12B.2 DEFINING SOCIETAL AND ECONOMIC RESEARCH AND APPLICATIONS (SERA) PRIORITIES RELATED TO DEVELOPMENTS IN NUMERICAL WEATHER PREDICTION AND THORPEX

Barbara G. Brown[1], Rebecca E. Morss[2], Jeffrey K. Lazo[2], Harold E. Brooks[3], Philip T. Ganderton[4], and Brian N. Mills[5]

1. INTRODUCTION

Societal and Economic Research and Applications (SERA) is one of the four key areas of focus in THORPEX, as outlined in the THORPEX International Science Plan (Shapiro and Thorpe, 2004). Proposed THORPEX SERA activities range from primary research to application development to capacity building (SERA WG 2006). These activities will come to fruition through efforts within national, regional and international programs. At the regional scale, priorities have been defined for the Southern Hemisphere (Gordon et al. 2006) and efforts are underway or planned in the Asian and European committees.

Development of research priorities for the SERA component of the North American (NA) THORPEX was the subject of a workshop held in August 2006 in Boulder, Colorado. The workshop included more than 40 U.S., Mexican and Canadian researchers and practitioners representing a cross-section of disciplines. Discussion papers addressing four SERA themes were solicited in advance of the workshop and, together with a series of plenary presentations, served as the primary catalyst for discussion.

This paper provides a partial synthesis of the following five priority topics that emerged from the deliberations and received general support from participants: (i) Understanding the use of forecast information in decision making; (ii) Communicating weather forecast uncertainty; (iii) User-relevant verification; (iv) Estimating the economic value of weather forecasts; and (v) Developing decision support tools and systems. Although these priorities are based on the workshop proceedings, their elucidation here is based on the authors' views rather than an explicit account of the meeting.

In addition, although the priorities were defined with THORPEX as the catalyst, the priorities and methods discussed and selected are relevant for SERA activities that are needed across a broad spectrum of development in the area of numerical weather prediction and weather forecasting. Thus, the results of the workshop and the priorities identified are applicable in many areas. Moreover, their broad implementation would lead to a greater involvement of social scientists in the weather forecasting field in general. This outcome would lead to greater benefits across the field of meteorology, including the development of forecasting systems with greater social and economic value.

The five priority research topics are briefly described in Section 2, followed by a discussion of the process and resources required to implement this SERA research agenda.

2. PRIORITY RESEARCH TOPICS

Brief descriptions of the research topics discussed at the August workshop are provided here. The theme papers on these topics, as well as the workshop presentations, are available from the workshop web page (http://www.sip.ucar.edu/thorpex/index.jsp).

Understanding the use of forecast information in decision making. Weather forecasts provide information that people can use in making decisions, thus affecting outcomes. Three key research questions are: (i) how do decision makers in these diverse contexts interpret weather forecast information? (ii) how do they combine forecasts with other information in their decision processes? and (iii) what constrains their use of current or improved forecast information? Research is needed both in specific decision environments (e.g., emergency management) and across a variety of contexts in order to compare and draw broader conclusions. A variety of methods are available to tackle these questions, including those that assume an optimizing decision maker (e.g., cost-loss and more complex prescriptive model experiments), and those that examine decisions in real contexts. For the latter type of study, fields such as decision sciences, behavioral psychology, sociology, and geography offer a great variety of tools (e.g., ethnographic studies; surveys, interviews, and focus groups).

Communicating weather forecast uncertainty. The rapid evolution of techniques for estimating weather forecast uncertainty has not been paralleled with concomitant advances in understanding of how to effectively communicate such information to users (NRC 2006). Forecast-related decisions under uncertainty are often complex, incorporating information and compiling uncertainty from multiple sources. Simply providing more information without considering this complexity may not benefit many users. Important research questions include: (i) how do users interpret forecast uncertainty? (ii) how do they respond to different forms of uncertainty

[1]*Corresponding author address*: Barbara G. Brown, National Center for Atmospheric Research (NCAR), PO Box 3000, Boulder CO 80307-3000; e-mail: bgb@ucar.edu

[2]NCAR, Boulder, CO

[3]NOAA National Severe Storms Laboratory

[4]University of New Mexico

[5]Environment Canada

communication (in terms of both the medium and the message)? and (iii) how do they incorporate forecast uncertainty into decisions? Related areas of inquiry include the role of uncertainty thresholds; risk perceptions; and how preferences interact in individual decision-making. Studies are needed for a variety of users in different decision contexts, for both hazardous and routine weather forecasts. Ideas, methods, and results developed in other decision-making contexts can be applied to weather forecasts and tested in laboratory and field settings.

User-relevant verification. Forecast verification – the process of evaluating the quality of forecasts – typically involves calculation of relatively simple metrics that compare point forecasts to corresponding point observations. Traditional verification methods provide little information that can help improve forecasts (the scientific purpose of verification), benefit users' decisions (the economic purpose of verification), or estimate forecast value. Addressing these deficiencies requires an understanding of the types of verification information that could benefit users; research on user-relevant features-based and scale-sensitive approaches; and the development and testing of new diagnostic methods (e.g., ways to view and summarize forecast error distributions) for evaluating user-relevant variables. Other areas of research include understanding how to effectively communicate verification information to users and investigating the relationship between forecast quality and value. Conducting this research requires interdisciplinary collaborations among meteorologists, verification experts, social scientists, and users. Case studies that would conceptualize, develop, and employ user-relevant verification approaches for several different users and forecast attributes would provide an initial demonstration of these concepts. Each case study would require development of an understanding of users' forecast and verification-related needs using methods such as interviews, surveys, and focus groups, combined with expertise in developing verification techniques. From these case studies, more general approaches to user-relevant verification might then be developed.

Estimating the economic value of weather forecasts. In economic terms, the value of improved forecasts is measured by individual or aggregate changes in well-being (utility). Key research areas include estimating the value of different forecast modifications (i.e., changes in forecast attributes) and evaluating various users' preferences among forecast modifications. Both can be studied using well-established tools (e.g., revealed- and stated-preference approaches) that economists have developed to value other non-market goods. Techniques from behavioral economics may also be employed; for example, preferences for different types of forecast information can be studied using laboratory experiments that give real or simulated users controlled information and decision sets. Forecast value may also be estimated using methods, such as hedonic pricing or sector- or firm-specific case studies, that draw on market data. Using cost-benefit analysis techniques, forecast valuation results can be integrated with cost information and meteorological knowledge to evaluate the overall societal costs and benefits of different forecast modifications.

Developing decision support tools and systems. Decision support systems (DSSs) and tools serve as a bridge to connect particular users with weather information providers. User engagement is likely the most important prerequisite for successful DSSs, facilitating greater understanding of users' problems, needs, and decision-making contexts, and promoting adoption of the tool and use of the information it provides. A major decision support priority is developing systems and tools that will enable users to incorporate THORPEX-related forecasts into decisions, particularly those enhanced with uncertainty information [e.g., generated through the THORPEX Interactive Grand Global Ensemble (TIGGE)]. Studies should be performed both to facilitate new uses of forecasts in well-served sectors and to benefit new user groups. One mechanism for conducting these studies is through decision support testbeds, in which new approaches and technologies are developed and evaluated in conjunction with other user-oriented research.

3. INTEGRATION OF RESEARCH TOPICS

The path to development of a SERA program as described here will require integration of all five of the research topics described in Section 2; all of these topics are interconnected and mutually dependent. For example, development of user-relevant verification approaches requires understanding of users' decisions. In turn, forecast quality information is a key determinant of forecast value, and user-relevant verification information is a critical link between forecasts and decisions.

The forecasting process can be viewed as an integrated chain of steps from forecast creation to value realization, with data and information initially produced by the forecasting "system"; this system includes the observation system, data assimilation, numerical modeling, forecasting, and associated research. The information produced by this system is communicated directly or through intermediaries to users who combine the forecasts with other information in their decisions, affecting outcomes. The impacts of current or improved forecasts accrue along the different stages of this chain.

The research priorities identified in this study are clearly identifiable in this chain. For example, decision making and communication of uncertainty are directly linked to users' applications of forecasts and the processing of forecast information and communication to users. Decision support systems and tools more formally integrate forecasts with other relevant information to help users make decisions. Verification and value are the two (linked) perspectives for evaluating a forecasting system. User-relevant verification approaches can help communicate user needs and outcomes back to the weather

forecasting system and into decision support tools. Forecast value can be added (or lost) at each stage of the chain; these sum to total value, the net benefit obtained by an individual decision maker, an entire sector, or society.

In summary, to truly assess and enhance the entire forecasting process requires an integrated approach including all of the elements defined here: understanding forecast use, communicating uncertainty, user-relevant verification, estimating forecast value, and decision support systems and tools.

4. IMPLEMENTATION OF A NORTH AMERICAN SERA AGENDA

SERA activities can significantly improve understanding of weather-society interactions to the benefit of the meteorological community and society. However, reaching this potential will require dedicated effort to bring together and maintain a sustainable interdisciplinary community.

In particular, although many disciplines were represented at the August 2006 workshop, a broader, more substantive and sustainable community is required to further specify and implement an integrated SERA research agenda. Development of this community will require increased collaborations with forecast users and entrainment of additional social and atmospheric scientists, particularly early-career researchers and practitioners, to work on productive interdisciplinary SERA projects.

Human resources must be complemented with sufficient financial support and other research infrastructure to fulfill the SERA agenda. Assembling a series of small but dedicated long-term grants for SERA research and ensuring that THORPEX project proposals from other working groups explicitly include a funding element for socio-economic analysis, will help address financial issues. With these elements in place, NA THORPEX SERA has a chance to flourish and realize some of the long-recognized potential so often promised – but unrealized – in previous efforts to integrate SERA activities with efforts to improve weather prediction.

ACKNOWLEDGMENTS

This paper is based on a longer manuscript being prepared by the authors (Morss et al. 2007). The authors acknowledge David Parsons and Gregory Holland for serving on the workshop organizing committee and all of the workshop participants for their contributions and ideas. The workshop was funded through an NCAR Opportunity Fund grant and the THORPEX International Program Office. NCAR is sponsored by the National Science Foundation.

REFERENCES

Gordon, N., A. Angari, M.A. Gan, J.L. McBride, E. Poolman, K. Puri, C.P. Rousseau, I. Simmonds, P. Steinle, M.J. Uddstrom, and W.J. Tennant, 2006: Southern Hemisphere THORPEX Science Plan. Southern Hemisphere THORPEX Regional Committee, 56 pp. http://www.wmo.int/thorpex/publications.html

Morss, R., J. Lazo, H. Brooks, B. Brown, P. Ganderton and B. Mills, 2007: Societal and Economic Research and Applications for weather forecasts: Priorities for the North American THORPEX Program, submitted to *Bulletin of the American Meteorological Society*.

National Research Council, 2006: *Completing the forecast: Characterizing and communicating uncertainty for better decisions using weather and climate forecasts*. National Academies Press, 112 pp.

SERA-WG, 2006: Meeting report of the THORPEX SERA Working Group, March 2006, Reading, UK. http://www.wmo.int/thorpex/reading_meeting.html

Shapiro, M.A. and A.J. Thorpe, 2004: THORPEX International Science Plan, Version III. WMO/TD-no. 1248, 57 pp.