Roulston et al. studies by asking similar questions with a larger sample of the U.S. public.

2.2 *In Other Fields*

There is broad literature on the understanding and use of uncertainty information from other fields—such as decision science, economics, finance, medicine, hazards, psychology, and risk communication—that is relevant to uncertainty in weather forecasting. For example, Hanoch (2004) proposes that when uncertainty information is communicated as relative frequencies instead of probabilities, both doctors and patients better understand the information, thereby improving their use of the information.

Another example is the issue of trust and the building of relationships through explicit expression of uncertainty. Although Quill and Suchman (1993) acknowledge that sharing uncertainty information initially may decrease user satisfaction, they propose that eventually it will establish realistic expectations, honesty, and collaboration between the provider and receiver of information.

The research that has been conducted in meteorology and the findings from other fields provide a good foundation for future work on uncertainty information in weather forecasts.

3. RESEARCH SCOPE AND METHODS

The goal of this study is to investigate the myriad of views people have about weather forecast uncertainty information. This research can be used to guide future provision of uncertainty-explicit weather forecast information. To do this, a web-based survey of the U.S. public is being developed and implemented.

3.1 *Some Research Questions*

The survey is shaped around several overarching research questions to elicit people's thoughts and opinions about weather forecast uncertainty information.

One overarching question is how people currently *perceive* uncertainty in weather forecasts. Recent work (e.g., NRC, 2006; Roulston et al., 2006) suggests that most people are aware that deterministic forecasts are not perfectly accurate and that people have adjusted their decision-making accordingly. To what extent is it true that people infer uncertainty when provided with deterministic weather forecasts? Related to this, how much confidence do people have in weather forecasts in general and in specific weather elements at various lead times?

A second broad research question is how people *interpret* weather forecast uncertainty information. For instance, does the finding from Gigerenzer et al. (2005) that a majority of New York residents understand the correct definition of PoP hold true for larger, nationwide samples? Moreover, how will this compare with their overall finding that people have difficulty understanding the reference class related to probabilistic precipitation forecasts? Following on from Murphy et al. (1980), does giving weather forecast uncertainty information numerically versus non-numerically affect people's understanding of the information?

A third overarching question is how people *use* weather forecasts that include uncertainty information. Similar to Roulston et al. (2006), how well are people able to use forecast uncertainty information in decision-making scenarios? Moreover, how does this change with the mode in which the uncertainty information is presented?

The final overarching research question is whether and how people *prefer* to receive weather forecast uncertainty information. First of all, do people prefer deterministic or uncertainty-explicit information? In what modes (e.g., probabilities, relative frequencies, odds, non-numerical text, forecaster confidence) do people prefer to receive uncertainty information? Are people interested in knowing why weather forecast information is uncertain?

These questions will provide insight into the range of people's attitudes related to weather forecast uncertainty information and likely will have practical

implications for National Weather Service, private weather sector, and broadcast meteorology products.

3.2 *Summary of Survey Questions*

The survey includes questions grouped into six main areas. The first two areas of the survey are included to obtain general knowledge on people's consumption of weather forecast information and its relevance to them. The first area focuses on people's sources of, uses of, and preferences for weather forecast information. It includes questions about from where people get weather forecast information, how often they get it, for what cities and areas they get it, how they use it, and how important it is to them to have information on various weather parameters (e.g., amount and type, precipitation timing, high/low temperature, wind speed and direction). The second area builds on work done by Stewart (2005) to assess the extent to which people find weather and climate to be salient to their lives. Questions from these two areas will provide information that is valuable in and of itself and that can help interpret responses to the questions relating to communication of uncertainty in weather forecasts.

The third and fourth areas focus specifically on weather forecast uncertainty information. The specific questions are framed around the research questions discussed above with a focus on temperature and precipitation forecasts. Among them are questions to assess people's (a) inference of uncertainty in a deterministic temperature forecast and confidence in weather forecasts, (b) interpretations of probabilistic precipitation forecasts, (c) preferences for receiving precipitation and temperature uncertainty information and in what formats, and (d) use of precipitation and temperature uncertainty information to make decisions based on hypothetical cost-loss scenarios.

The fifth area of the survey, which follows up on previous work by Lazo and Chestnut (2002), includes questions to elicit the value of weather forecast information to members of the U.S. public. The sixth area of the survey includes questions to gauge the effects of weather on people based on their work and leisure time spent outdoors and any property damages, injuries, health effects, and anxiety they have experienced due to weather. These questions, as well as demographic information, will be used to better understand variations in people's understanding of, use of, and preferences for weather forecast information and uncertainty information.

3.3 *Survey Implementation*

As indicated above, the survey questions were framed based on broad research questions and to expand on previous work. The questions were honed through informal feedback with colleagues and formal feedback via one-on-one verbal protocol (i.e., think aloud) analyses. Pretesting the survey in these ways provided input about the clarity and content of the questions.

The survey is being implemented to the U.S. public via the Internet with a target completed sample of 1200 respondents. Using the Internet as the implementation medium means that some coverage error is inevitable; nevertheless, this exploratory survey likely will generate new research ideas and provide interesting results for comparative analyses with previous work. The survey data will be collected in mid-November, and data analysis will commence thereafter.

4. SUMMARY

A national, web-based survey is being implemented to assess people's understanding of, uses of, and preferences for weather forecast uncertainty information. Because this work is exploratory and is expected to raise additional questions, this survey is the first in what likely will be a series of studies on the provision of uncertainty-explicit information in weather forecasts.

5. REFERENCES

AMS (American Meteorological Society), 2002: Enhancing weather information with probability forecasts. *Bull. Amer. Meteor. Soc.*, 83, 450-452.

Gigerenzer, G., R. Hertwig, E. van den Broek, B. Fasolo, and K. V. Katsikopoulos, 2005: A 30% chance of rain tomorrow: How does the public understand probabilistic weather forecasts? *Risk Analysis*, 25, 623-629.

Hanoch, Y., 2004: Improving doctor-patient understanding of probability in communicating cancer-screening test findings. *J. Health Comm.,* 9, 327-355.

Lazo, J. K. and L. G. Chestnut, 2002: Economic value of current and improved weather forecasts in the U.S. household sector. Report to NOAA, 213 pp.

Mass, C. F., 2003: IFPS and the future of the National Weather Service. *Wea. Forecast.,* 18, 75-79.

Murphy, A. H., S. Lichtenstein, B. Fischoff, and R. L. Winkler, 1980: Misinterpretations of precipitation probability forecasts. *Bull. Amer. Meteor. Soc.*, 61, 695-701.

NRC (National Research Council), 1999: *A Vision for the National Weather Service: Road Map for the Future*. National Academy Press, 88 pp.

NRC, 2003: *Communication Uncertainties in Weather and Climate Information*. National Academy Press, 68 pp.

NRC, 2006: *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts.* National Academy Press, 124 pp.

Pielke, R. A., Jr., and R. E. Carbone, 2002: Weather impacts, forecasts, and policy: An integrated perspective. *Bull. Amer. Meteor. Soc.*, 83, 393-403.

Quill, T. E. and A. L. Suchman, 1993: Uncertainty and control: Learning to live with medicine's limitations. *Human Medicine*, 9, 109-120.

Roulston, M. S., G. E. Bolton, A. N. Kleit, and A. L. Sears-Collins, 2006: A laboratory study of the benefits of including uncertainty information in weather forecasts. *Wea. Forecast.*, 21, 116-122.

Ryan, R. T., 2003: Digital forecasts: Communication, public understanding, and decision making. *Bull. Amer. Meteor. Soc.,* 84, 1001-1003.

Stewart, A. E., 2005: Assessing the human experience of weather and climate: A further examination of weather salience. Preprints, *AMS Forum: Environmental Risk and Impacts on Society: Successes and Challenges,* Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 1.6.