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J13.1 FORECAST UNCERTAINTY: "COMPLETING THE FORECAST" PROGRESS AND POTENTIAL

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1. INTRODUCTION

The National Research Council (NRC 2006) published the report *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*, which identified a major gap in weather forecasts. This paper provides a status of the National Weather Service (NWS) response to the first two recommendations from this report. The first recommendation states "The entire [Weather] Enterprise [government, academia, private sector, non-governmental organizations] should take responsibility for providing products that effectively communicate forecast uncertainty information. The NWS should take a leadership role in this effort." The second recommendation states "NOAA should improve its product development process by collaborating with users and partners in the Enterprise from the outset and engaging and using social and behavioral science expertise."

2. BACKGROUND

Before proceeding to the discussion on the two recommendations, it is helpful to fully describe the meaning of forecast uncertainty. Fig. 1 is a diagram identifying the sources of uncertainty, how uncertainty is estimated, the many ways uncertainty is communicated, and what the desired societal impacts are from communicating forecast uncertainty.

Sources of forecast uncertainty span across the entire forecast process, from observations to the data assimilation into models, the models themselves, the statistical and non-statistical post-processing, and eventually to the forecaster-generated outputs. The accumulation of these forecast uncertainty sources can be estimated using a number of techniques. Estimating uncertainty based on climatology is used more for longer-range forecasts, as the technique uses climate values (e.g., probability of high temperatures between 85-90F in Washington, D.C., on July 4th) to produce confidence intervals. Ensemble models are the most widely used model-based technique to produce both probabilities and/or estimation of forecaster confidence (e.g., large spread of the ensemble members indicates larger uncertainties than a tighter grouping of the ensemble members). Forecast skill, or the average range of forecast error, can be used to estimate uncertainty. For example, day 1 forecasts are often made with a single value, while the 5 to 7-day forecasts are often made as 5 to 10 degree intervals. Another way to estimate forecast uncertainty is to provide the forecaster confidence associated with the particular

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forecast. The confidence in a forecast is usually dependent on the lead time, the weather phenomenon forecasted (e.g., difficulty forecasting snow totals from a nor'easter vs. temperatures under a ridge of high pressure), and many other factors that may increase or decrease confidence. For example, recent poor forecasts may make a forecaster less confident with the next forecast.

There are many ways forecast uncertainty can be communicated, but from Fig. 1, six primary means were identified. The six were split into two groups -- quantified (i.e., primarily objective) uncertainty and qualified (i.e., primarily subjective). Quantified uncertainty includes the percentage or odds of an event occurring, a probability density function (i.e., range of values or confidence intervals), and the likelihood of alternate scenarios (e.g., best guess and second-best guess). Qualified uncertainty includes a description of forecast confidence, expressions of uncertainty (i.e., a lexicon of terms), and alternative scenario narratives.

The estimation and communication of forecast uncertainty should lead to a desired societal impact. In a general perspective, forecast uncertainty enables more informed decisions based on a better under-standing of the forecast. Examples are the mitigation against losses or improvement of economic efficiency based on a risk analysis (e.g., cost-loss ratios). A less measurable and arguable societal impact is improved user response based on increased trust or credibility (refer to page 13 of the NRC, 2006, report for a more detailed explanation).

3. PROGRESS

Since the publishing of the NRC (2006), the NWS has significantly increased the production and delivery of forecast uncertainty information. For example, Area Forecast Discussions (AFD) now often contain considerable references to ensemble model outputs, differences in the deterministic global models, and the forecaster's confidence. Other NWS operational products provide probabilities, such as probabilistic tropical cyclone storm surge and wind speeds. Additionally, NWS is generating experimental probabilistic products, such as probabilistic quantitative precipitation forecasts and probabilistic winter precipitation guidance (www.hpc.ncep.noaa.gov).

One community within the NWS that has taken the lead on providing forecast uncertainty and effectively communicating that information is the hydrological community. Many of the river forecasts are presented with probability values (http://water.weather.gov/ahps/).

4. POTENTIAL

The NWS has made substantial progress generating forecast uncertainty information. However, there has only been isolated social science studies performed (and in progress) that focus on how to effectively communicate uncertainty information to a wide array of users. Active studies engaging the utility of uncertainty information involve storm surge and hurricane communication, and emergency management decision processes. A current social science study targeting the point-and-click (PnC) web pages of the NWS (www.nws.noaa.gov) asked participants in a survey "Would you like more information about the uncertainty associated with a forecast?" Totals from 5078 participants resulted in 58.6% either strongly agreeing or agreeing to want more uncertainty information. Only 11.3% of respondents disagreed or strongly disagreed. A case can be made that there is still a lot of potential that the Weather Enterprise and the NWS, specifically, can do to not only generate and deliver forecast uncertainty information, but communicate that information effectively.

5. DISCUSSION AND CONCLUSIONS

So what is next as the Weather Enterprise enters the 5th year since the NRC report was published? For the NWS, Fig. 2 illustrates the strategy for "completing the forecast". Four user groups are identified as having specific needs, with those needs listed below each user group. Users range in sophistication from highly technical to a general understanding of uncertainty information. For example, industries such as energy demand the raw probabilistic guidance, without the need for education and will build forecast tools for their individual needs. Forecasters at the NWS require forecaster tools, as well as training and social science investment on how to communicate uncertainty better in their products and decision support services. Government decision makers, core partners of the NWS, require automated tools that ingest probabilistic information to provide them with go/no go decisions. The general public requires the most investment in social science, as well as outreach, education, and partnerships (e.g., media).

Some critics argue that the NWS is not adequately providing enough leadership toward meeting recommendations 1 and 2 from the NRC report. However, based on the sheer number of forecast uncertainty products that have been added operationally across the NWS, significant progress has been made, and continued investments are being made in response to the NRC recommendations.

6. ACKNOWLEDGEMENTS

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7. DISCLAIMER

This paper represents the views of the author and does not necessarily represent a position of the National Weather Service or any other government agency.

8. REFERENCES

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

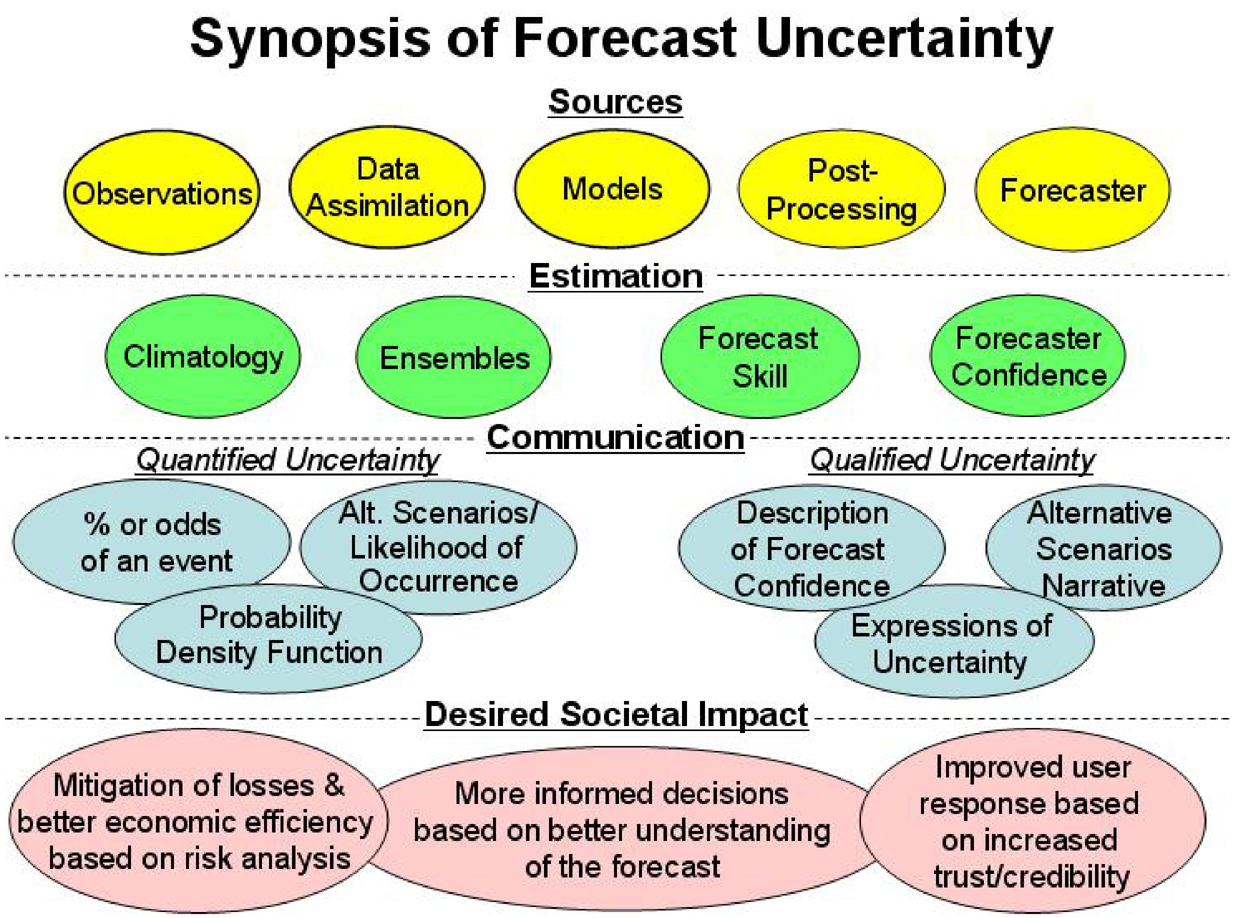

FIG. 1. Description of forecast uncertainty, from the sources, estimation, and communication of forecast uncertainty information leading to the desired societal impacts.

FIG. 2. Illustration summarizing the NWS strategy for delivering forecast uncertainty information to four major stakeholders: private industry, forecasters, government decision makers, and the general public. Note that social science is needed beginning with the forecasters and continues with the government decision makers and general public.