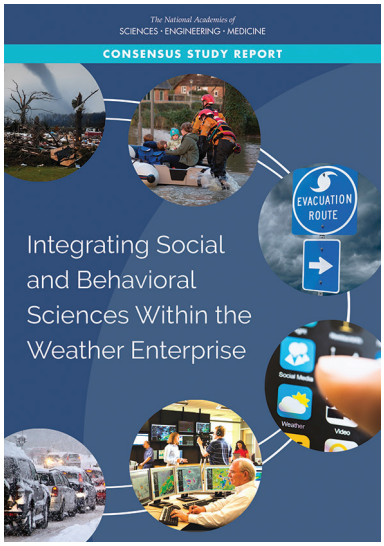
Consensus Study Report
HIGHLIGHTS
November 2017

Integrating Social and Behavioral Sciences Within the Weather Enterprise



Our ability to observe and predict severe weather events has improved markedly over the last few decades. Forecasts and warnings are being made with greater accuracy, geographic specificity, and lead time, which allows people and communities to take appropriate protective measures. To translate this progress effectively into similar advances in protecting communities from hazardous weather, however, requires more than meteorology.

In 2012, Superstorm Sandy was preceded by accurate forecasts and widespread warnings, yet failed to trigger, for many people, appropriate protective behaviors that experts in the weather enterprise recommended and were hoping to see. During a deadly tornado outbreak in Oklahoma in 2013, thousands of people fled their homes in cars despite years of messaging about the dangers of encountering tornadoes in a vehicle. Analysis later found that several factors, including people's recent experiences with another large tornado event, and conflicting advice from different local broadcast officials, contributed to this outcome. The 2017 hurricanes Harvey, Irma, and Maria illustrated several key challenges we still face, for instance, in effectively communicating about weather hazards with inherent uncertainties, informing decisions about evacuating large population centers, developing more resilient urban infrastructure, and providing response and recovery support that ultimately increases weather readiness for all.

As a result of such experiences, there is growing recognition that a host of social and behavioral factors determine how we prepare for, observe, predict, respond to, and are impacted by weather hazards. This report suggests strategies to better engage researchers and practitioners from multiple social and behavioral science fields, to advance these fields through weather-related research, to more effectively apply relevant research findings, and to foster more cooperation among public, private, and academic sectors.

THE EVOLVING WEATHER ENTERPRISE

The weather enterprise comprises the set of public, private, and academic institutions that observe, predict, communicate and provide decision support information related to weather. While the National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration (NOAA), is the original source of most U.S. weather observations, forecasts, and watches/warnings, it is no longer the direct source of weather information for

most Americans. Rather, NWS information is carried to different audiences through a complex communication chain that can include local television stations, cable television and radio, websites, weather apps for mobile phones, and social media channels such as Twitter and Facebook. These ever more diverse communication pathways underscore the need for social and behavioral sciences (SBS) research to better understand how different target populations receive and process weather information, and how people are affected by differing, sometimes conflicting information coming from these sources.

As illustrated in the figure, SBS research offers potential not just for improving communications of severe weather forecasts and warnings, but also for improving preparedness and mitigation for weather risks, for hazard monitoring, assessment, and forecasting processes, for emergency management and response, and for long-term recovery efforts.

FIGURE 1 Stages of communication and decision support that must be addressed under the Weather Ready Nation paradigm, with examples of how SBS research can provide critical insights and understanding in each of these stages.

Road weather concerns in particular deserve attention. Vehicle accidents are by far the largest cause of weather-related deaths and injuries in the United States. An estimated 445,000 people are injured and 6,000 killed annually due to weather-related vehicle accidents. In hazardous weather, drivers face unique vulnerabilities and opportunities to make choices that affect both their own safety and that of many others. Evolving systems to convey road weather information and transformative changes such as autonomous vehicles can fundamentally alter how people deal with hazardous weather in their vehicles. Social and behavioral science is critical for understanding the needs and behavior of transportation managers and individual drivers in the face of such developments.

RECENT ADVANCES AND REMAINING CHALLENGES

Over the past few decades, a large, diverse body of research at the social science and weather interface has emerged. This research has explored factors that influence the interactions and decisions of weather enterprise professionals; the ways that people receive, interpret, and use hazardous weather forecasts, warnings, and preparedness information; the factors that underlie social vulnerability to different types of weather hazards; and the economic value of weather information to different sectors and stakeholders. New tools and models are also making it possible to collect, analyze, interpret, and apply different types of data and information. For instance, studies of the spread and influences of information across broad social networks are now possible with social media analyses and the application of "big data" analytics.

The consistent collection and analysis of high-quality social science data is a critical foundation for progress in SBS research; however, limited, inconsistent funding has inhibited progress in this realm. Financial support for research at the SBS-weather interface comes primarily from NOAA, the National

Science Foundation (NSF), and the Department of Homeland Security (DHS and FEMA). While the level of financial support for SBS-related research appears to have grown over time, it still represents a small fraction of the overall support of weather research.

Research progress has also been inhibited by challenges that arise when fostering interdisciplinary work among diverse science communities with different knowledge sets, research goals, and capacities. For example, rather than viewing SBS research as an "add-on" to meteorology, interdisciplinary framing of weather-related research should be pursued from the outset of a project. Addressing these barriers requires a more realistic understanding by meteorologists and others of the diverse disciplines and research methodologies used within the social and behavioral sciences; of the time and resources required for robust SBS research; and of the inherent limitations in providing simple, universally-applicable answers to complex social science questions.

A FRAMEWORK TO SUSTAINABLY SUPPORT AND EFFECTIVELY USE SOCIAL AND BEHAVIORAL SCIENCE IN THE WEATHER ENTERPRISE

Government agencies, private sector weather companies, and academic research institutions in the weather enterprise all have critical roles to play in advancing the support for and application of research at the SBS-weather interface. Collectively the weather enterprise should consider the following recommendations as priority actions:

1. Invest in Leadership to Build Awareness

Across the weather enterprise, leaders must invest time to understand and spread awareness to key constituencies and stakeholders about the ways that SBS can help advance their organization's goals related to weather preparedness, hazard monitoring, assessment, and forecasting processes, emergency management and response, and long-term recovery. To aid these efforts, organizations within the weather enterprise need to augment their leadership teams to include executives and managers with diverse social science backgrounds and establish policies to affect necessary organizational changes.

2. Build Capacity Throughout the Weather Enterprise

Building capacity to support and implement SBS research depends upon sustained funding and increased intellectual resources, including professional staff trained and experienced in SBS research and its application. Current ad hoc approaches for supporting various SBS research activities have made it difficult to build sustained momentum for this field of research. Instead, NOAA should strive to build more sustainable institutional capacity for supporting SBS research, such as establishing innovative public-private partnerships for interdisciplinary weather research, developing an SBS-focused NOAA Cooperative Institute, or creating SBS-focused programs within existing Cooperative Institutes.

It is equally important for partner organizations such as NSF, FHWA, and FEMA to help advance these capacity-building efforts. Federal agencies and private sector weather companies alike, together with leading SBS scholars, should immediately begin a planning process to identify specific investments and activities that collectively advance research at the SBS-weather interface. This planning process should also address critical supporting activities for research assessment, agenda-setting, community building, information sharing, and the development of methods to collectively track funding support for this suite of activities at the SBS-weather interface.

To sustain SBS-weather research and its integration into operations, concerted efforts are also needed to build capacity in future professionals at the undergraduate and graduate levels, for instance, through interdisciplinary coursework or joint degree programs; and in professionals working today, through training programs that help researchers from the social, physical, and engineering sciences better understand each other's research methodologies, capacities, and limitations.

3. Focus on Critical Knowledge Gaps

Building scientific understanding of weather-related actions, behaviors, and decisions will require wise investment in research that addresses specific knowledge gaps and will help accelerate the maturation of the field overall. Key areas identified as knowledge gaps to address include:

- **Weather enterprise system focused research.** This includes system-level studies of weather information production, dissemination, and evaluation; studies of how forecasters, broadcast media, emergency and transportation managers, and private weather companies create information and interact and communicate among themselves; studies of forecaster decision making, such as what observational platforms and numerical weather prediction guidance forecasters use and how they use them; studies of how to assess the economic value of weather services; and studies of team performance and organizational behavior within weather forecast offices and other parts of the weather enterprise.
- **Risk assessments and responses, and factors influencing these processes.** This includes research on how to better reach

and inform special-interest populations that have unique needs, such as vehicle drivers and others who are vulnerable to hazardous weather due to limited resources or capabilities. It also includes research on how people's interest in, access to, and interpretation of weather information, as well as their decisions and actions in response, are affected by their specific social or physical context, prior experiences, cultural background, and personal values.

- **Message design, delivery, interpretation, and use**. This includes research on how communicating forecast uncertainties in different formats influences understanding and action; how to balance consistency in messaging with needs for flexibility to suit different geographical, cultural, and use contexts; and how new communication and information technologies interact with message design and are changing people's weather information access, interpretations, preparedness, and response.

CONCLUSION

To expand from the goal of accurately forecasting atmospheric conditions to the goal of protecting of life and property is not an incremental step, but rather a major shift in emphasis for the weather enterprise. While efforts to advance meteorological research and numerical weather prediction should continue, realizing the greatest return on investment from such efforts requires fully engaging the social and behavioral sciences—both to expand the frontiers of knowledge within SBS disciplines, and to foster more extensive application of these sciences across the weather enterprise.

Ultimately, it takes patience and persistence to build a robust presence of social and behavioral sciences within enterprises that have historically been dominated by physical science disciplines. But as has been illustrated in other realms such as public health, with high-level leadership and vision, consistent financial support, and innovative partnerships, tremendous successes can indeed be achieved—to the great benefit of society at large.

COMMITTEE ON ADVANCING SOCIAL AND BEHAVIORAL SCIENCE RESEARCH AND APPLICATION WITHIN THE WEATHER ENTERPRISE

Ann Bostrom (*Co-chair*), University of Washington, Seattle; **William Hooke** (*Co-chair*), American Meteorological Society; **Raymond Ban**, Ban and Associates; **Ellen Bass**, Drexel University; **David Budescu**, Fordham University; **Julie Demuth**, National Center for Atmospheric Research; **Michael Eilts**, Weather Decision Technologies, Inc.; **Charles Manski**, Northwestern University; **Richard Nelson**, American Association of State Highway and Transportation Officials; **Yvette Richardson**, Pennsylvania State University; **Jacqueline Snelling**, Federal Emergency Management Agency; **John Toohey-Morales**, WTVJ NBC-6; **Joseph Trainor**, University of Delaware; **Laurie Geller** (*Study Director*), **Heather Breiner** (*Associate Program Officer*), **Amanda Purcell** (*Associate Program Officer*), **Erin Markovich** (*Program Assistant*), National Academies of Sciences, Engineering, and Medicine

For More Information . . . This Consensus Study Report Highlights was prepared by the Board on Atmospheric Sciences and Climate, Board on Environmental Change and Society, and Board on Human-Systems Integration based on the Consensus Study Report *Integrating Social and Behavioral Sciences Within the Weather Enterprise* (2017). The study was sponsored by the National Oceanic and Atmospheric Administration (the National Weather Service and the Office of Weather and Air Quality) and the Federal Highway Administration. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Board on Atmospheric Sciences and Climate web page at http://www.nationalacademies.org.

Division on Earth and Life Studies
Division of Behavioral and Social Sciences and Education

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org