NCAR
Weather and Society Watch
A Publication of NCAR's Societal Impacts Program (SIP) Volume 6, Number 1 January 20, 2012

WSW Special Issue
Socio-Economic Research to Build a Weather Ready Nation

Introductory Remarks by Jeffrey K. Lazo*

Last year the United States experienced perhaps one of the worst years on record with respect to weather impacts on society. 2011 was also unusual compared to some other years in that these events were widespread in terms of type, location, and societal impacts and not largely focused on a single landmark event such as a Katrina. Depending on who is doing the counting, the country experienced 12 disasters exceeding a billion dollars in damage each, with something near 1,000 weather-related fatalities. The count of billion dollar events in 2011 includes a blizzard, a wildfire, a drought, a hurricane, two floods, and six tornadoes (http://www.ncdc.noaa.gov/oa/reports/billionz.html).

In addition to significant numbers of fatalities and injuries, the societal impacts include burnt timber, houses and other buildings, and crop losses from the Texas, New Mexico, and Arizona wildfires; fallen trees and power lines, flooded areas, and socio-economics losses from business closures from Hurricane Irene; evacuations, breached levees, damaged buildings and crop losses from the Upper Midwest and Mississippi River flooding; direct losses to crops, livestock and timber, and indirect losses to related businesses and communities from the Southern Plains / Southwest drought and heatwave; the diverse social and economic impacts in Chicago from the Groundhog Day Blizzard; and the extensive wind and hail damage to buildings, vehicles, and infrastructure from the six tornado outbreaks (April 4-5, April 8-11, April 14-16, April 25-30, May 22-27, June 18-22) across at least 22 states (AL, AR, GA, IA, IL, IN, KS, KY, LA, MN, MO, MS, NC, NE, OH, OK, PA, SC, TN, TX, VA, and WI). In addition are the socio-economic costs of response to all of these events, as well as the social/psychological and ecological/ecosystem impacts that don't normally get counted as "economic" impacts.

I would wager that most if not all of these events were reasonably well forecasted and warned for. I would also wager that feasible near-term improvements in forecast skill for most of these events would not have significantly reduced the social or economic impacts and would not have appreciably saved lives or reduced injuries.

I would further wager that a much greater return on investment—measured in terms of lives saved and damage avoided—could come from research, applications, and operations to improve the communication, understanding and response to forecast and warning information than could come from research to improve forecast skill, false alarm rates, or even lead time.

But what is that type of research? Who does it? How is it done? What questions are asked, and how are they answered? How are they translated into actions or processes that will ultimately reduce the socio-economic impacts of wildfires, hurricanes, droughts, floods, and tornadoes?

This issue of *Weather and Society Watch* is full of articles of research and activities embodying the effort to improve the communication, understanding, and response to forecast and warning information.

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In This Edition

Ice on trees and snapped branches were a common sight in Corpus Christi, Texas, on the morning of February 4th, 2011. (Courtesy: NWS Corpus Christi)

For more about the rare Texas winter storm and National Weather Service communicaton during the event, please see the winter storm article on page 18.

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Drobot and Chapman discuss (not so distant?) future intelligent transportation systems of which the Vehicle Data Translator (VDT) program is a part. Their work combines meteorology (weather observations and forecasting), technology (in-vehicle sensors and real-time communication and warning systems), and applied user-needs assessment (a survey of what information travelers find most interesting for inclusion in future vehicle information systems). Among other things, this work illustrates how solutions to real world problems require innovative partnerships between and support from multiple stakeholders such as the AMS, NCAR, and the Federal Highway Administration (as well as private sector support from the automotive industry). Given the high number of weather related accidents, such work may well do more to reduce weather related injuries and fatalities than much more high profile efforts within the meteorological community focused on "improving the forecast."

In their thoroughly referenced article, **Klockow and Peppler** present an excellent overview of how a variety of existing theories and approaches can help us better understand the decision making of individuals threated by a tornado hazard (approaches likely applicable to any weather hazard communication). Based on extensive field work and interviews with survivors of the Alabama and Mississippi tornadoes last Spring, the authors discuss place based understanding as part of an approach to understand survivor's behaviors – blending among other approaches concepts from geography, anthropology, and risk psychology. Klockow and Peppler point out that ex post judgments of other people's decision making is often based on external perspectives and preconceptions and not necessarily on a valid understanding of the decision process or ecological conditions of the decision maker. They briefly discuss a range of theoretical approaches and prior studies that can help develop a better understanding of these behaviors beyond simply thinking that "those stupid people in the public sure think some crazy things." It is hard for me to emphasize how important it is for the weather community to support and embrace the approach advocated by Klockow and Peppler of building upon the diverse and solid foundation of existing knowledge from the social sciences about decision making, communication, and risk response behavior.

Casteel and Downing provide an interesting discussion on communication of severe weather with mobile communication methods. They explain and identify some of the potential and limitations of mobile warning methods, especially with respect to the Commercial Mobile Alert System currently coming online. Their discussion of the potential advantage of pushing messages to non-smart phones raises interesting questions about the efficacy of mobile methods to reach vulnerable populations. Many of the issues and questions, explicit or implicit, in their article beg for some good empirical research.

League, Philips, and Bass present results from their Tornado Warning and Technology Survey of emergency managers (EMs). Recognizing the critical link EMs play in the warning and response system, these Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) researchers are using well-formed research methods to inform the development and application of new radar technologies. This effort is one of the few projects anywhere underway to integrate a social science-based understanding of end-user needs into a meteorological research and development program.

Losego, Galluppi, Montz, and Smith also investigate the information needs of emergency managers – more broadly defined using an EM support function taxonomy. Their work also extends to school administrators. Using case studies, in-depth interviews, and surveys, they are assessing information needs and decision making with an eye to developing decision support tools. Their work seems to nicely complement League et al.'s with EMs.

Riley's article is another example of the application of qualitative methods to assess information needs, this time with respect to climate. She interviewed a number of decision-makers on current and potential impacts of climate change and their associated decision making with a goal of assessing their information needs. This discussion ties closely with weather issues as climate is experienced as weather, and perceptions of climate change must be assessed in the environment of weather variability. Many of the results and research needs she identifies are equally applicable in the weather context.

Nichols and Hoekstra represent one of the only extant other projects attempting to assess, understand, and integrate end-user needs as a primarily meteorological program ensues (Warn-on-Forecast). Their focus on educational institutions (K-12 and universities) connects with key stakeholders to assess their information sources, needs, and decision making processes. Such work can not only inform the meteorological research and development but ultimately helps connect with user communities as the program proceeds, perhaps to make them better prepared as new informational tools are developed.

And finally (leaving the "hardcore" operational meteorologists to last but not least), **Goldsmith, Codero and Metz** discuss efforts to provide more usable information during an ice storm in south Texas in February 2011. Embodying the objective of serving the users, the Corpus Christi and Brownsville offices used a range of technologies and practices to get the information out on a rare winter storm in an area normally ill-prepared for such an event. Using webinars, emails, social media, YouTube and other channels (in additional to traditional ALL-CAPS), these efforts represent a paradigm shift to decision support.

One of the most significant messages I got from the recent Weather Ready Nation Workshop and Symposium in Norman, Okla., last December was that to meet the goals of a Weather Ready Nation, social science research (and this includes all the social sciences) is critical. (See http://www.joss.ucar.edu/events/2011/weather_ready/information.html). The articles in this issue give a flavor of the type of research that is being and can be undertaken—yet it is still very limited, and we have a long way to go to help meet the goals of the workshop (and the broader community) "to improve the nation's resiliency against severe weather, especially tornadoes, to protect lives and property."

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Driving the Future

Mission Possible: Improving Driver Safety and Mobility with the Promise of Connected Vehicles

by Sheldon Drobot* and Michael Chapman**

For those of us working with Intelligent Transportation Systems, the recent Mission Impossible movie had a particularly alluring scene where Ethan Hunt and his passenger used a tactile heads-up display to route through traffic. Futuristic? Yes, but not as much as you might think. Since 2009, the University Corporation for Atmospheric Research's (UCAR) National Center for Atmospheric Research (NCAR) has worked with the U.S. Department of Transportation's (USDOT) Federal Highway Administration (FHWA) and Research and Innovative Technology Administration (RITA) to develop a Vehicle Data Translator (VDT) program that ingests, parses, processes, and quality checks mobile data observations (e.g., native and/or external) along with additional ancillary weather data (e.g., radar, satellite, fixed observations, and model data). The VDT then provides "road weather hazard" information, such as slick roads or reduced visibility, which could be combined with traffic information and other data in a decision support system such as the one shown in the film.

Conceptually, the use of vehicle data is relatively simple (See Figure 1). Many vehicles already sense ambient environmental conditions, such as air temperature and atmospheric pressure. Additionally, one can conceptualize how windshield wipers might be indicative of some type of precipitation condition, while anti-lock brake activation could suggest slippery roads. Our research is aimed at taking this suite of data, combining it with traditional atmospheric measurements from radar, satellite, and surface stations, and then providing road weather hazard information to a variety of users. Drobot et al. (2010) and Chapman et al. (2010) provide in-depth discussions on the VDT and the road hazard algorithms.

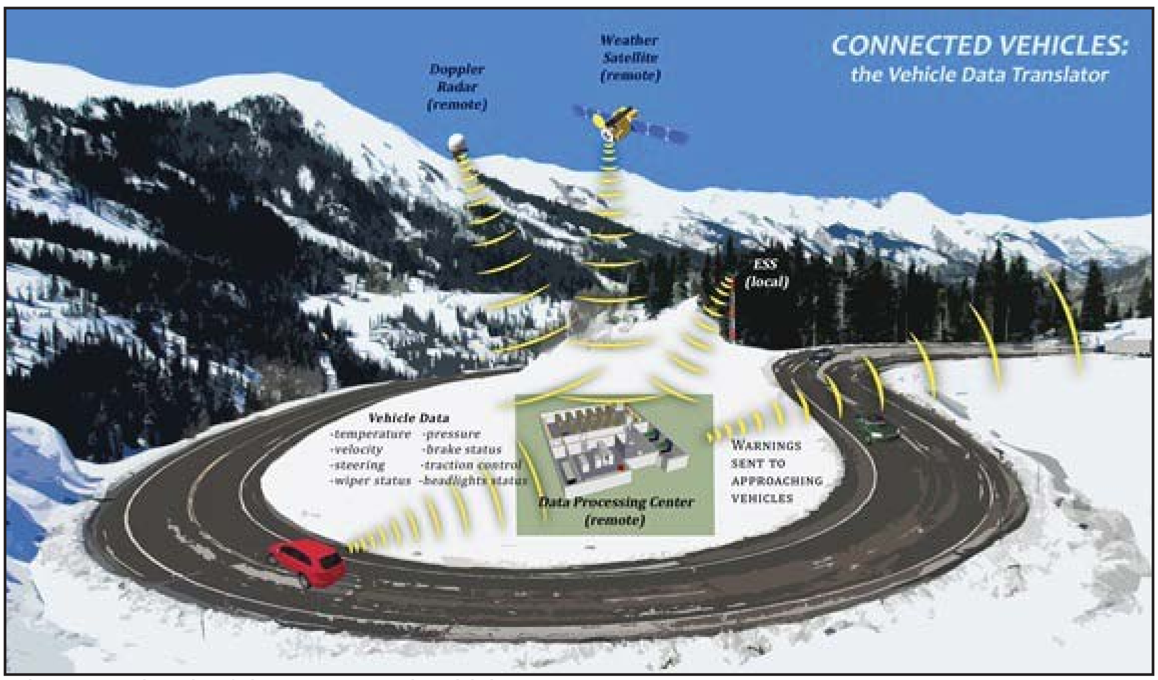

Figure 1. Sketch of the Connected Vehicle Concept

A critical component in developing these road weather hazard products is a better understanding of what the end user desires, and in what format they want that information. To address these questions, the American Meteorological Society (AMS) recently appointed an ad-hoc subcommittee with financial support from the FHWA Road Weather Management Program. The subcommittee subsequently developed a national driver preference survey targeted to approximately 1700 U.S. drivers. When provided with a list of new information types that are anticipated as being available in vehicles in the near future, respondents showed overwhelming support for most information types (Figure 2, online only). Road closure information is marginally ahead of local weather conditions and local weather forecasts in terms of responses in the 'very interested' and 'extremely' interested categories. Interestingly, weather conditions do rate of higher interest than traffic conditions, accident information, and routing suggestions. Parking and points of interest are not highly desired by the respondents. Moreover, when looking at the responses for 'not at all interested', local weather conditions and local weather forecasts have the lowest totals, with only 8% of the respondents showing no interest. For more details on the survey and other responses, please see AMS in the reference section (2011).

When assessing safety and efficiency on the roads, the traveling public already has access to several resources (e.g., 511 systems, traveler and/or traffic information). Although access to this information is becoming easier with increasing

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Driving (continued from pg 3)

coverage and speed of the Internet, smart phones, and in-vehicle telematics technology, the AMS survey results suggest travelers are not currently obtaining much weather information while on the road (AMS 2011). With the research and development of the VDT, practical road impact information will be generated and passed along to the traveling public through the various communications and telematics channels. The weather information (e.g., slickness, visibility, precipitation type/rate) will be specific to the road surface and can be directly pushed to communications infrastructure such as 511, in-vehicle communications, and smart phones (Figure 3). Outside content providers in the private sector can also use this information to provide tailored applications to the end-user including forecast traffic times, smart-routing, and forecasted road impacts and/or hazards.

How might this work in reality? Imagine the following scenario:

During an anticipated typical morning drive to work, Samantha embarks on her normal 30-minute commute. The morning is clear but cold. Along the commute, Samantha begins to encounter some light fog but the roads are dry and traffic is moving at usual speeds of 55-65 MPH. As she approaches a low river valley with a couple of small bridges spanning a river, an audible warning of "Slow Down—Slick Roads in approximately two miles" alerts Samantha from her radio warning system, and she begins to steadily slow down. A few seconds later another alert says, "Collision alert—1.3 miles… take next exit for re-routing," and Samantha heeds the warning. She takes the exit and is advised to re-route to another set of roads. She is told her expected time to her final destination will be delayed by approximately 20 minutes. She calls her work and lets them know that she will be in a few minutes late due to a wreck. After taking the new route, Samantha tunes into the local radio station in order to satisfy her curiosity as to what might have happened on her normal route. During the traffic report, the reporter explains that due to frost on the road and foggy conditions, four cars were involved in an accident on the viaduct and it is anticipated that traffic will be delayed by 1.5 to 2 hours. She is hopeful that everyone is okay, and relieved to have the connected vehicle re-rerouting information.

Over the last few decades, technology has advanced greatly. Yet, the way we drive our car today has not changed dramatically. With the coming revolution in connected vehicles, that is about to change. Hollywood is becoming reality. Get ready.

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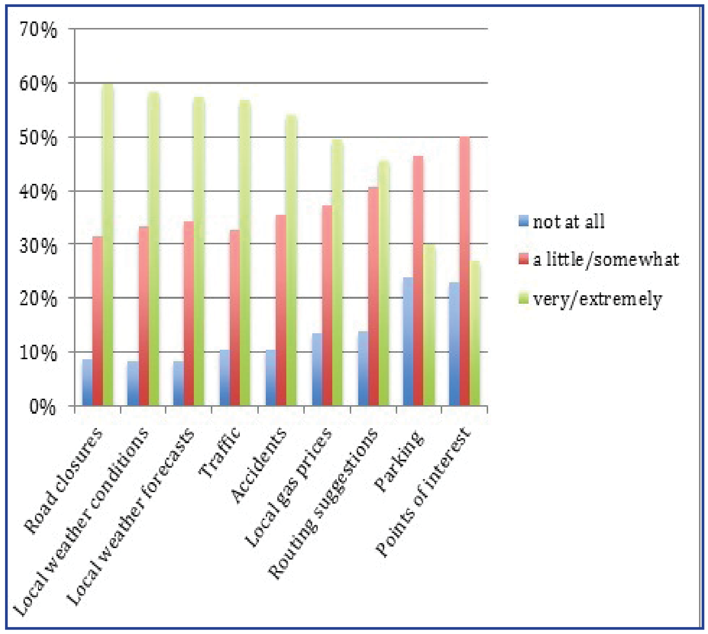

Figure 2. Interest level in various road and weather conditions for travelers

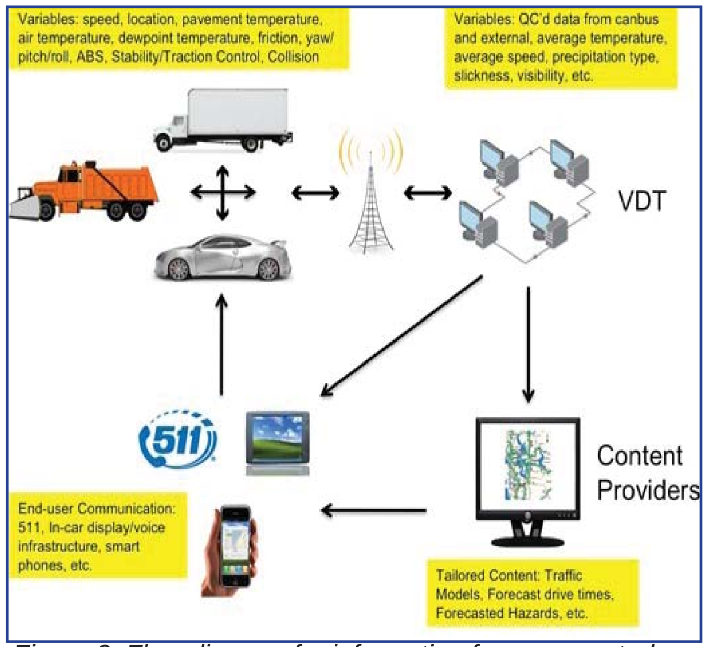

Figure 3. Flow diagram for information from connected vehicles and the VDT to the traveling public

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Folk science: Local understandings of the tornado hazard on April 27, 2011

by Kimberly E. Klockow* and Randy A. Peppler**

Editors note: Author Kim Klockow conducted the interviews (with the help of Sheldon Drobot—see acknowledgment at end of article) and refers to herself as "I" throughout much of the article. Author Randy Peppler worked with Kim to conduct the data analysis and write the article.

> "It was everything out of character for everything that I've ever known about tornadoes. In the 57 years I've been on this earth. I never dreamed that that tornado down there would come up here and flatten my house. And I certainly never dreamed that it'd stay on the ground over here."

With his right hand, one of my interviewees—we'll call him Bill—pointed toward the southwest, where a tornado originating outside of Tuscaloosa had carved a path through the pine trees straight toward him on April 27, 2011. He was clearly still astonished that the tornado made it all the way from Tuscaloosa to his suburb outside Birmingham, even though he had correctly identified the southwest as the direction from which tornadic storms typically come. "I think I got lulled into a false sense of security because nothing's ever happened here. Another thing, you don't expect a tornado to stay on the ground that long. Plus you don't know that a tornado can come up the hill along the ground and that tornado did it. They just don't do things like that—or didn't."

Previously in the interview, Bill told me that he'd watched the news footage from Tuscaloosa earlier in the day with his wife, shocked but not alarmed at what was happening. After a few minutes of watching, he went back out to his driveway to work on his motorcycle in preparation for a road trip the next day. This trip and its demands weighed far more heavily on his mind than the tornado occurring over 30 miles away. Disconnected from information, the first indication Bill had that the tornado was arriving (besides the sirens that he discounted "because his county is too large" for a siren to concern him) was the debris that fell around him as he watched in disbelief.

As we continued talking, Bill discussed his previous tornado experience, noting that a tornado had passed 3-4 miles to his north in 1998. Meteorologists know it's a matter of pure chance that Bill was not struck in 1998, and it seems logical that Bill would have counted this as a near miss, an important perceptual shade of gray facing the meteorologist's black-and-white tornado verification system, described by Barnes et al. (2007). Perhaps, also, it would be logical that Bill would conclude that tornadoes *could* hit him. But that's not what Bill took from the experience. Throughout the interview, what he was attempting to convey was that, to his understanding, tornadoes go "there," not "here," that hills stop tornadoes from pushing forward, that tornadoes over 30 miles away just won't stay on the ground to reach you. And he was still struggling to reconcile the inescapable truth that his understanding about tornadoes had been wrong. His disbelief had left him scrambling for shelter as the forest snapped behind him, and Bill, his wife, and their dog survived in the bath tub. His next-door neighbors were not as fortunate. And it turned out that Bill was lucky he had so little time—if he'd had more, he would have gotten into his earthen cellar that collapsed and was piled over in debris.

I couldn't go anywhere without hearing this type of story. Some beliefs were pervasive among many individuals across the states, and some were strongly attached to place. Almost everyone interviewed in and around the town of Smithville, Miss.—including city officials—believed that the SW-NE-oriented waterway just west of town shielded them from tornadoes. Only after the tornado began to cross the waterway did many citizens *personalize* the risk—it was at this point that they not only *believed* the tornado was happening (and most were very well aware of that as the tornado approached) but they internalized that it could happen *to them*. I heard some variant of the 'hills kill the tornadoes most of the time' story dozens of times, and Bill's view that "tornadoes go 'there,' not 'here'" was extraordinarily pervasive. In the rural town of Cordova, Ala., hit twice on April 27, several separate people reported a belief that a new highway strip called Corridor X was responsible for bringing the tornadoes *to* them. These beliefs apparently stuck out to the National Weather Service (NWS) Service Assessment (SA) team (NWS 2011), as well. In the SA (section 4.11.4.4, p. 35), the team labels these beliefs "weather myths," describing them only as "preconceived notions based on local, often erroneous, information regarding weather threats" that resulted in people discounting their storm risk. The team then noted that meteorologists ought to "consider identifying and dispelling local myth."

I admit that I'm not yet exactly sure what an ideal strategy should be for handling the phenomenon of "weather myths," but that is because I do not feel that the phenomenon has been clearly described, categorized, and explained. Until we do that, how can we know what, if anything, could be appropriate "to do" about "it"? Briefly here then, in an attempt to define and explain what these so-called "weather myths" might be, we introduce geographic theories about place and psychological theories regarding risk judgment and perception to Bill's story and a few types of "weather myths", varying by proposed tornado mechanism and/or place. These come from a larger set of 71 in-depth interviews conducted in Alabama and Mississippi following the April 27, 2011 tornado outbreak. We will use the term "folk science" instead of "weather myths" as it connotes a more positive description of the place-based and perhaps culturally-situated environmental knowledges that have been acquired and developed by people living in a place over a long period of time. This point of view is critical for framing people not as stupid or misinformed, but as empowered in their relationships to one another and to place.

The literature on place attachment (summarized recently by Smith and Cartlidge 2011) is vast, and can help us to frame the comments of Bill, the residents of Smithville, and others in their local contexts. For example, Relph (1976) described how one of the most basic aspects of human nature is the ability to develop emotional ties to place, with "home" seen as a place of refuge filled with

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particular life experiences; Tuan (e.g., 1977) famously explored the emotional bonds people make with places. This notion should be extraordinarily important for framing how people relate hazards to place (or fail to do so), a point we will revisit below when connecting the comments heard to risk theory. Low and Altman (1992) went further, describing how place attachment involves a complex interplay between emotions, beliefs, and actions centered on a place. Living in a place, therefore, is not simply a matter of surviving in it; additionally place becomes embedded in everything we do and is the foundation upon which we base our life's activity. The relationship we have with place surpasses the functional to encompass affective dimensions of the lived experience.

Similarly, place-based knowledge, including about the environment, is inherently "local", and the property of "localness" and the long-term, situated practices that generate "localness" (e.g., Steward 1955; Turnbull 1993; Huber and Petersen 1997; Nazarea 1999; Ingold and Kurttila 2000) provide a way of drawing distinctions between the insights emanating from different knowledge production systems (such as weather insights gleaned from living in a place and those produced by scientific research). In other words, putting yourself in the shoes of others—considering particularly where those shoes have been—greatly enhances your understanding of the notions people come up with to understand their world. While the study of place-based environmental knowledge, its local relevance, and the resulting intuition and meaning it produces often has been conducted in the context of Indigenous peoples (e.g., Basso 1996; Antweiler 1998; Berkes 1999; Menzies and Butler 2006), it also has been documented and studied within modernist settings (e.g., Danielson 1990; Strauss and Orlove, eds. 2003), and therefore it is instructive to study within our context in order to understand the local behavior that may result from it. Attachments to place, relationships in place, and knowledge generated in place undoubtedly played some role in how the people we talked to framed the tornado hazard as the storm moved into the environment near them. Through storm interactions with that local environment, people seemed to feel that the threat from the storm hazard would be lessened. If you come to see home as a place of refuge and stability, at least in a general sense, then seeing it as vulnerable could be antithetical and confusing.

The folk science documented in Alabama and Mississippi often took the form of socially negotiated knowledge, a hallmark of 'sense of place' formation—for example, the entire corridor of Amory–Smithville reporting a belief in the protective properties of the waterway, and reporting also that such knowledge was commonly accepted. Weather characterizes place, and lived experience in place, as much as surface characteristics; people live where the air and soil meet, thus, it is natural that weather (and interpreting it) should become a common focus for conversation (e.g., Danielson 1990). While these ideas explain some of the story, there are other elements of the quotes that might be better explained by looking to ideas from other traditions, such as risk psychology.

One of the biggest struggles for Bill, and a majority of the interviewees, was internalizing the possibility that a tornado could hit him directly. Believing there was a tornado was nothing compared to personalizing this risk to themselves. From outside the situation, this behavior could simply be labeled "denial," but the behavior actually falls into a broader class of heuristics people use to selectively filter, or attend to, information they receive (Gigerenzer and Gaissmaier 2011). People commonly color information coming in with their own brand of rosy glasses, attenuating certain risks and amplifying others with lenses such as risk characteristics (Slovic 1987), framing of the implications of the risk on lifestyle choices and social structure (Douglas and Wildavsky 1982), and projecting future states given selective and state-dependent information retrieval (Gilbert 2007, among numerous other perceptual lenses.

At first glance, Bill and others seem to rely heavily on normalcy bias, or the discounting of one's potential to experience catastrophic events—even in warnings (Donner, Rodriguez and Diaz 2007)—to make their risk judgments. Even this characterization could be a little unfair, however. Is it really a bias to heavily discount a tornado warning when less than 1% of the spatial extent of a warned area will experience a tornado, and approximately 70% of all tornado warnings turn out to be false alarms? Additionally, is it irrational to hypothesize links between local geographical features and tornado behavior when a majority of the tornadoes you've heard of conform to these beliefs? (e.g., most tornadoes are short-lived and the local area is hilly, so infer that hills kill tornadoes).

Given the information available to individuals, what we'd like to call "biased" behavior actually can be exceedingly rational and/or efficient from a memory perspective (Fiedler 2000; Dougherty, Gronlund and Gettys 2003; Gigerenzer and Gaissmaier 2011). While Bill had previously experienced a near-miss, was it irrational for him to believe tornadoes don't happen "here, at this very spot"? It is possible that gaining this insight into the way warnings work could make people adjust their personal risk assessments downward for not only tornadoes, but other risks as well. For example, Lazo et al. (2010) found that individuals who had experienced hurricanes in the past were less likely to prepare for future hurricanes.

In addition to cognitive dispositions toward risk, people also make use of subtle nonverbal, intuitive, and experiential rubrics as informational cues for formulating judgments and making decisions. This is known as the affect heuristic (Slovic and Peters 2006). Bill made vivid descriptions of the atmospheric conditions that day, noting that environmental cues were of primary importance in helping him to suspect that the day could be bad generally. He just "felt it in his bones," and he reported a dread-like sensation that was not sufficiently strong on its own to keep him in front of the television for a half hour, but served to keep him alert to weather conditions as he worked on his bike. These sentiments were very common, and are part of the reason that confirming a threat may be so important—people have a fundamental need to observe the threat, whether visually or by touch, smell or sound.

In addition to these senses, affect also includes emotional experiences. Emotionally processing risk information can change the way it is weighted in judgments (Slovic and Peters 2006). Notably, valence—or general type of emotion (like positive vs. negative)—are not predictive on their own; rather, according to the appraisal-tendency framework (Han, Lerner and Keltner 2007), each individual emotion evokes a particular need that is to be filled. Interestingly, an emotion such as fear, which might intuitively seem to put people into a thoughtless frenzy, actually drives deep mental processing and motivates protective responses. Thus, it may be important to understand how to best use fear as tornadoes approach. The attitudes of broadcast meteorologists in particular may be very important to shaping the emotional states of viewers, as reported at the 2011 National Weather Association Town Hall session in Birmingham. While viewers reported a desire to see someone calm and professional, they were reading the fear in the voices and actions of the broadcasters, and these feelings helped them to understand how dire the situation was. This is only a small portion of the literature worth exploring on emotion and affect in general; however, it is important to understand that judgment and decision-making do not occur outside of a fully embodied experience.

It is our hope that this brief introduction to a few relevant geographic and psychological theories stimulates some new lines of thought and discussion among those who are concerned with truly serving and protecting those in harm's way, lines of thought that do not revert to the mantra of "those stupid people in the public sure think some crazy things." Communication is an exercise in mutuality—in learning about the point of view of those with whom you are conversing. To be sure, if meteorologists are heard as they wish to be heard, they need to take some time to listen to—and interpret in an ecologically valid manner—what people are hearing.

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Acknowledgements

Sheldon Drobot helped conduct interviews in Alabama and Mississippi, and Angelyn Hobson transcribed the many hours of interview recordings. Funding was provided by the University of Colorado National Hazards Center Grant Program, funded by NSF CMMI1030670.

May 24, 2011, EF4 tornado just east of the I-44 interchange leading into Chickasha, Okla. (Photo by Scott Blair)

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Communicating Severe Weather to Mobile Stakeholders: Challenges and Future Trends

by Mark A. Casteel* & Joe R. Downing**

Momentous weather events have occurred over the past year. From the tragic and devastating tornados in Alabama and Missouri that set an all-time record in April, to the record heat and drought in the southwest, to the torrential rains caused by Tropical Storm Lee and Hurricane Irene, 2011 ranks as one of the most severe weather event years in recent memory. In Joplin, Mo. alone, the National Weather Service (NWS) Central Region service assessment team found that the tornadoes on May 22, 2011, were responsible for 159 deaths and over 1,000 injuries.[1] Further, a Dun & Bradstreet report estimated a loss of $3.3 billion in business sales. Further, EQECAT, which is a risk management company, estimated between $1 and $3 billion in insured loses. Given the potential of severe weather events to affect both life and property, it is imperative that the NWS continue its critical charge to inform the public in a timely manner about possible threats.

Historically, the NWS has been charged to disseminate watch and warning information both directly to the public (through weather radio and Web postings) and to their media and commercial partners, who then redistribute the information over a variety of media channels such as TV, radio, and the Web. Further, some commercial Web sites allow users who sign up to have the watch and warning information "pushed" to their cell phones using short-message service (SMS) text messaging. The advent of sending warning information to cell phones has been especially helpful to educate an increasingly mobile public. For individuals who are not near a TV, radio, or computer, the message is, instead, pushed to their cell phone. On the surface, at least, this appears to be a reasonable, and fairly low cost, method to get the word out.

Although SMS appears to be a reasonable and practical solution to keep the public informed, it has a number of shortcomings that make it a less than ideal solution. As many readers probably know, wireless communications can become bogged down during crises (as occurred during the East Coast earthquake in September), and sending many SMS messages only exacerbates this problem. Additionally, messages that also include graphics or hyperlinks can make a bad problem even worse, given the network bandwidth required to send graphics or to browse the Web. SMS can also be notoriously unreliable, with tests showing that up to 5% of messages are never received during heavy load events.[2] Finally, long messages get concatenated (spread over multiple screens). As a result, some message screens might appear out of order or be lost completely.

Within the past few years, a monumental change has occurred in the potential to distribute weather information more widely and rapidly, based on rapid advances in mobile technology. Cell phones are now ubiquitous in the United States, with the most recent statistics from the Cellular Telecommunications and Internet Association (CTIA, the non-profit organization supporting the wireless industry) showing a saturation rate over 100% (some people own more than one cell phone). Further, it is estimated that over 70% of these phones are "smart" phones that are capable of browsing the Web. Of course, with the advent of smartphones (as well as connected tablets) has come the ability to download weather-specific mobile applications (better known as apps). While almost all of these apps have the ability to show current weather and radar information for the user's location, some apps offer greatly expanded capabilities, such as event-specific information (golfing, beach outings, marine weather, and so forth). Many of these apps are also either free or low cost, making the access to weather information literally at one's fingertips.

Apps offer a great solution to those individuals who have a smartphone. Of course, not everyone owns a smartphone. Additionally, another consideration is that using the information available through the app requires the user to take the time to launch the app to get the information. This might seem a minor concern, but considering that most people feel that there is not enough time in a day to get everything done, it is not a stretch to imagine that many people do *not* check their weather apps regularly.

A critical technological innovation that is just around the corner (April 2012) may minimize some of the shortcomings associated with these existing technologies. In a unique collaborative approach, the federal government is partnering with the wireless industry to roll out an alerting system known as the Commercial Mobile Alert System (CMAS), which is a direct outgrowth of the Integrated Public Alert and Warning System (IPAWS), overseen by the Federal Emergency Management Agency (FEMA). CMAS is also sometimes referred to as Personal Localized Alerting Network (PLAN). CMAS/PLAN (hereafter referred to as CMAS) is unique in that it allows officials to send text-based emergency messages to wireless providers, who will then deliver those messages to their subscribers' phones. The phones do *not* need to be smartphones, although they do need recent software to receive the alert. There will be no charge to the subscriber to receive these messages since the wireless companies have absorbed these costs.

CMAS alerts will be one of three types: Presidential alerts, Amber warnings, and imminent threats, including those posed by severe weather. End users can opt out of the Amber and imminent threat alerts, but cannot opt out of receiving Presidential alerts. Although the message will look like a traditional text message, CMAS warnings are sent through cell broadcast technology (rather than the point-to-point technology used by SMS messages) and are distributed to *only* those cell users who are in range of a cell tower within the affected warning area. The messages do not require GPS and, as the messages are only sent one-way (from cell tower to phone), there are no privacy concerns about tracking individuals' phones. The geographically targeted nature of the CMAS message ensures that only those individuals within the warning area receive the alert. This will be especially helpful for those individuals who may be traveling or who otherwise are unfamiliar with their geographic location. Anyone who receives a CMAS message will know that he or she is in the affected area, and, one hopes, take protective action. CMAS messages will also be distinct from SMS messages by having a special distinct ring tone and vibration cadence.

A tornado shelter in rural Dekalb County, Ala. (Photo by Blake Beyea)

From a social science perspective, there are two interesting aspects of CMAS messages that raise questions about their effectiveness for the end user. First, based on recommendations from an advisory group, CMAS messages (at least in the initial iteration of these guidelines) will be limited to 90 characters, though cell phones are capable of handling up to 160 characters per screen. Information in the message will include the following elements: type of event, location of event, time frame and expiration of event, and a suggested action plan. An interesting (and presently unknown) question is how effectively a 90-character message will be at prompting the public to take appropriate and protective action. A second characteristic of CMAS messages is that such messages *cannot* include hyperlinks or clickable phone numbers. This prohibition was adopted for fear that many users would simultaneously access the information upon receiving the warning, thereby potentially crippling the wireless networks. This raises the question, of course, of whether the lack of a hyperlink will truly prevent those with smartphones from immediately launching a Web browser to search for additional information. These are not minor issues, and some have claimed that any federal mobile alerting system that does not include the newest technologies (hyperlinks, maps, multimedia content) is actually regressive. A rejoinder to this argument is that those individuals who might be the least likely to own a smartphone might be those also least likely to be tuned in to currently unfolding weather events and hence, most in need of at least a basic text alert. This is an advantage of CMAS in that it will work with any cell phone that has the updated software.

It is laudable that the federal government is trying to update their alerting technologies. Clearly, the goal here is to develop a messaging strategy that is designed to reach the most people. A number of questions remain, however, from both a technical and a social science perspective. We believe the most pressing questions to address concern the utility of the 90-character message itself; will it be sufficient at both *informing* the public and prompting appropriate *protective actions*? Also, will the public be receptive to alerts that provide nothing more than very basic information that begs for additional information? Indeed, these are empirical research questions that beg for an answer.

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Footnotes

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Tornado Warning Communication and Emergency Manager Decision Making

by Cedar League*, Brenda Philips** and Ellen J. Bass***

According to the Storm Prediction Center[1], 2011 is tied as the second deadliest year on record for tornado deaths with 552 direct tornado fatalities. The May 22 Joplin, Mo., tornado itself accounted for 158 deaths and over 1000 injuries. 2011's 12 natural disasters accounted for $1 billion or more in damages each[2].

Despite these losses, one positive outcome has been the countless examples of how these events have brought citizens closer, working together to rebuild their homes, their communities, and their lives. The weather enterprise has also come together to address the impacts of these events, and there is a timely opportunity to "strike while the iron is hot" to raise public awareness about severe weather threats, warnings, preparedness, protective action, and response.

The weather enterprise refers to the National Weather Service (NWS), emergency managers (EMs) and storm spotters, the media, and the private weather sector. An integrated warning system describes how these groups (ideally) work together to forecast, detect, and communicate severe weather threats to the public[3].

Emergency managers are an important link between the NWS, the media, and the public. EMs are responsible for communicating severe weather information and tornado warnings to the public on a regional, city, or neighborhood scale. This information is communicated through a variety of methods, such as activating sirens, notifying schools, hospitals and other critical services, activating the emergency alert system, cable television interrupt, social media, or a mass notification system.

Yet, communicating the uncertainty of if, when and where a tornado may occur is a challenge for EMs (as it is for the entire weather enterprise). Prior research indicates that social, environmental, and technological forces shape the organizational decision-making processes of emergency managers[4]. Emergency managers are also diverse in terms of their background, training, and access to resources; thus, there is no one size fits all approach to EM operations and decision-making[5].

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)[6] is conducting research that highlights the critical role EMs play in an integrated warning system while also informing the development of a network of low-power, high resolution, X-band radars. CASA's new technology has the potential to increase lead-time for tornado warnings through earlier detection, reduce false alarms, and reduce uncertainty in end-user decision-making. But in order to make advances in new technology most effective, a better understanding of end-users' needs and decision-making processes is needed, as well as the behavioural response to severe weather events.

Since 2007, CASA's End User Integration team, comprised of systems engineers, geographers, a resource economist, sociologists, a political scientist and meteorologists, has used a mixed methods approach including interviews, surveys, focus groups, observations, and part-task experiments with Oklahoma and Texas emergency managers. The goal of these studies includes identifying: 1) the types of weather warning systems used to disseminate warnings to the public, including the advantages and disadvantages of those systems; 2) EM warning practices including subregional warnings and preferred lead times for warnings; and 3) the use of weather products and storm spotters in EM decision-making.

CASA's End User Integration team recently conducted the "Tornado Warning and Technology Survey" with 125 Oklahoma EMs and 157 Texas EMs. Furthermore, focus groups were conducted with 55 Oklahoma EMs and 10 Texas emergency officials to uncover qualitative information and more in-depth detail about their warning and decision-making process during tornado events. Below are select findings from this research, including quotes taken from Oklahoma EMs during focus group sessions[7].

Warning Systems

Sirens (or outdoor warning systems) were by far the most prevalent warning system used by EMs. However, EMs noted several downsides to siren systems. Sirens are not meant to be heard indoors; however, some EMs sense that the public expects to hear them regardless of their location. Sirens also evoke confusion among the public: "*Our sirens have the capability where they can alert for tornadoes… high winds, chemical spills… they have different tones. But in our area, we do not do that because of the confusion that it can emit from the sirens… We sound them for tornadoes, not high winds*."

Emergency managers rely on multiple warning methods to reach different sectors of the public and to ensure redundancy in case a single notification method fails. They actively encourage purchasing of weather radios: "*We really promote those because that gets to people regardless of whether they are within earshot of the outdoor warning siren or not*." While EMs from smaller jurisdictions use mass notification systems to disseminate tornado warnings, those in larger jurisdictions find these systems too limiting with respect to call rate, and it would take far too long for all of the messages to be sent.

Subregional Warnings

With the NWS's move to storm-based or polygon warnings, the CASA team investigated EMs' subregional warning capabilities. While less than half had the capability, even fewer were actually using it. One risk averse EM noted, "*If we sound the sirens, it's* *for everybody*." Other EMs said they are simply too busy to make a decision about warning a smaller area of the public. Some EMs are also concerned about over-warning the public, which they believe prevents the public from taking protective actions.

Timing of Warnings

As some EMs are risk averse, while others are concerned about over-warning, the issue of EM tornado warning dissemination is critical. EMs do not always activate the sirens following an official NWS warning and will sometimes activate even if an official NWS warning is not in effect. As one EM noted, "*No, I do not send out warnings automatically just because I'm included in the warning area… I consider warning areas, but I also want to make sure there's an imminent threat because we found that if you put out too many warnings, people become complacent, and also if you put out a warning too early, then they don't react in the way that we want them to*." Another stated "*If I can see something, if I've got eyes on something… we will always err on the side of caution*."

Warning Lead Time

The team investigated the EM's ideal lead time to issue a tornado warning. There was some consensus for twenty minutes: "*Twenty minutes would be really nice… We can do what we need to do. If you're not going to do what you need to do in 20 minutes, forget it.*" One EM wanted more than 20 minutes lead time in order to prepare for an event; however, he did not want to give the public any more than 20 minutes, as he believed they would go out and do something careless.

Spotters

The majority of Emergency Managers rely on storm spotters as their "eyes on the ground" to verify severe weather. Spotters are typically public works or SkyWarn volunteers. While spotters are a critical component of EM decision-making, one EM notes, "*One of the problems you find with spotters is nightfall. Once it becomes nightfall or it's rain-wrapped, they can't see it.*"

Discussion and Future Work

To reduce future losses, the weather enterprise can learn from the tornado events of 2011, working collaboratively across multiple disciplines to look for a way to move forward. There have already been several notable efforts in 2011 to address the societal and physical impacts of severe weather, and what can be improved upon in the future (e.g. NWS Service Assessments for the Joplin Tornado and the Historic Tornadoes of April 2011, Integrated Warning Team meetings [summer 2011], Weather and Society*Integrated Studies Workshop [August 2011], National Weather Association Town Hall Meeting for Alabama survivors [October 2011], and the Weather Ready Nation Conference [December 2011]).

Communicating a tornado warning to the public is not as easy as just "pushing a button." Furthermore, new technology may not automatically translate into better warnings and warning decisions. A better understanding of the warning process and of public response to tornado events is needed to reduce negative impacts of natural hazard events. It is for this reason that CASA is incorporating social science research into the design of the radar network to make sure the new radar system meets the needs of the user.

For emergency managers, a real benefit of the CASA network is its ability to provide neighborhood-scale information. For example, on May 24, 2011, an emergency manager in Newcastle, Okla., was able to detect a shift in the direction of a tornado headed for his jurisdiction using CASA radar, allowing enough time for officials to relocate first responders and keep them safe from impact. This is just one example of how high resolution, low level data can benefit end-user decision making for very localized events.

CASA is now in the process of deploying a five-year, $10 million project in collaboration with the North Central Texas Council of Governments in the Dallas-Fort Worth area beginning February 2012 to establish the nation's only Urban Weather Demonstration System. Our vision is to create a national model for weather observation from a technological, operational, and socioeconomic benefits perspective, where multiple stakeholders jointly fund the operation of radar observation networks. We will continue our research with the emergency management community, with the goal of reducing losses to severe weather and flooding events.

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***** Ellen J. Bass (ejb4n@virginia.edu) is an associate professor of Systems and Information Engineering at the University of Virginia. She holds a doctorate from Georgia Institute of Technology in Systems Engineering. To learn more about EM decision making, see Bass et al. 2009. Incorporating emergency management needs in the development of weather radar networks. Journal of Emergency Management, 7(1): 45-52**

(references continued on pg 12)

Decision Making (continued from pg 11)

Acknowledgement

This work was supported in part by the Engineering Research Centers Program of the National Science Foundation under NSF Award Number 0313747. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the National Science Foundation.

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Improving Risk Characterization for NWS Decision Support for Emergency Managers

By Jessica L. Losego*, Kenneth J. Galluppi, Burrell E. Montz***, and Catherine F. Smith******

In anticipation of extreme weather events, there are two communities that come together to plan and prepare: the National Weather Service (NWS), which informs about hazards, and the emergency management community, which works to minimize risk to life and property due to hazards. These groups try to form a common understanding about the impending dangers associated with an event regarding the anticipated magnitude of the event, where and when it will occur, and who may be impacted. However, there is a gulf between what NWS communicates and what emergency managers (EMs) need with respect to the nature of the risk and vulnerable areas. EMs must characterize and manage the risk to understand what lives and infrastructure will be impacted and to communicate that information to others. NWS often tries to characterize the hazard with the assumption that the relationship to risk is implied. This leaves the EMs to interpret for themselves the nature of the hazard and to assess the associated risks.

The connection between these two communities can be described using the National Research Council's (NRC) risk paradigm concept (Fig 1, 1983). The left side of the diagram connects knowledge about a hazard, characterized in terms of significance, and relates the hazard to what is actually vulnerable or exposed to the hazard. This result is termed risk characterization. The critical link between risk characterization and management of that risk—the job of EMs—is risk communication, which includes issues such as uncertainty, confidence, perception, and modes of communication. Effective risk communication enables EMs to understand all the pertinent physical conditions needing to be managed and to pass that information along to others.

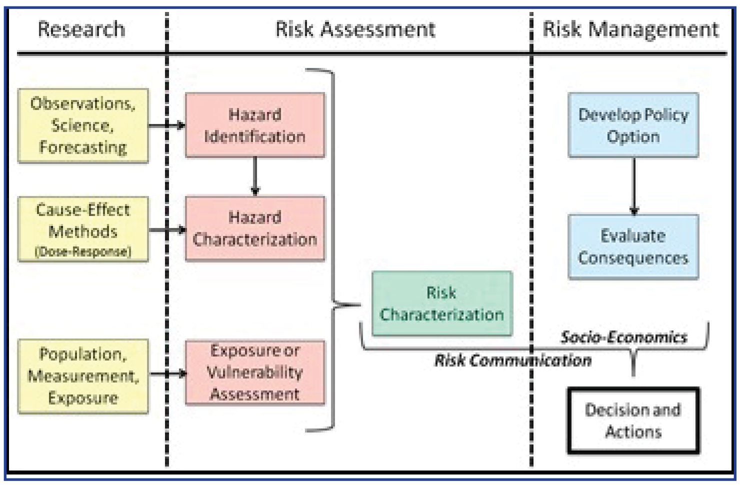


Figure 1: Diagram of NRC1983 report risk paradigm.NWS operates in the left and center sections but has not bridged to risk management where EMs operate.

The NWS currently focuses on hazard identification and characterization of weather and does so rather effectively. However, to reduce the impact on life and property, EMs need to understand the hazard's significance sufficiently well to make the appropriate connections as to who is exposed or vulnerable in order to make appropriate decisions to reduce the risk. As other socio-economic factors weigh into risk management, it is critical to have a complete and understandable risk characterization communicated to EMs so that proper and prioritized actions can be taken. The process of understanding hazards, exposure, and risk can only be achieved by a joint effort between the NWS and EMs that leaves little of the process open to interpretation and assumption by personnel not optimally prepared to make those connections.

To assist the NWS in understanding how it might better facilitate EMs' decision making processes within the NRC risk paradigm, the University of North Carolina and East Carolina University have joined with the NWS Office of Science and Technology (OS&T) and Office of Climate, Water, and Weather Services (OCWWS) in a cooperative pilot project. The goal is to understand, from an EM perspective, what critical decisions EMs operate towards, what knowledge about weather hazards and vulnerability underpins these decisions, and how to best package and deliver this information to meet their needs.

To develop this appreciation, we are looking at the entire EM community, which includes the 15 Federal Emergency Management Association (FEMA) Emergency Support Functions (ESF) listed in Table 1 (online only), of which only one is the "emergency manager". Each ESF has its own responsiblities, decisions, and timelines during an event, creating dynamic and ad hoc networks of EMs and comunications among ESFs (Fig 2). The county EM director's main function is to coordinate information and resources that enable the ESFs to do their jobs in support of accomplishing common objectives in managing risk or crisis. This information coordination includes hazard information obtained from the NWS and numerous other sources. This project examines the EM processes in order to understand 1) how information provided by the NWS is translated into actionable knowledge and decisions and 2) how the weather information process can be made more direct and influential when connected more strongly to risk characterization.

We examine both EM and NWS current practices to understand how information flows and is used in EM processes and to establish a baseline to allow us to highlight gaps between knowledge needs of EMs and information provided by the NWS. The next step is to see when and how hazard information can be better linked to risk and, thus, better communicated. Improving the process includes providing information more pertinent to EMs' needs, getting it more directly into the hands of decision makers, improving timeliness, and solving other information and knowledge bottlenecks.

A variety of techniques, including focus groups, interviews, observation of practices, and surveys, are used in an iterative cycle of gathering and hypothesizing to collect data about what is actually occuring. To date we have found that, in general, EMs struggle with finding and understanding relevant weather information and, more importantly, with properly connecting it to their decisions and

(continued on pg 14)

Decision Support (continued from pg 13)

operations centered on reducing risk and crisis impacts. NWS products and services describe hazards and, at times, connect them to hazard assessments to provide meaning, but stop well short of connecting to vulnerability and risk characterization. This leaves EMs to interpret its context.

To better understand the needs of the EM community and learn about NWS current practices, we examine real situations or “use cases” in an iterative manner, building an understanding one step at a time, starting with small groups. The first use case was on winter weather and the second on tropical weather.

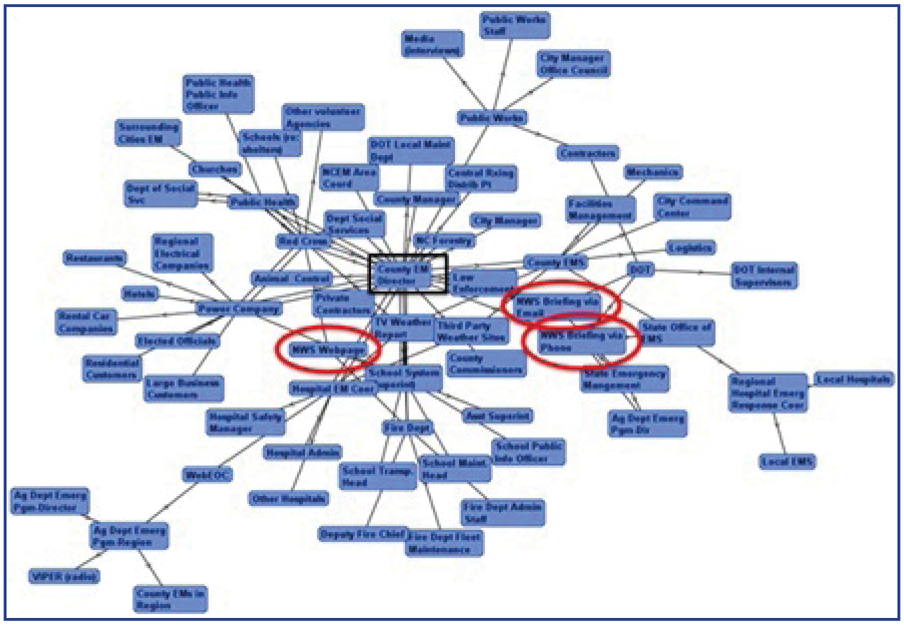


Figure 2: Networking diagram showing communication two days before a winter storm. Red circles indicate NWS injection points. County EM director is center, connected to many ESFs.

Winter Weather Use Case

We undertook the first case during the winter of 2010-11 and will resume this winter. After conducting mutiple focus groups in North Carolina, with various ESFs to establish critical decisions, collaborators, and timelines, three critical sub-groups whose decisions can have a major societal impact emerged for winter weather: power companies, the state Department of Transportation, and schools. We narrowed our focus to schools, since we believe they are the most underserved by weather information.

We first established a baseline of current schools’ processes and their use of weather information and then worked to identify gaps in information. We did this by conducting multiple interviews of nine counties in central and western North Carolina via phone or in person before any winter storms occurred, as well as after storms. We also conducted a statewide survey of school administrators who make the decision to close schools. Findings include:

- Critical decisions to close schools are often based on the safety of 16-year old drivers
- Forecasts for road conditions, the most critical parameter, are not available for most roads
- School staff have little to no training in meteorology yet interpret weather and advise on critical decisions
- Location-specific onset time of wintry conditions is crucial for school closing decisions but is hard to find and interpret, and the information that is provided does not work well with the timelines of schools
- Most school officials are unfamiliar with useful NWS products (e.g. Hourly Weather Graph)
- Relevant information needs to be in one place for easy access on the web
- School staff often drive the roads from 3:00-5:00 a.m. to determine conditions but have no way to easily gather and share observations or forecasts.

Our next step was to take what we had heard from the school reps and develop prototypes to translate what we learned into products that might more directly meet their needs. Fig 3 shows two of these prototypes.

After testing these prototypes with our initial group of schools, we visited several more schools to verify our findings and present our prototype ideas. Many of our findings were confirmed, and new ideas emerged for us to test. We will continue the use case this winter by working with schools to allow them to use some prototypes during events.

Tropical Weather Use Case

Our second use case is examing EM processes during tropical weather. We followed steps similar to the winter use case and first established a baseline of current processes, decisions, and timelines for all ESFs. We gathered this information through four focus groups conducted in coastal counties in North and South Carolina. We also interviewed 35 ESF representatives in five North Carolina coastal counties via phone. None of these were county EM directors.

Hurricane Irene made landfall in North Carolina as we were beginning our next phase of information collection, which was talking with county EM directors. This was advantageous because it refreshed in the EMs’ minds their processes and use of weather information, making it easier to identify gaps in information and knowledge between NWS and EMs.

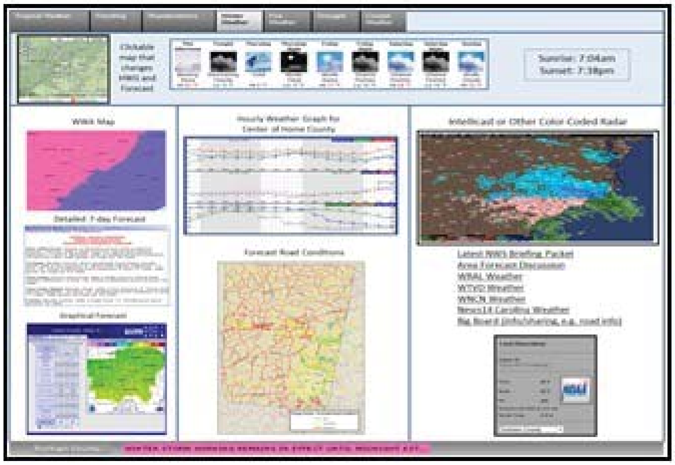
Some preliminary findings include:

- EMs’ top operational concern is the onset time of tropical storm force winds; products to easily get this information do not exist.
- Surge information is needed at 72 hours to be operationally useful. EMs can deal with uncertainty, so having a best guess at 72 hours is better than not having any information. This type of information needs to be easy to access,understandable, and zoomable to a local level.
- Maximum Envelope of Water (MEOW) and Maximum of MEOW (MOM) surge products are not widely used in North Carolina because they are hard to find and understand.
- Briefing packages released by many NWS offices to county EM directors are a critical method of communication. These packages are then

passed on to ESFs so that everyone in the county is getting the same information.

- EMs who do not receive briefing packages to pass on to others struggle to find the time to gather the relevant information themselves, as it is not easy to find.
- EMs go to several different weather sites to get what they need to gain confidence in their understanding. They currently cannot find everything they need in any one place.

Based on these findings, we developed, along with local NWS offices, several prototypes with direct input from EMs. Prototypes included an onset time of tropical storm force winds map, a graphic showing the extent of the potential impact of hazards beyond the cone of uncertainty, and a one-page point and click text summary of “where” and “when” information that is most relevant to EMs.



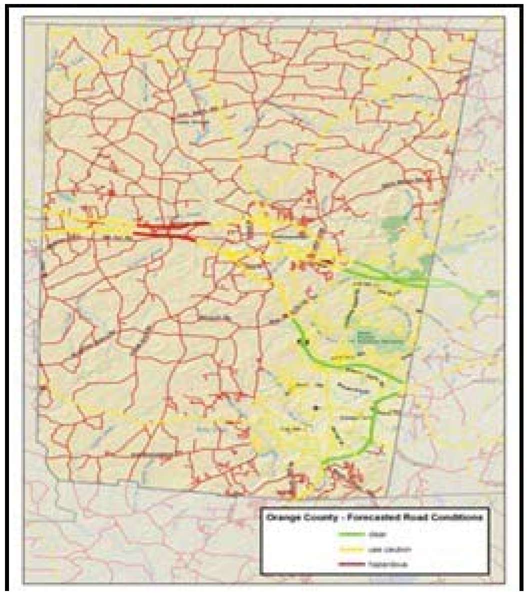


Figure 3: (Left) EMs prefer relevant information to be placed in one easy-to-find and use location. Currently they are not aware that many products exist and can have difficulty finding products they are familiar with. (Right) At 9:00 p.m. the night before a storm, schools officials would like to receive a fore-cast of road conditions for 4:00 a.m. the next day.

During this use case, we also focused on learning about the current practices of local NWS offices during events. Because we often hear about EMs struggling to find relevant weather information, we inventoried briefing pages on local NWS offices’ sites nationwide. We then conducted a nationwide survey of Warning Coordination Meteorologists (WCMs) asking respondents: 1) if they had a special briefing web page for EMs (and to list it if they had one), 2) if they had a separate briefing package, 3) their opinions on what content is most important for these briefings, and 4) what they believe is the best mode to communicate this information. Of the 98 respondents, more than half reported that they have a special webpage for the EM community, and approximately 93% provide briefing materials beyond this special web page to EMs. PowerPoint and videos are the most used forms for the briefing materials. These results coincide with what we have heard from the EM community.

In addition to this national look at NWS practices, we have also actively engaged our local coastal offices in our focus groups, graphics brainstorming sessions, prototyping, and shared the results of our interviews.

Summary

The emergency management community consists of 15 different support functions that manage risks, not hazards, and have varying needs for weather information. NWS currently provides mostly hazard information that, while helpful, often is not meeting the knowledge needs of EMs, forcing them to interpret for themselves weather information that in itself can be hard to find and understand. Many EMs are unaware of existing NWS products (e.g., Hourly Weather Graph), and often times the most crucial information an EM needs is not presented in a direct way, if at all.

Through this project we are working to understand how weather risk information can be communicated from NWS to EMs. Using various social science methods, such as focus groups, interviews, and surveys, we are studying the complex, dynamic, and ad hoc nature of the EM community. An iterative rapid prototyping approach allows us to test various ideas to determine if they meet EM needs. From these methods, we identify the gaps and needs for weather knowledge that NWS can provide, and begin moving towards communication and characterization of risk that will support improved decision making.

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An Assessment of the Climate Information Needs of Oklahoma Decision Makers

by Rachel Riley*

Climate change is often discussed on a global scale but climate impacts are frequently experienced on a local scale. Local, state, tribal, and federal leaders have the ability to influence adaptation and mitigation measures that can address some of the impacts of climate events. However, the decision-makers must be knowledgeable and have access to the appropriate information in order to make sound choices. It is also necessary for climate information providers to understand the needs of their users. Interaction between climate scientists and decision-makers is crucial (U. S. Global Change Research Program 2009a) so that research is fruitful and decision-makers' needs are being met.

The Southern Climate Impacts Planning Program, a National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Sciences and Assessments (RISA) program, conducted a climate information needs assessment for decision-makers in Oklahoma in 2010 and 2011. Twenty-three semi-structured interviews were conducted with representatives from a variety of local (n=3), state (n=10), tribal (n=2), federal (n=6), non-profit (n=1), and private (n =1) agencies. The semi-structured approach allowed for consistent findings across the interviews but also provided participants with the opportunity to focus on the climate-related issues they deemed most important. The participants represented the water resources (n=7), energy (n=2), transportation (n=2), agricultural production (n=5), ecosystems (n=6), human health (n=1), and society/public safety (n=7) sectors. It should be noted that some participants fell into more than one sector.

Figure 1. Oklahoma Panhandle field conditions in April 2011 (Courtesy of Ladene Beer)

This study aimed to answer four research questions: 1) What do decision-makers in Oklahoma think are the most significant climate-related issues facing them today?; 2) What are the most significant climate-related issues they will face in the future?; 3) What are the spatial and temporal scales in which they make decisions?; and 4) What do they perceive as their most substantial climate-related research needs? Interviews were recorded and transcribed and the data were analyzed thematically and according to the sectors consistent with the 2009 National Climate Assessment (U.S. Global Change Research Program 2009b). A summary of the findings is presented below.

Current Climate-Related Issues

It was important to get a baseline understanding of how climate currently impacted decision-makers before asking the participants about their future concerns. The participants cited being impacted by numerous climate-related events such as extreme cold, extreme heat, and severe winds. However, the events cited most frequently were flash floods and droughts, followed by water resource issues, ice storms, and tornadoes. Some of the particular issues included power outages resulting from strong winds or ice storms, limited water supply or stunted crop growth due to drought (e.g., Figure 1), buckling roads due to extreme heat, and invasive crop species due to untimely freezes and warmth. Whatever the issue, it was clear that climate has a tremendous impact on the operation of Oklahoma agencies.

Anecdotal Evidence of Change

The participants were asked whether they had noticed any changes in the climate or environment before they were asked how the projected changes in climate would impact them. Some of the participants described changes, but many of them cautioned that their observations were purely anecdotal. A few participants also said they were not sure whether the observed changes were due to changes in climate, land use, or whether their memory was biased toward recent events. One decision-maker also commented how the extreme variability of Oklahoma's climate makes it difficult to know whether it is actually changing.

Despite these caveats, some of the climate changes noted by the participants included an increase in the magnitude and frequency of extreme events, more untimely freezes, and more intense but less frequent rain events. Some participants also remarked about changes in plants, such as a northward shift in plant hardiness zones and invasive species such as red cedar trees, milo, and kudzu Changes in wildlife were also cited, such as an increase in the rattlesnake and decrease in roadrunner and jackrabbit populations, and that geese do not migrate like they once did. Figure 2 (onine only) shows the complete list of changes.

Future Climate-Related Concerns

The projected changes in climate for Oklahoma were described to the participants before they were asked about the most significant climate-related issues they would face in the future. Projections for Oklahoma include more intense but less frequent rain events, an increase in the frequency of hot extremes and heat waves, the warm season becoming longer and arriving sooner, and a decreasing number of cold extremes. More intense but less frequent rain events, which would lead to an increase in flooding rain and drought, was the most commonly cited change that would have the greatest impact.

In a period of drought, competing interests for water (e.g., energy production, drinking, and recreation) mean that problems can arise when water is in short supply. Alternatively, heavy rain and floods deposit sediment into places it should not be, such as reservoirs. This decreases the water storage capacity of the reservoir. Heavy rain and flooding is also abusive to road and bridge infrastructure. A transportation engineer said design equations take shear velocity into account, which is very different for flash flood type events. So, the design equations would need to change if rainfall patterns were to change.

A lengthening growing season would produce tradeoffs for the agriculture sector. On one hand, a warmer climate would mean that crops would have more time to grow. Alternatively, a warmer climate would also be conducive to invasive pests, which can be problematic for agriculture producers. Lengthening warm seasons also impact wildlife. One biologist noted that temperature changes can alter the timing of incubation. If the air temperature is warm enough to incubate a hen's egg before she is ready to sit on it, unsynchronized hatching might occur and the hen would not be able to take care of all her chicks.

Scales of Decision-Making

If climate projections are to be useful to decision-makers, they should be presented in a way that is consistent with the temporal and spatial scales that are useful for planning activities. To this end, the participants were asked about their maximum planning timescales. The participants in all but two of the seven sectors cited a maximum horizon of 15 years or less. And even though comprehensive planning occurs on this scale, the bulk of their planning focused on one to five years in the future. The transportation and water resource sectors have a longer planning horizon—50 and 100 years respectively. These two sectors build and maintain large, expensive infrastructure such as dams, reservoirs, bridges, and highways, so they have to make sure that the infrastructure lasts a long time.

One reason that decision-maker planning timescales are shorter than one might expect is because climate is just one of many variables that decision-makers consider. Some sectors such as agriculture are also extremely sensitive to the variability of the climate and cannot afford to have a long planning horizon. As one agricultural participant noted, from the perspective of a producer, "I can't worry about what's happening 10 years from now. If I'm still not making money two to three years from now I'm gone."

Spatially, the most commonly cited scale needed for climate projections was regional within the state. While some participants wished they could have city-scale climate projections, they realized that would not be feasible. The agricultural participants said climate projections would not be useful to them unless they are provided at the city/farm scale, with one reason being the extremely variable precipitation in Oklahoma. The precipitation is often very localized, and crop producers need model projections to have a very high spatial resolution for them to be usable. Moreover, the participants in the agriculture and water resources sectors were primarily interested in river basin and sub-basin scales as opposed to scales based on political boundaries. Information also needs to extend beyond the Oklahoma state boundaries, since decision-makers often work across those boundaries or need to prepare for changes occurring in other parts of the country that might impact them in the future.

Research Needs

One of the most substantial research needs, aside from providing decision-makers with model projections on the scales that are useful to them, was to determine the critical thresholds that are used for decision-making or taking action. Morss et al. (2011) also came to this conclusion. For example, a critical threshold might include the temperature at which a crop no longer grows or the rain rate at which substantial flooding occurs in a city. Meteorologists and climatologists have ideas about what thresholds are important (e.g. 100°F, 57 mph winds) but information is valuable to decision-makers only when it is presented in a way that is consistent with the point(s) at which they take action.

Another need that surfaced across numerous sectors was the need to understand changes in second order variables such as evaporation rates, soil temperature and moisture, days near or below freezing, or air pollutant levels, as opposed to just first order variables like precipitation and temperature. Temperature and precipitation trends are too abstract for many decision-makers to be able to understand how climate change might impact them.

Concluding Thoughts

The points discussed here only provide a summary of the wealth of knowledge gained through this study on the climate-related needs of decision-makers in Oklahoma. While the attempt was made to gather as in-depth information as possible across a variety of sectors in Oklahoma, the assessment was not comprehensive nor is it generalizable to all Oklahoma decision-makers. Yet, it provides a stepping stone to begin to understand the climate-related issues that Oklahoma decision-makers are dealing with and/or might deal with in the future, and insight into how the climate community might be able to better serve them.

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How K-12 School District and University Officials Anticipated and Responded to National Weather Service Tornado Warnings: Spring 2011 Case Studies

by Amy C. Nichols* and Stephanie Hoekstra**

School district officials are responsible for the safety of approximately 25 percent of the United States population during weekdays in the school year, yet they are not typically trained in meteorology. Because much of the student population includes minors with no legal autonomy, school officials often end up taking on a surrogate parental role. Universities play a unique role within their community, as they are akin to cities within cities that also have business, research, educational, and surrogate parental responsibilities to their students. They are open 24 hours a day, 365 days a year, and their campuses have people coming and going at all hours.

Our two research studies examined tornado warning response at six school districts and five public universities during the severe weather season of 2011. As part of these projects, we contacted school districts and universities that were placed under tornado warnings (but not impacted by a tornado) and conducted interviews with 11 school district officials, nine university officials, and one meteorologist. Although this is a very small sample, our findings provide insight into how these decision makers act during severe weather and set the stage for larger, more in-depth studies by providing preliminary hypotheses on the response of a small subset of representatives from two weather sensitive organizations. These studies addressed four primary research questions:

1. What is the timeline of events in decision making?

2. What sources of information do school district and university officials access during severe weather?

3. What non-weather factors influence decision making?

4. What types of weather information might improve operations, with an emphasis on the value of extended lead time?

Decisions and Sources: Similarities and Differences From the Case Studies

During the majority of the year, K-12 school district officials write and review severe weather (and other hazard) plans and conduct severe weather drills. Generally the superintendent is alerted of approaching severe weather a day or two in advance via National Oceanic and Atmospheric Administration (NOAA) websites and local television broadcasts. From this point, superintendents are in constant contact with district staff and faculty, relaying vital information and preparing schools to take (or not take) shelter. When severe weather is approaching, district officials communicate with faculty and staff on field trips and ensure that people on school grounds are brought inside. The issuance of a National Weather Service (NWS) tornado warning acts as a trigger for school officials to activate their severe weather plan and bring students to designated sheltered areas. Weather radios, TV broadcasts, and phone calls from other staff are common sources alerting school decision makers of the status of severe weather. The weather information is relayed throughout the district via phone calls, emails, texts, and public address systems. When the severe weather has passed, many district officials debrief and discuss what aspects went well and what changes need to be made to procedures. Communication throughout the district and monitoring of the weather is a continual process starting from when severe weather is approaching to when it has passed. There is no designated employee within the school district who is responsible for monitoring the weather and crafting plans; each district distributes these roles differently. Often, another employee, such as the transportation director, is the main weather information source for the district and the person who suggests certain actions to be taken. School district officials tend not to be trained in weather and a few found NOAA-issued information difficult to understand. They have built a relationship based on trust and, thus, listen to their local broadcasters and university meteorology programs that provide spatially specific and clear information, making their decision-making process more efficient.

As opposed to school districts, the universities sampled have a dedicated staff member (emergency manager or someone with emergency management responsibilities) whose job responsibilities include the monitoring of weather and the creation of plans for severe weather events and other types of hazards. They typically become aware of the possibility of severe weather at their campus one or two days ahead of time, often through direct communication with NWS via emails, briefings, or packets containing information. This possibility of severe weather triggers the start of preparation through communication with other departments on campus. This communication includes the push of weather information and recommended preparatory actions to the campus community and the pull of information about planned events and preparation activities. As the weather gets closer, the dedicated staff member monitors the area to the west of the campus for impacts and assesses the spatial proximity of the severe weather to the campus. When a NWS tornado warning is issued for the university's county, multiple systems notify the staff member of its issuance, so that person can determine if the campus is affected and set off emergency notification systems, such as sirens, text messages, or emails if the campus is included in the warning. The staff member continuously updates critical departments on campus of the weather status until it has passed, and then begins steps for recovery, if needed. Throughout the entirety of this process, university emergency managers are constantly monitoring the weather through NWS updates, radar sources, local emergency management, and/or private weather information providers.

Non-weather factors and decision making

Plans and procedures act as the backbone for response. These plans need to be flexible since every event is different. One superintendent mentioned, “you can’t have a plan that addresses every contingency… it has to be sort of that day’s call based on the time that all this occurs.”

Below are some examples illustrating the flexibility of plans:

- Despite the fact that a warning had expired, one university emergency manager decided to wait to issue the all-clear until a second storm had passed in case a new tornado warning was issued.\
- Instead of listening to the NOAA weather radio, one district superintendent followed the advice of the husband of an employee, who is the local meteorologist, to keep students in shelter even when the warnings were expiring, saving them from moving hundreds of students multiple times.
- Because an emergency manager knew that there was a lecture occurring at the forecasted time of storm arrival, he allocated additional volunteer emergency responders to the site of the lecture to make sure there were adequate personnel to assist in case evacuation became necessary.
- Because the warnings occurred during the early morning when staff were arriving to school, one superintendent decided to put everyone in the gym so his limited staff could supervise the students, even though he was aware of the increased potential danger of that location compared to the hallways.

School and University Weather Information Preferences and Perceptions of Lead Time

School district and university officials prefer more specific spatial, temporal, and intensity information. They want to know if their campuses will be affected, when the impacts will occur, and what impacts to expect. University emergency managers expressed the importance of developing relationships with their local NWS Weather Forecast Offices. And although school district officials did not explicitly state an interest in building a relationship with the NWS, they could potentially benefit from more NWS guidance.

A main goal of one of these study’s funders, the Warn-on-Forecast project, is to extend tornado warning lead times. Therefore, a portion of these studies focused on gathering initial thoughts from these user groups on longer lead times. One significant observation is that the NWS definition of lead time *may not* be how school district and university officials perceive the term. These users became aware of severe weather and began making decisions, communicating with others, and preparing to take action *long* before the warning was issued. The tornado warning acted as a trigger to activate plans and emergency notification systems that had been prepared for implementation during the time *leading up* to the event.

Extending current NWS tornado warning lead times to up to two hours, as suggested by NOAA’s Warn-on-Forecast, would force a paradigm shift in warning response, as changes in the way warnings are delivered (ex. as probabilistic forecasts) would require school district and university officials to reconsider their plans and procedures. Initial thoughts from these two user groups were that the additional time could be spent reviewing plans and preparing to take action, which already occurs with the time they have now as the storm approaches. Notification or sheltering would then occur as the threat becomes more imminent. This raises the question of whether a tornado warning with more lead time would be defined as a “warning” by these users. Below are two comments from interviewees:

“I don’t think a warning needs to be issued until it’s imminent.”
- Director of Safety and Security at a Missouri school district

“…we would still wait until we had a reasonable sense that danger was present.”
-University Emergency Manager

Concluding Thoughts

This research is valuable for helping software developers understand how various weather sensitive organizations use weather information and warnings by approaching new weather product development from the perspective of the user, instead of assessing already-developed NWS products. Assessing and addressing the needs of people responsible for the safety of large groups is an important new direction in meteorological software development. This research represents a small subset of new research methods being developed to change the research to operations equation from technologically driven to user driven. These studies have helped form the basis for future research on these and other weather-sensitive decision makers with the responsibility for large, vulnerable populations. The studies looked at one type of hazard—tornado warnings—but additional research and information on these and other types of hazards are still needed to fully understand the hazardous weather decision making processes of school districts and universities.

If you would like a copy of the final theses or have any comments, questions, or stories to share, please email the authors at the email addresses provided below.

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The Use of Innovative Communications to Enhance Weather Information for a Rare Winter Storm in South Texas

by Barry S. Goldsmith*, Mike Buchanan**, Scott Cordero***, and John Metz****

Introduction

From late February 1-February 4, 2011, significant winter weather impacted nearly 2 million people from the Coastal Bend to the Rio Grande Valley in South Texas, a region known for warm winters. Long durations of frigid temperatures culminated with a prolonged period of freezing rain, which covered exposed surfaces with up to 3.8 cm (1.5 in.) of ice. The widespread icing was the first such event for South Texas in over 20 years, and required a much higher level of decision support due to increased population and impacted infrastructure, including roads, businesses, schools, and health facilities. The National Weather Service (NWS) offices in Corpus Christi and Brownsville used innovative methods and trusted relationships to communicate the threat to emergency management, public health, public safety, and transportation, education, and media partners several days in advance. Early warning resulted in decisions that likely saved lives and mitigated significant economic loss.

Event

A strong cold front swept across South Texas on February 1, followed by a sprawling arctic high pressure ridge, which spread from western Nebraska and eastern Wyoming southward through Texas. By daybreak on February 2, temperatures ranged from -5°C (23°F) at Beeville to 1°C (34°F) at McAllen. Temperatures would remain near freezing (0°C) through the daylight hours of February 2 under a steel-gray overcast, dropping below 0°C in all areas by midnight LST (06 UTC) on February 3.

The approach of an upper level disturbance lifted a limited amount of low level moisture into light precipitation, starting around 7:30 a.m. (1330 UTC) on February 3 near the Lower Rio Grande Valley coast and spreading north and west through the day and overnight, eventually covering all of South Texas with a coating of ice. The freezing drizzle continued for up to 24 hours in some locations. Temperatures remained at or below 0°C for at least 30 hours in South Texas—up to 60 hours in some locations—February 1-4. Ice accretion ranged from 1 cm (0.375 in.) across the Coastal Bend near Corpus Christi, to 3.8 cm (1.5 in.) in Brownsville. Most of the ice accumulated on exposed surfaces, including elevated roadways, bridges, power lines, trees, and grasses.

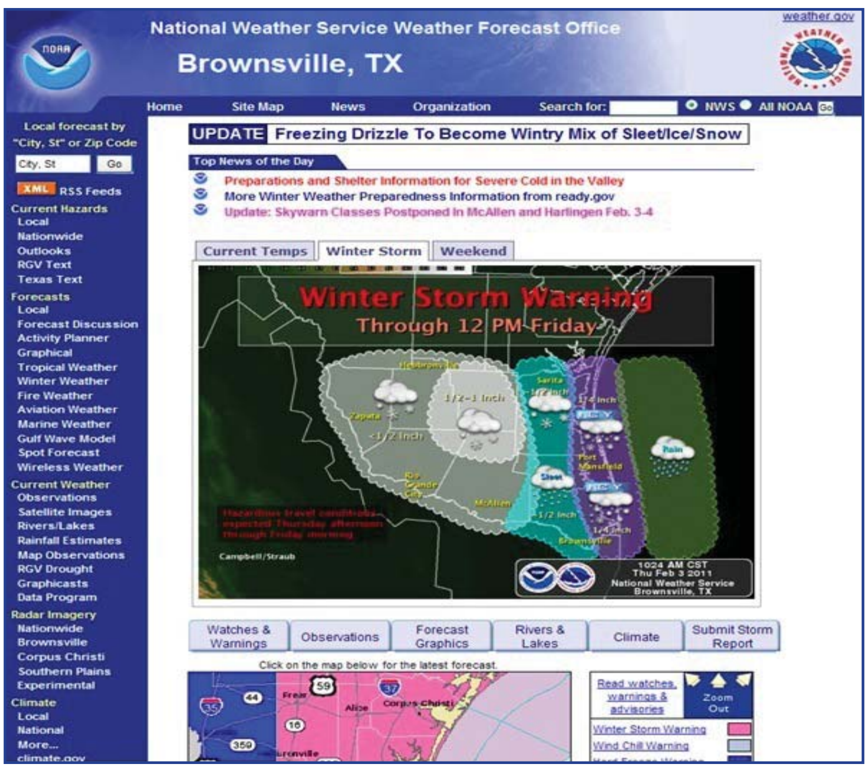

Figure 1. Front page of NWS Brownsville/Rio Grande Valley web site

The long duration freeze and icing caused an estimated $11 million in reported crop damage, particularly to sugar cane. Ornamental, unprotected tropical plants were heavily damaged. Rolling blackouts across the state of Texas were implemented through the arctic outbreak and winter weather to prevent long term outages. Power outages peaked at 65,000 residences. There were nearly 200 reported vehicle accidents on state and federal highways in the Rio Grande Valley; dozens of persons were admitted to local hospitals with injuries from the accidents, and there was one fatality from a vehicle rollover. Dozens more persons suffered minor injuries from slips and falls on the ice.

Innovative Communication

The NWS offices in Corpus Christi and Brownsville utilized an array of Internet-based communication tools available to their employees and to decision makers in public safety, public health, education, transportation, and the media to provide a continuous stream of weather information, from the planning stages through the entire event. Decision makers were notified a week prior to the event with "heads-up" email messages describing the expectation for a long duration freeze, dangerous and potentially life-threatening wind chill, and increasing confidence for a wintry precipitation mix beginning on February 3. The email notices were supplemented by the following communications at each office:

- Daily webinars, starting on January 31 and continuing through February 4
- Winter weather "breaking news" banner link to web log (see Figure 2, online only), safety tips in "Top News of the Day", and weather graphics of current conditions and forecast hazards on front page of each website (Figure 1)
- Web log updates (Figure 2, online). The updates highlighted "breaking news" including traffic accident and road closure reports, power outages, ice accretion reports, rapid forecast updates, safety alerts, special graphics, and photographs.

NWS Corpus Christi added the following innovations:

- Voice, text, and graphic "multi-media" briefings in English and Spanish (Figure 3), recorded and uploaded to YouTube™ , then linked from the home page for wide distribution
- Hourly email updates to key emergency management partners
- Monitored social media via HootSuite™, including from Nuevo Laredo, Mexico
- Participated as a subject matter expert in the *Victoria Advocate* (newspaper) chat room

NWS Brownsville/Rio Grande Valley added the following innovations:

- Local television and newspaper web sites share NWS graphics and snippets from email correspondence (See Figure 4, online only)
- Received hourly updates of road closures from Texas Department of Transportation; NWS included the data in Winter Weather Updates.

Figure 3. (See Figures 2 and 4 online) Snow (nieve) and ice (hielo) forecasts from Spanish language briefings by NWS Corpus Christi

Traditional communications were also used by each office prior to and during the event. These included the official outlook, watch, warning, and advisory text products starting with Public Information Statements on January 30 and continued with Freeze Watches/Warnings and Winter Weather Watches/Warnings/Advisories as the event approached. A Local Area Emergency was issued by the City of Corpus Christi Department of Emergency Management to heighten awareness for life threatening road conditions during the peak of the storm. NWS Corpus Christi relayed the message through the Emergency Alert System, ensuring wide distribution to the general public. Dozens of telephone, radio, and television interviews were conducted. Local Storm Reports (LSRs) were issued in near real-time to update primary media partners on icing conditions, in case innovative communications failed or were not available.

Impact Reduction

Prior to the current emphasis on weather decision support, the process for meeting the NWS stated mission of "providing…warnings…for the protection of life and property and the enhancement of the national economy" at the local level was predominantly a one-way street driven by government meteorologists issuing ALL CAPS text "products" in a fairly technical language, often assuming that decision makers and other listeners and readers would be able to comprehend the message to carry out their missions in ample time to protect life and property in their communities. Metrics used to define the effectiveness of warning texts included "lead time", calculated solely on the time the text was issued to the time the first verifying data were observed by trained weather spotters or other trusted sources.

For a significant winter weather event, a lead time of 12 to 18 hours from the first warning message may be considered sufficient from the meteorologist's viewpoint. To the community, that same lead time may be perceived as insufficient. The time required to bring in additional staff and equipment to prepare roads for ice and snow, prepare public utilities for potential power outages, and cancel early morning school bus runs can be longer than 12 hours. Infrastructure preparation, public comprehension and preparedness actions, and overall awareness of the threat are critical to a successful outcome on society.

New tools, techniques, and trust relationships are being implemented throughout the NWS to improve real-world communication well before the first snowflake falls, the first tidal surge arrives, or the explosive growth wildfire is sparked. Objective data and anecdotal evidence from South Texas decision makers involved with the February 1-4, 2011, winter weather episode suggested the NWS focus on advance communication of potential weather hazards, well beyond the typical watch/warning "lead time", paid dividends and saved life, property, and money.

Independent school district officials who used webinar and email information from NWS Brownsville/Rio Grande Valley were able to close school the night before the arrival of glaze ice in the Cameron and Willacy County on February 3; officials in Hidalgo County elected to hold classes during the morning of February 3, with plans ready for staggered early dismissal based on the forecast arrival

(continued on pg 20)

Innovative Communications (continued from pg 19)
of icing later in the day and through continuous contact with staff early in the morning. Public safety and public works personnel were ready to treat and close roads a day before glazing began, and hospitals were staffed in advance to handle additional patients injured in vehicle accidents or from slipping. Airports and sea ports from the Rio Grande Valley to the Coastal Bend prepared for rare de-icing, and moved aircraft and other ice sensitive equipment indoors prior to the onset of freezing rain.

There were nearly 200 vehicle accidents, dozens of accident related injuries, and at least one driving fatality on February 3 across the Rio Grande Valley. Objective data and anecdotal evidence suggests those numbers would have been substantially higher had the Rio Grande Valley not been effectively "shut down" for commerce and education due to advance NWS decision support.

Early February traffic volume across the Rio Grande Valley is among the highest of any time during the year. Local travelers, seasonal residents, and transmigrants combine for more than 100,000 vehicles on elevated highways and interchanges per day. The Annual Average Daily Traffic (AADT) count for Hidalgo County between Weslaco and the Highway 281/Highway 83 interchange (McAllen/Pharr) exceeds 100,000 vehicles, with 131,000 vehicles at the interchange itself (Texas Department of Transportation, 2009). The potential for *thousands* of accidents is very high on these elevated roads in a region where winter driving is almost never necessary.

Coordinated preparedness actions by jurisdictions from the Rio Grande Valley to the Coastal Bend, triggered by NWS decision support services, reduced the number of travelers on and February 3 and 4 to a small fraction of average. Such reductions may have saved lives, as well as millions of dollars in repair or recovery costs to vehicles and highway infrastructure. Millions more in medical expenses may have been saved by reducing the potential number of critical human casualties in vehicle accidents.

Conclusion

This event, and catastrophic events that followed across the United States through spring and summer of 2011, show the importance of hazardous weather communication to an increasing number of decision making stakeholders. The shift toward synergistic weather information sharing among stakeholders has been aided by the 21st century communication technology revolution. Innovative approaches to providing this information, from plain language confidence forecasts by trusted NWS employees to the technological tools that allow an increasingly diverse universe of decision makers is making a difference. Evidence from the South Texas winter weather events of February 1-4 showed success in the mission of protecting lives, property, and the economy—a mission that defines all who provide weather information for a safe, healthy, and productive society.

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About WSW

Weather and Society Watch is published bi-annually by the Societal Impacts Program (SIP) at the National Center for Atmospheric Research (NCAR). The purpose of *Weather and Society Watch* is to provide a forum for those interested in the societal impacts of weather and weather forecasting to discuss and debate relevant issues, ask questions, and stimulate perspective. The newsletter is intended to serve as a vehicle for building a stronger, more informed societal impacts community.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of NSF or other sponsors. Contributions to *Weather and Society Watch* are subject to technical editing at the discretion of SIP staff.

Weather and Society Watch is available on the World Wide Web at: http://www.sip.ucar.edu/news/. Archives of WeatherZine, a previous weather impacts newsletter upon which *Weather and Society Watch* was modeled, are available on the Web at http://sciencepolicy.colorado.edu/zine/archives/.

About SIP

The Societal Impacts Program (SIP) was initiated in 2004 at the National Center for Atmospheric Research (NCAR) and is funded by NCAR, the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and external grants.

The mission of SIP is to infuse social science and economic research, methods, and capabilities into the planning, execution, and analysis of weather information, applications, and research directions.

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