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LIVING WITH EXTREME WEATHER WORKSHOP: SUMMARY AND PATH FORWARD

*[1,2]Kelvin K. Droegemeier, [3]Lans P. Rothfusz, [1]Alicia J. Knoedler, [4]John T. Ferree, [5]Jennifer Henderson, [6]Kodi L. Nemunaitis-Monroe, [7]Danielle Nagele, and [8]Kimberly E. Klockow

[1]Office of the Vice President for Research and [2]School of Meteorology
University of Oklahoma
Norman, Oklahoma

[3]National Severe Storms Laboratory
Norman, Oklahoma

[4]National Weather Service Forecast Office
Norman, Oklahoma

[5]Virginia Polytechnic Institute and State University
Blacksburg, Virginia

[6]Cooperative Institute for Mesoscale Meteorological Studies
Norman, Oklahoma

[7]NOAA Office of Program Planning and Integration
Silver Spring, Maryland

[8]NOAA/OAR Office of Weather and Air Quality
Silver Spring, Maryland

1. BACKGROUND AND MOTIVATION

Despite substantial advances in technology and our understanding of the atmosphere, it has become clear in recent years that extreme weather (e.g., tornadoes, hurricanes, flash floods, straight-line winds, blizzards, hail) fundamentally represents a social and behavioral science challenge to society (e.g., NRC 2006; Schultz *et al.* 2010; Hoekstra *et al.* 2011; NOAA 2013; and Ripberger *et al*. 2014, 2015). Experience and research show that physical science, engineering and technology *alone* cannot prevent hundreds of people from dying each year due to extreme weather events, or mitigate the substantial deleterious impacts on built infrastructure and the economy.

Making progress toward the bold goal of dramatically and consistently decreasing mortality from extreme weather requires solutions to deep, fundamental questions that engage multiple disciplines. Research by the social, behavioral and economic sciences (SBES), in particular, when integrated fully with that from physical science, technology and engineering, has the potential for making the greatest societal impact. Recognition of this fact has increased substantially during the past decade, as evidenced, among other things, by the pioneering WAS*IS initiative (Demuth *et al.* 2007), the AMS Symposium on Societal Applications: Policy, Research and Practice (formerly known as the Symposium on Policy and Socioeconomic Research), several sessions on related topics at recent Annual Meetings of the American Meteorological Society, by the creation of a American Meteorological Society journal *Weather, Climate and Society*, and in two Weather Ready Nation (hereafter WRN; NWS, 2013) workshops (NOAA, 2012; Lindell and Brooks, 2012). In the latter, a comprehensive list of key research questions was developed, numerous excellent recommendations were offered regarding the creation of research centers, funding programs, and educational activities, and strategies for improving operational forecasts and warnings were offered. Similarly, SBES research in the context of climate change likewise is seen as pivotal toward mounting an effective response (NRC 2010).

2. WORKSHOP GOALS

Building upon the important activities noted above, collaborators from the University of Oklahoma and several NOAA organizations organized an invitation-only workshop, held in Norman, OK on 18-20 May, 2015, to bring together scholars who engage SBES in research in the context of

* Corresponding Author Address: Prof. Kelvin K. Droegemeier, University of Oklahoma, 201 Stephenson Pkwy, Suite 3100, Norman, OK 73019. Email: kkd@ou.edu.

extreme weather, and to broaden and deepen existing research collaboration networks. The formal title of the workshop was: "Living with Extreme Weather: A Workshop to Integrate Understanding and Improve Societal Response" (see http://extremeweather.ou.edu/). The goals included the following:

- Identify existing bodies of knowledge from relevant domains that can contribute to the current state of knowledge regarding predicting extreme weather, formulating and communicating to the public threat information, and understanding and predicting public response;
- Develop foundational research questions, both within and across disciplines, along with strategies for addressing them, so as to make substantial advances toward dealing with extreme weather;
- Lay the groundwork for bringing to life-saving operational practices the results of these new research collaborations.

Underpinning these goals was a number of framing questions, including the following:

- What are the greatest challenges in formulating and communicating extreme weather threat information to the public (e.g., information aversion)? What new approaches might be most useful for making progress to address those challenges and what research is needed to explore them?
- What are the greatest challenges in mitigating loss of life due to extreme weather and how do they relate to demographics, previous personal experiences, information source, confirmation bias, and trust?
- What strategies are best suited for stimulating and sustaining multi-disciplinary collaboration and how should such interaction be organized?
- What research frameworks are needed to conduct and evaluate research on workshop topics, and how can they effectuate a smooth and rapid transfer of research outcomes to operational practice?

And finally, the following outcomes were established not specific to the workshop itself but rather as part of an ongoing engagement with the broadened community of scholars.

- Identification of disciplines that can contribute to research problems relevant to extreme weather that, to date, have not been involved or well integrated;
- Identification of perspectives and methodological approaches that can contribute to reformulating the severe weather warning process and evaluating its success;
- Development of fundamental, cross-cutting research questions and recommendations for multi-agency programs to support the study of these questions and assess their outcomes in operational experimentation.

3. STRUCTURE and PARTICIPANTS

a. Agenda and Supporting Materials

In light of the rather daunting goals of the workshop, considerable effort was expended to create an interesting, engaging, and novel structure by a) devising an agenda informed, in part, by a pre-workshop survey given to all participants to discern particular interests and scholarly strengths of the participants and draw disciplines together by presenting issues and challenges in an integrative manner; b) providing background information in advance, in the form of topical brief videos as well as supporting documents, on key topics of relevance to all attendees, so as to minimize on-site presentations and maximize the time available for personal interactions (for examples, visit https://www.youtube.com/playlist?list=PLowCkjeYmJBSREJAJidfb_XXBwCr7tufo and http://extremeweather.ou.edu/#resources); c) providing extensive time on site for networking; d) offering immersive learning opportunities via participation in mock operational forecasting activities; e) using real-time tools, such as a Sketchbook, for participants to post their thoughts, ideas, suggestions, references, etc; and f) using thematic break-out groups in which participants considered practical issues and focused on creating frameworks for studying them in a scholarly manner. The workshop agenda, reflects these elements and was quite effective. Some modifications were made as the workshop proceeded to take full advantage of new ideas as they arose.

Of course, holding a weather-themed workshop in Oklahoma during the height of tornado season afforded the possibility of participants to experience severe weather first hand, and indeed, an event did occur the evening of Tuesday, May

19. Tornadic storms developed west of Norman and threatened to move into the area near the end of the day. A live feed to local television stations was established in the meeting venue, providing participants with an extraordinary ability to witness, in real time, how extreme weather information is conveyed via the media. The impact on those from outside Oklahoma, and from disciplines other than meteorology, was quite powerful. In fact, we leveraged this opportunity, while waiting for the weather to subside, to create the "final exam" shown in Figure 1 below.

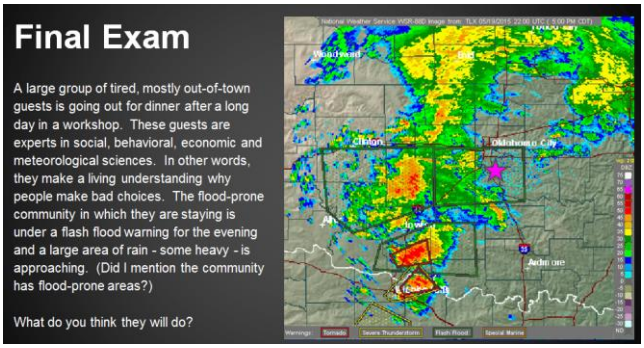

Figure 1. Workshop exercise created in real time during an extreme weather event that impacted the meeting venue.

b. Selection of Participants and Disciplines Represented

In assembling the participant list for this invitation-only workshop, the planning committee gave considerable attention to selecting scholars from a wide array of SBES fields at the national level while simultaneously ensuring broad representation in gender, race and ethnicity, geographic location, institution type, time from terminal degree, experience, and participation in previous activities (e.g., WAS*IS, WRN workshops) to ensure continuity. For example, as a means for identifying possible candidates, the Organizing Committee held discussions with key SBES leaders from the National Science Foundation and obtained additional input, via conference calls and email exchanges, from the heads of major social science professional societies via COSSA (Consortium of Social Science Associations).

The list of 84 invited participants (which includes the Organizing Committee) is shown in Appendix B and consisted of scholars from 26 states (27% from EPSCoR jurisdictions and 29% from Oklahoma). (Note that 98 individuals actually registered, including four who cancelled, leaving the final total at 94.) Sixty participants were from outside of Oklahoma, which was an important workshop goal, and 54% were female. Approximately 70% represented SBES disciplines, with the remainder coming from atmospheric and related physical sciences, engineering and technology – another important goal. Specific disciplinary representation is shown below in Table 1. Although the preponderance of attendees had not previously attended a WRN workshop or a WAS*IS activity, some were aware of their existence.

Table 1. Disciplinary representation of workshop invited participants.

Discipline	Number of Attendees
Meteorology/Atmospheric Science (research, operations)	19
Geography (demography, epidemiology, hazards, decision science)	13
Communication (health, risk)	10
Psychology/Cognitive Psychology/Human Factors	9
Sociology (hazards, risk, disasters, response, uncertainty)	7
Political Science/Public Policy	6
Anthropology (health, disasters)	5
Economics	5
Civil/Industrial/Systems Engineering	3
History/History of Science	2
Health/Environmental Health	2
Philosophy and Ethics	1
Emergency Management	1
Adult Education	1
TOTAL	**84**

4. VALUE ADDED TO PREVIOUS ACTIVITIES

As noted above, the Living with Extreme Weather Workshop (hereafter LWEW) benefitted greatly from but also built upon the aforementioned historical activities. In so doing, it sought to add specific and new value to previous planning by:

- Strategically engaging professional societies and other organizations to draw upon a broad array of SBES scholars from across the nation, many of whom were unaware of the relevance of their research to the extreme weather challenge, the WRN initiative, or of the strong emphasis on SBES by the atmospheric sciences community;
- Identifying and applying best practices, particularly from the literature, for effectuating inter-disciplinary collaborations and research in teams. This includes using mechanisms for building common vocabularies, viewing research challenges from vastly different yet complementary and mutually beneficial viewpoints, and applying research methodologies and tools across disciplinary boundaries in novel ways;
- Building awareness of and gaining access to highly valuable data sets for research, particularly from surveys but also from physical event data bases and physical and SBES models;
- Creating formal frameworks, particularly via the use of technological platforms, for building and continuously maintaining relationships and collaborations across the community, and identifying, promoting, and presenting opportunities to pursue specific research projects and become engaged in translation research and operational evaluation; and
- Leveraging new developments and focusing mechanisms, such as FACETs (Forecasting a Continuum of Environmental Threats; Rothfusz *et al.* 2014; Karstens *et al.* 2015), which is a NOAA priority and is built upon the premise of a fully integrated physical/social/behavioral sciences weather warning framework.

5. OUTCOMES AND RECOMMENDATIONS

The breakout sessions and final plenary produced a wide variety of thoughtful comments and recommendations that coalesced around three "content" topics, two "approaches" related to them, and one keystone finding. We summarize below these outcomes, which inform recommendations in the subsequent session.

a. Keystone Outcome

Although strides have been made during the past several years, as noted in Section 1, on topics related to integrating SBES and weather and using research outcomes to inform or enhance operational practice, more progress is possible on specific recommendations emerging from the two WRN workshops, and on the WRN road map overall. Reflecting that observation, a recurring theme within the LWEW workshop was the need for a structured framework or facilitation mechanism to coordinate the many activities needed to realize the component of the WRN vision involving social sciences (and here expanded to include SBES broadly defined). Such a mechanism, echoing a recommendation from the first WRN workshop report but structured somewhat differently, is recommended in Section 6 below. It is seen as a potentially transformative concept that would bring together multiple stakeholders in an effective manner and also purposefully build community, create common vocabularies, and provide resources to facilitate interaction in ways that presently are not available. In other words, it speaks not only to *what* needs to be done, but also very specifically to *how* and *who*.

b. Knowledge Practices and Disciplinary Challenges

Participants generally agreed that decision makers and domain/disciplinary research experts need to learn more about one another's activities, including constraints and capabilities. Simply bringing researchers and operational practitioners together from multiple disciplines does not mean effective or sustainable collaborations will result. How do SBES scholars learn about the forecast process, and how can operational forecasters better understand SBES issues and help with problem identification and formulation? Indeed, problem definition and a common view of key questions from multiple perspectives is essential for posing questions that do not foreclose multiple disciplinary frames. Research methodologies that are specific to given disciplines (e.g., rigorous surveys in the context of social sciences) can be utilized in other domains (e.g., meteorology), though the methods must be understood and the analysis tools appropriately applied and statistical constraints effectively understood. Further, a deeper understanding about recipients of extreme weather information and messages, and how recipients perceive and utilize them, is essential, particularly given the richness of diversity involved and the cultural texture of communities. In this regard, translators – people who have expertise in a given domain but are able to communicate their activities effectively to other domains and "see both sides" – need to be identified, cultivated and fully engaged.

Students can and should play an important role in building a cross-disciplinary and trans-disciplinary community (e.g., NRC 2014), and efforts should be directed toward creating innovative curricula that not only allow but also encourage the value proposition of students working across disciplines in a meaningful way. For students in the SBES who wish to gain more than a basic understanding of meteorology, new courses are being developed that speak to societal and policy issues.

The breakout sessions reiterated recommendations from previous workshops, particularly with regard to developing a deeper and broader understanding of risk, risk communication, threat definition and assessment, information credibility, decision making, and uncertainty. However, they went further by emphasizing the importance of organizing available literature and knowledge in a manner that builds awareness of its availability to individuals outside a given field and helps translate its meaning across traditional disciplinary boundaries. Once again, simply making something available does not ensure its effective utilization.

c. Data and Knowledge Discovery

An important trans-disciplinary challenge identified by participants is the need for new information about different groups that comprise the public and multiple means of data collection. Within the hazards and disaster research literature, there is still a great deal of information to be learned about understudied or misunderstood publics and how they receive, interpret, and act on weather warnings and forecasts. In particular, vulnerable populations, such as transient populations or those who speak a primary language other than English, are often overlooked or are difficult to access in the transitory nature of extreme weather. In order to develop effective communication strategies in the forecast and emergency management arena, then, participants noted that the community needs to collect more data—about varied risk perceptions, socioeconomic obstacles, unique needs and decision making processes. Participants emphasized the need to understand what people do now and *why* they do it that way. There are different ways to think about "appropriate behaviors," depending on one's context, social capital, access to resources, and cultural background. Further, there needs to be systematic and sustained mechanisms for data collection and transparent means of sharing this knowledge with each other.

For researchers across the SBE landscape, these data are valuable not only in what they reveal about the different populations in the United States but in the ways they encourage the use of new and innovative data collection techniques. Collecting rainfall rates from windshields, for example, or using remote sensing techniques to collectively map disaster areas are a few cited examples. In terms of traditional mechanisms, survey work is important and offers valuable information that can be generalized, but participants also identified gaps in understanding that could be addressed by longitudinal studies, in-depth narratives, and participatory research. Workshop participants noted the funding and collaborative challenges of working across longer timeframes of a decade or more. Still, participants acknowledged that a deep or "thick" understanding of specific populations, issues, and events can contribute to more meaningful changes in policies and operational decisions. Drawing on the broadest range of methodologies will help reveal the nuances of various communities and their vulnerabilities.

Equally important are mechanisms that help effectively represent this information for decision makers. Participants suggested that understanding more about decision thresholds of professional and practitioner groups is an important but less studied focus of SBE research. Knowing as much about the complicated and varied issues faced by those in these expert groups—comprised of policy makers, emergency managers, and public officials—is equally important. What forms of data are most helpful in navigating uncertainty in extreme events, and what should this data look like to best capture the multilayered needs of those populations professionals serve? The ability to overlay several data sets in a mapping software could be compelling in showing emergency managers where to target their assets or where first responders will likely need to go first. That is, while an important focus of SBE research is on different publics, a similar emphasis needs to be extended to expert communities all along the warning process.

d. Research to Operations Transition

As with other workshops in the weather enterprise, this workshop highlighted the challenge of ensuring that this new knowledge discovery gets translated into the operational setting. It is still unclear the best ways to move from research to operations. Thus while participants identified new knowledge, better instruments, and open source sharing as key goals for future collaborations, ensuring that such information can be

operationalized is key. What are the problems, challenges, and success stories for translating research into practice? Where are the best points of entry and how can these considerations be built into research designs early in the process? Participants toured the Hazardous Weather Testbed and were made aware of the valuable research conducted there, but it was unclear how disciplinary insights could meaningfully be translated into such a framework.

Although moving from research to operations is a fundamental step to success in SBE research, participants also highlighted the opportunity for operational challenges to inform research questions. What issues do expert and professional groups face in the creation and dissemination of weather forecasts and warnings? What technological, cultural, and policy obstacles do they face? How can SBE research become embedded in operations in meaningful ways and how can SBE scholars work with these expert and professional groups to better understand and address their challenges? To this end, many participants encouraged an emphasis on a two-way dialogue between research and operations.

e. SBES Disciplines in Collaboration

Developing a deeper understanding of each other's methodologies, creating frameworks for sharing instruments, and using open source databases across disciplines were all identified as keys to better facilitation of collaborative research across SBE disciplines. Many participants highlighted difficulties in knowing where there are overlaps or shared research interests across disciplines. Learning about scholarship outside one's disciplinary domain takes time, and the mechanisms that enable quick but meaningful understanding of each domain's norms and cultural values doesn't exist. Building a community of practice that facilitates this exchange of research methods, instruments, and world views would help minimize time needed to develop an understanding of different disciplinary standards and would, instead, focus trans-disciplinary groups on developing common research priorities. It would likewise promote sharing of information between expert and professional groups who have valuable insights to contribute to problem definitions. Several participants pointed to the need to expand the current group from academia and operations to include other sectors and community leaders, such as political, secular, and religious groups.

Similarly, fruitful research partnerships necessitate exposure to different definitions of success and the metrics used to account for it. While one group may measure success in terms of a decrease in the number of fatalities during an event, others may count the number of lives saved – or the number of people reached with a particular hazard communication. Thus, in the same extreme weather event metrics for success can vary widely. It is not merely enough, then, to acknowledge methodological and achievement differences; participants expressed concern that variance in disciplinary approaches and frameworks be discussed and respected. Thus, the content of disciplinary expertise and the disciplinary norms and values of research practices are equally important to collaborative success.

Beyond the methodological differences, another concern is knowing what kinds of studies have already been completed and what those insights tell us about what work still needs to be done. Perhaps one of the strongest suggestions from participants is to develop a repository where they can share their own work, as well as disciplinary literatures that inform those studies. This would allow researchers to move beyond the silos of their own disciplinary perspectives and encourage more transparency in how problems get defined and those that have received attention. Sharing collective research gaps through a repository that can be contributed to by group members would help problems get defined in more complex and inclusive ways. Developing deeper relationships with scholars across disciplines will further enable a quicker response to transdisciplinary funding calls and to disasters that require immediate action and collection of data for later analysis. Participants emphasized the importance of interdisciplinarity but recognize the need to have relationships and disciplinary understanding in place before extreme weather strikes. This kind of ongoing partnership leads to true collaboration on multiple levels.

f. Engaged Communities and Place-Based Work

The place-based nature of extreme weather necessitates that researchers consider a multiplicity of tools and approaches that best match particular group needs, their vulnerabilities, and their cultural differences.

Although participants' disciplinary and sector expertise became a central thread of discussions in the context of collaboration and cooperation, breakout sessions and presentations focused on the need to consider the expertise and interests of the communities in which SBE scholars work. How

can researchers connect to communities in concrete ways? How can we build community interest in SBE research efforts? And are there opportunities to leverage citizen science, coalitions, or crowd sourcing? The emphasis here came from the sentiment that there is a disconnect between work that is being done from a more top down, disciplinary and bureaucratic way and what communities are doing at a grass roots level. The value of exploring those boots-on-the-ground success stories brought about by local Boy Scout Troops or civic volunteers cannot be overstated.

Leveraging local and national initiatives and building capacity in communities at various scales demands attention to efforts outside officially recognized mechanisms; but it also presents an opportunity to operationalize what participants felt were underutilized concepts in existence already, such as Weather Ready Nation Ambassadors. That is, in the context of Weather Ready Nation, participants sought ways to make strategic goals more concrete and meaningful to different publics and wondered how research in SBE might inform these efforts.

6. KEYSTONE RECOMMENDATION

One overriding outcome emerged from the workshop that serves as a keystone recommendation. Specifically, as noted previously, a recurring theme within the LWEW workshop was the need for a structured framework or facilitation mechanism to coordinate the many activities needed to realize the component of the WRN vision involving social sciences.

To this end, as an initial step, the LWEW organizers are creating a special "community" within NOAA's Virtual Laboratory (VLab) environment to foster networking and collaboration. Many of the recommendations from the LWEW participants are being incorporated into this web-based service, including the creation of a repository of relevant work, a networking portal, and several other devices to continue growing the community. This includes providing assistance in the evaluation of solicitations as well as in the development of grant proposals. This VLab service is being developed and supported by NSSL.

The other principal step toward addressing the call for a structured framework involves an administrative construct described in the next section.

7. RECENT ACTIVITIES AND NEXT STEPS: CREATING A NATIONAL ALLIANCE

a. Concept

Subsequent to the workshop, and as a major action related directly to the Keystone Recommendation described previously, the organizing committee developed and shared with workshop participants the concept of creating a [1]*National Alliance for Social Behavioral Systems and Extreme Environmental Events* (provisional name). Based upon input received and funding already secured (see below), we plan to proceed with establishing the Alliance.

Use of the alliance construct, in the context of a *national activity*, is intentional and vital – in contrast to the more traditional notion of a local center or institute – for emphasizing the fact that the Alliance will serve as a *community-based, inclusive convener and facilitator of an array of activities on a national scale rather than a location where work is performed to enhance the stature or capabilities of a single institution*. The national alliance concept also embodies the ability, similar to that of a consortium, to create new and innovative partnerships among government, academic, philanthropic, and corporate entities to stimulate and support the pursuit of potentially transformative ideas *that would be difficult or impossible within the traditional government/academic framework*.

Second, although the National Alliance will focus on challenges specific to individual disciplines as well as those residing at the boundaries among them, it will do so in the context of a *social-behavioral systems-level approach*, whereby the physical science, technology, and social-human elements are intertwined within a broad and complex ecosystem that must be understood on multiple levels to ensure effective operational implementation.

Third and finally, the National Alliance will emphasize the study of extreme environmental events, though *initially with a focus on tornadoes and their parent storms and storm complexes*. This approach will allow full leveraging of the knowledge base of extreme events across a broad array of environmental phenomena while focusing initially on a very specific and challenging

[1] No compelling reason exists to limit Alliance activities to the United States, and thus attention is being given to make the Alliance international in scope and participation.

phenomenon that is relatively rare in occurrence but notably significant in its impact.

With that preface, the mission of the National Alliance is envisioned as follows:

> *With a role of serving researchers and operational practitioners across the nation wishing to collaboratively study challenging problems at the nexus of social/behavioral/economic sciences and extreme environmental events from a systems perspective, the Alliance helps organize, facilitate, and resource such collaborations, and also works to ensure sustained progress, with a strong emphasis on scholarship, experimentation in operational settings, and the rapid translation of research outcomes into operational practice.*

b. Guiding Principles

In creating the Alliance, particularly one that engages challenges at the boundaries of traditional academic disciplines and involves many numbers as well as types of organizations, a set of guiding principles is especially valuable. Those for the Alliance are as follows:

a) An intellectually stimulating, creative, and vibrant *national framework* that brings together researchers from multiple disciplines and institutions to attack some of the most challenging, societally relevant problems at the nexus of extreme weather and SBES using a *systems approach*;
b) Reliance upon *traditional funding* mechanisms (e.g., Federal grant agencies) to study notable research challenges in extreme events (e.g., tornado dynamics, convective initiation, predictability, data assimilation, numerical prediction, community resilience and preparedness, response to life-threatening situations, hazard mitigation);
c) Utilization of *private and philanthropic funding*, facilitated and promoted by the Alliance, to address challenges for which traditional funding mechanisms would be inappropriate or unlikely to find a receptive audience;
d) Emphasis on *human-centered design, rapid prototyping, experimentation, a systems approach, and community engagement* involving faculty, researchers, students, and practitioners;
e) The rapid and effective *translation of research outcomes* into practicable solutions for improving safety and saving lives, and quantitative measurement of the associated impacts; and
f) New strategies for *recruiting and educating students* at the boundaries of traditional disciplines, leading to a new generation of researchers and practitioners.

c. Administrative and Programmatic Structure

The Alliance will be housed in a prominent location within a Partners Place building on the University of Oklahoma Research Campus to ensure maximum synergy with the National Weather Center's University, NOAA, and Department of Interior programs. *Critical to the concept of the Alliance, and the effective execution of its national mission, is a cultural environment that promotes intellectual vitality, unbridled creativity, unencumbered exploration, the ability to rapidly test and evaluate new ideas and technologies, and an ability to fully leverage unique resources such as NOAA's Hazardous Weather Test Bed as well as resources at other institutions across the nation*.

The Alliance will be overseen by a visionary, enthusiastic and highly credentialed *Director*, who will have overall responsibility for the success of the Alliance and its programs. The Director will be hired by and report to the University but be advised by a Steering Committee co-chaired by an individual from the University, and by an individual drawn from the national community. The Steering Committee will comprise eminent and visionary leaders and stakeholders in academia, government (as allowable) and industry drawn from organizations nationally. In order to direct as much funding as possible toward meeting the Alliance's mission, administrative and clerical staff support will be provided from existing resources to the extent possible, and augmented as necessary. In addition to the Alliance Director, the Alliance will support a Director of Research and a Director of Partnerships.

The *Director of Research* will be responsible for stewarding the research portfolio by engaging the national community to identify and understand the most important issues to be addressed, facilitating the pursuit of funding, assisting with building collaborative teams across disciplines and organizations nationally, and drawing upon input from all stakeholders, especially those with operational responsibility. Research Theme leaders (see below) will coordinate activities for a

given theme and work collaboratively on mechanisms for cross-theme integration.

The *Director of Partnerships* will be responsible for creating partnerships, and building the funding portfolio via leveraging, with Federal, corporate and non-profit organizations nationally. This Director also will market the Alliance and its activities, demonstrably promoting the value of partnerships and leveraging of funding from all sectors. Critical to this position is the ability to thoughtfully and effectively articulate the nature of the challenges faced by society owing to extreme events, the importance and uniqueness of the approach taken by the Alliance, the value of partnerships in executing the Alliance's mission, and the tangible outcomes produced by the Alliance. Partnerships could take a variety of forms, ranging from philanthropic investment and co-funding of research projects to involvement in creating new technologies and licensing the associated intellectual property.

Perhaps the most important aspect of the Alliance will be its role as a facilitator of creative activity with a *national* scope. Consequently, the Alliance's programs must reflect this role and will do so via the following:

- Developing and maintaining an **online system for facilitating effective interaction** among Alliance participants that continues to build a broad and engaged community, enhances awareness and understanding of research capabilities and needs across disciplines, serves as a portal to past research results (reports, articles, videos, publications) data sets and grant awards, creates greater awareness of tools and research approaches, facilitates the identification and sharing of challenges and research questions, and hosts webinars and online forums;
- Providing **seed and travel funding for the development of interdisciplinary collaborations** and for **exploratory** activities. In this manner, the Alliance serves not as a source of funding for research *per se*, but rather as a mechanism for helping create the collaborative, multi-disciplinary teams, resources, and initial results needed to pursue and capture grants and contracts by Alliance participants;
- Providing information not only about **funding opportunities**, but also **supporting analyses** that translate such opportunities across disciplines and pinpoint possible methods for engagement. The Alliance also assists researchers in actually developing competitive proposals and conducting pre-submission reviews to maximize competitiveness;
- Working closely with the **Hazardous Weather Test Bed** to expand its activities in the SBES arena and provide specific opportunities for engagement by Alliance participants;
- Bringing substantial emphasis to the development and testing of **FACETs** as an important initial focusing activity for Alliance participants;
- Promoting university **curricular innovations**, at both the graduate and undergraduate levels, at the nexus of SBES and extreme environmental events, including online courses and the development of mentors for both academic as well as research programs;
- Facilitating and funding **student and faculty exchanges** among Alliance institutions; and
- Serving as a mechanism, in collaboration with existing organizations (e.g., American Meteorological Society, Consortium of Social Science Associations) by which the community can effectively inform policy planning, help set **priorities and create/define opportunities** rather than only respond to them, and advocate for research **funding**.

d. Research Agenda

The research agenda of the Alliance will be *tightly focused* and crafted around themes which *integrate* the physical science, engineering, and technology domains with the social, behavioral and economic sciences. Guiding the agenda will be *key questions* that can only be addressed via an integrative approach, with research outcomes used to feed *technology incubator test beds (see below)*. Such questions are numerous, but fortunately, the workshops held to date have provided such questions with recommended strategies for addressing them.

Functionally, the research framework can be envisioned as shown in Figure 2, with a number of parallel research themes complemented by *test beds* that *automatically and meaningfully link the themes together* in a crosscutting manner, and in

so doing focus the research toward tangible goals and move outcomes into practice.

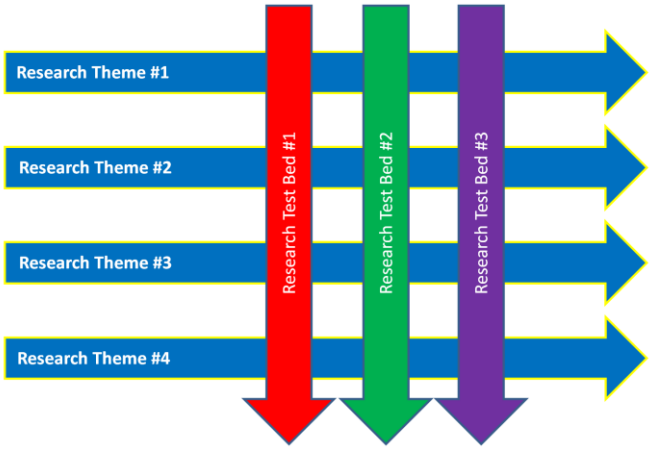

Figure 2. Conceptual research framework for the Alliance.

e. Uniqueness, Expected Benefits and Impacts

The National Alliance, with its emphasis on a systems approach and tight integration of the social-behavioral-economic sciences, will be unique to the extreme weather community. Among its many benefits is the fact that it will provide a formal, community-based mechanism for facilitating a variety of activities and ensuring focused, sustained progress on important problems at the nexus of SBES and extreme environmental events.

Although the Alliance necessarily must have an institutional home, it will operate as a physically distributed, virtual organization that involves participants spanning vast geographic and disciplinary domains. Additionally, the Alliance will provide practical services to researchers that heretofore have been unavailable (e.g., online collaboration system, solicitation analysis, proposal development and pre-submission review services, funding to build collaborative teams and generate early results), but which are essential for effectively engaging the nation's research enterprise in addressing the challenges cited previously.

Finally, the Alliance will serve as an organic framework for developing and continuously updating community research priorities and suggesting courses of action in funding and policy.

f. Initial Funding

To launch the Alliance and underpin the development of other support mechanisms that will help ensure long-term viability and excellence, significant initial funding already has been secured, with an announcement forthcoming. A program development team, drawn nationally from workshop participants, will draft a detailed structure and execution plan for the Alliance, taking into consideration the input received on the draft that was shared with workshop participants in late fall, 2015. It is hoped the Alliance will formally be established by summer, 2016.

6. ACKNOWLEDGMENTS

The Living With Extreme Weather Workshop was funded by grant NA11OAR4320072 from the National Oceanic and Atmospheric Administration (NOAA) to the University of Oklahoma through the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), and by the Office of the Vice President for Research at the University of Oklahoma. The authors gratefully acknowledge the assistance of Randy Peppler and Tracy Reinke of CIMMS, Linda Crank of the NOAA National Severe Storms Laboratory, Amy Tougas, Gabe Wingfield, Susan Dubbs, Michelle Wells, and Melany Dickens of the Office of the Vice President for Research, University of Oklahoma, and Jennifer Sprague of the NOAA Office of the Chief of Staff. Discussions with Dr. John Cortinas, Director of the NOAA Office of Weather and Air Quality, were vitally important to the success of the workshop and to follow-on activities.

7. REFERENCES

Demuth, J.L. and Co-Authors, 2007: WAS*IS: Building a community for integrating meteorology and social science. *Bull. Amer. Meteor. Soc*, **88**, 1729-1737.

Hoekstra, S. and Co-Authors, 2011: A preliminary look at the social perspective of warn-on-forecast: Preferred tornado warning lead time and the general public's perception of weather risk. *Wea. Clim. and Society*, **3**, 128-140.

Karstens, C.D. and Co-Authors, 2015: Evaluation of a probabilistic forecasting methodology for severe convective weather in the 2014 Hazardous Weather Testbed. *Wea. Forecasting*, **30**, 1551–1570.

Lindell, M.K. and H. Brooks, 2012: Workshop on Weather Ready Nation: Science Imperatives for Severe Thunderstorm

Research, Held 24-26 April 2012 in Birmingham, AL, 99pp. Available from http://www.nws.noaa.gov/com/weatherreadynation/files/WRN_FinalReport120917.pdf.

NOAA, 2012: Weather Ready Nation: A vital Conversation on Tornadoes and Severe Weather, March, 2012, 20pp. Available from http://www.nws.noaa.gov/com/weatherreadynation/files/WRN_Vital_Conversation032912.pdf.

NOAA, 2013: *Service Assessment: May 2013 Oklahoma Tornadoes and Flash Flooding.* US Department of Commerce, National Oceanic and Atmospheric Administration, 42 pp. Available from http://www.nws.noaa.gov/os/assessments/pdfs/13oklahoma_tornadoes.pdf.

NRC, 2006: *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Research Council, National Academy Press, 112 pp. Available from http://www.nap.edu/catalog/11699/completing-the-forecast-characterizing-and-communicating-uncertainty-for-better-decisions.

NRC, 2010: Facilitating Climate Change Responses: A Report of Two Workshops on Insights from the Social and Behavioral Sciences. National Research Council, National Academy Press, 174pp. Available from http://www.nap.edu/catalog/12996/facilitating-climate-change-responses-a-report-of-two-workshops-on.

NRC, 2014: Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. National Research Council, National Academy Press, 152pp. Available from http://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering.

NWS, 2013: *Weather Ready Nation Roadmap* (Version 2.0). NOAA National Weather Service, 81pp. Available from http://www.nws.noaa.gov/com/weatherreadynation/files/nws_wrn_roadmap_final_april17.pdf

Ripberger, J. and Co-Authors, 2014: Social media and severe weather: Do tweets provide a valid indicator of public attention to severe weather risk communication? *Wea, Clim. and Society*, **6**, 520-530.

Ripberger, J. and Co-Authors, 2015: The influence of consequence-based messages on public responses to tornado warnings. *Bull. Amer. Meteor. Soc*, **96**, 577-590.

Rothfusz and Co-Authors, 2014: Forecasting a continuum of environmental threats: Exploring next-generation forecasting of high impact weather. *Eos, Trans. Amer. Geophys. Union*, **95**, 325–326.

Schultz, D.M. and Co-Authors, 2010: Decision making by Austin, Texas residents in hypothetical tornado scenarios. *Wea. Clim. and Society*, **2**, 249-254.