WORKSHOP ON WEATHER READY NATION

Science Imperatives for Severe Thunderstorm Research

BY MICHAEL K. LINDELL AND HAROLD BROOKS

NOAA and the National Science Foundation sponsored *Weather Ready Nation: Science Imperatives for Severe Thunderstorm Research* to move forward research initiatives to better understand, forecast, and warn for tornadoes and severe weather. Prior to the workshop, teams of authors produced white papers summarizing the state of the science in eight areas and addressed issues raised by previous studies (e.g., National Research Council 2003, 2006, 2011; OFCM 2010; SAB/SSWG 2009; UCAR 2012). Workshop participants were instructed to read the white papers before arriving at the conference venue.

RESEARCH ISSUES. The major issues identified in the Birmingham workshop are categorized below in terms of the eight white paper topics. A number of issues crossed disciplinary lines and thus were discussed in more than one disciplinary group. Consequently, the allocation of issues to groups is somewhat arbitrary.

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DOI:10.1175/BAMS-D-12-00238.1

In final form 25 March 2013

WEATHER READY NATION: SCIENCE IMPERATIVES FOR SEVERE THUNDERSTORM RESEARCH

WHAT: More than 60 attendees representing the disciplines of civil engineering, communication, economics, emergency management, geography, meteorology, psychology, public health, public policy, sociology, and urban planning met to discuss the major issues facing severe thunderstorm research, forecasting, and warning and make recommendations for research support and policy changes.
WHEN: 24–26 April 2012
WHERE: Birmingham, Alabama

Physical understanding for improved forecasts. The principal point of discussion on this issue was the need for advances in meteorological theory and observational methods that would result in a better understanding of the causes of missed events (i.e., improved probability of detection) and a reduction in the number of false alarms. In addition, workshop participants identified a need for research that would result in a better understanding of wind effects on structures.

Forecast and warning process. Most groups noted a need to improve forecast accuracy, especially an investigation of the utility of new storm observation platforms—ranging from storm penetrating aircraft to instrumentation of personal vehicles. Participants also proposed studies of forecaster staffing and training, as well as the identification and dissemination of "best practices" in local National

Weather Service (NWS) offices. In particular, there is a need for behavioral research on forecasters' judgment and decision processes and the ways these processes differ across individuals and NWS regions. This would include examination of variation among forecasters in the probabilistic meaning of their warning polygons. For example, do individual forecasters intend the boundaries of their warning polygons to correspond to a 75%, 90%, 99% or some other confidence interval—or do they even think of warning polygons in these terms?

Continuing technological advances have created a need for research on the relationships among warning channels [e.g., National Oceanic and Atmospheric Administration (NOAA) Weather Radio, Emergency Alert System, Integrated Public Alert and Warning System/Commercial Mobile Alert System, sirens, commercial broadcast and print media, websites]. Do these channels generally transmit consistent messages? If not, how do warning recipients resolve inconsistencies? There is a related concern about issues in warning message/channel compatibility such as an inability to transmit spatial information (e.g., warning polygons) via radio or telephone text messages. Also noted were needs for a better understanding of nonmeteorological aspects of the warning process and a better understanding of how NWS warnings fit into the multitude of warning sources/messages.

Individual/household behavioral response. Forecast characteristics such as timeliness and accuracy have significant behavioral implications, so there is a need to better understand the consequences of current and increased levels of forewarning. Specifically, does more forewarning *necessarily* reduce casualties and other storm impacts or are there response constraints (such as lack of access to safe rooms and shelters) that negate the usefulness of increased forewarning? Do population segments differ in their ability to make use of increased forewarning? Systematic simulation studies should be conducted that model risk area populations' level of forewarning along with their access to structures varying in effectiveness to better understand the degree to which increased forewarning can reduce casualties. Moreover, there is a need for better understanding of the ways in which population segments with disabilities are constrained in warning receipt and protective action implementation.

Workshop participants in most groups identified a need for a better understanding of the ways in which users interpret forecasts and warnings. Major issues are users' interpretations of meteorological uncertainty; their definitions of false alarms (and, more broadly, warning accuracy); and their interpretation of the forecasters' intended representation of uncertainty in warning polygons. Such research should examine the transmission of threat information in different formats such as probabilistic/quantitative (wind speed probability and tornado strike probability) versus deterministic/qualitative (watch/warning) messages. Research that systematically examines the cognitive demands and behavioral consequences of verbal ("very likely" versus "very unlikely"), numeric (probabilities or odds ratios), and graphic ("confidence/credibility intervals" or isoquants) information would be extremely valuable in developing alternative warning messages. The need for such cognitive research is consistent with some workshop participants' calls for increased laboratory experimentation to examine people's interpretation of forecast and warning products. In addition, to achieve better integration of social science research with current and future forecast/warning products, there is also a need for better integration of social science and epidemiological approaches to post-disaster surveys.

Individual differences across population segments (including those with disabilities). Participants indicated there is a need to identify and understand weather information user groups. A preliminary typology comprises weather specialists (NWS and private sector meteorologists), emergency managers for communities and facilities (utility, school, hospital, nursing home, etc.), the general public (individuals/households in different types of structures at home and work), tourists and other transients, and underserved populations (e.g., population segments with cognitive and physical disabilities). Research is needed to identify people's sensory (e.g., sight and hearing), cognitive (especially probabilistic information processing), and physical (e.g., walking distance and speed) limitations and assess the implications of these limitations for receiving, interpreting, and acting on warnings. Such research also needs to assess these population segments' current level of knowledge and thus their training needs, as well as to identify optimal protective action for different population segments in different situations.

Household emergency preparedness. Research proposed in this area included a better conceptualization and operationalization of fundamental concepts such as community emergency preparedness (i.e., what do communities and households need to do to become storm ready other than the criteria required by the

NWS *StormReady* program?—see www.stormready.noaa.gov/guideline_chart.htm) and to identify the antecedents of household, organizational, and community emergency preparedness. To the degree that emergency preparedness is determined by people's beliefs about hazard adjustments (e.g., the effectiveness and cost of safe rooms) as well as their beliefs about weather hazards, investments in public education programs can reduce impacts of weather disasters. However, there may be little that can be done to increase emergency preparedness if it is largely determined by demographic characteristics, which are difficult or impossible to change. There is also a need to better understand the organizational and institutional contexts, such as a local culture of disaster preparedness, within which preparedness occurs.

Pre-impact planning for disaster recovery. Research in this area needs to define and measure fundamental concepts such as disaster impacts, which are not limited to deaths and injuries but also include psychosocial, sociodemographic, economic, and political impacts and community recovery. (For example, how do we assess the level of recovery, the speed with which it is achieved, the distribution of levels of recovery across different population segments, and the degree to which hazard mitigation is incorporated into the recovery process?) There is also a need to develop a repository of better data on storm impacts to support the risk/cost/benefit analyses needed to support policy decisions. In addition, research needs to better explain the factors that determine people's purchase of hazard insurance, the extent to which insurance purchase substitutes for hazard mitigation and emergency preparedness actions, and the role of insurance in the disaster recovery process.

Economic analysis of tornado warning system. Some participants advocated conducting a comprehensive probabilistic, multidisciplinary risk analysis of high-impact/life threatening weather. This would be an end-to-end analysis that begins with the detection of tornado conditions and follows through the entire forecast, warning dissemination, and protective response process. Such a study would be consistent with other workshop participants' call for an assessment of the economic value of current and alternative warning systems because it would yield a better understanding of public information needs and the most (cost) effective ways to disseminate that information. These comprehensive studies should also expand the criteria for forecast evaluation from forecast error probability [i.e., false alarm rate (FAR) and probability of detection (POD)] to expected forecast error cost (i.e., FAR and POD multiplied by their respective consequences).

Hazard mitigation (safety rooms and shelters). Research in this area should involve a systematic analysis that examines the benefit/cost tradeoffs for individual/community investments in shelters and safe rooms. A related concern for voluntary construction of shelters/safe rooms is the identification of barriers to implementation such as cost (including financing) and constructor expertise. Alternatively, there are concerns about the likely rate of adoption/implementation of building codes that require construction of shelters/safe rooms and the secondary impacts that required shelter/safe room construction would have on housing affordability for different types of housing—single family, multifamily, and mobile/manufactured housing.

ORGANIZATIONAL RECOMMENDATIONS. The discussion groups consistently recommended that NOAA/NWS and the National Science Foundation (NSF) place an increased emphasis on the formation of interdisciplinary teams in addressing a variety of research needs. One such need is for systematic quantitative evaluation of existing and emerging detection/forecast/warning systems. For existing systems, interdisciplinary teams could perform rapid post-storm assessments that include the collation and archiving of incident data from multiple agencies, including collection of perishable data on storm damage, casualties, behavioral response (e.g., warning reception, risk perception, information seeking, and protective response), and social impacts (i.e., psychosocial, sociodemographic, economic, and political). For emerging forecast/warning systems, interdisciplinary program evaluations should be conducted during all stages of system development including conceptual design (usability analysis), implementation (formative evaluation), and operation (summative evaluation).

Some participants proposed greater institutionalization of social/behavioral science approaches to weather risk management by establishing what one group characterized as a NOAA Directorate of Human Dimensions of Weather. This proposal is quite similar to a recommendation of NOAA's Science Advisory Board and Social Science Working Group (SAB/SSWG 2009, p. 7) that NOAA establish an Office of Societal Impacts. It is also similar to Recommendation 2.4 of the National Research Council Committee on Estimating and

Communicating Uncertainty in Weather and Climate Forecasts stating that "NOAA should acquire social and behavioral science expertise including psychologists trained in human cognition and human factors, with training in behavioral decision theory, statistical decision theory, survey design and sampling, and communication theory, with special focus on graphics and product development" (National Research Council 2006, p. 86). Finally, this recommendation was also echoed in a 2011 workshop in Norman, Oklahoma—*Weather Ready Nation: A Vital Conversation on Tornadoes and Severe Weather* (UCAR 2012).

CONCLUSIONS. The major issues identified within each of the research areas were consistent with recommendations from previous workshops and committees. However, the Birmingham workshop report was quite detailed and made 12 specific research recommendations (see Research Report 12–02R online at http://hrrc.arch.tamu.edu/publications/reports). Workshop participants echoed the recommendations of previous workshops and committees in recommending an increase in the number of social scientists who work closely with NWS meteorologists at all levels of the agency. Social scientists can contribute to many aspects of the NWS mission—from staffing, training, and job design all the way through the design of warning messages and the assessment of community weather resilience. Their contributions will be most effective if they are in daily contact with NWS staff ranging from forecast meteorologists to senior administrators.

ACKNOWLEDGMENTS. We wish to acknowledge the guidance of Dr. Steve Koch, NSSL Director and Chair of the Workshop Executive Committee, and the other members of the Executive Committee.

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