

Evaluation of the National Weather Service Impact-based Warning Tool

Submitted to the NWS Central Region Headquarters

April 10, 2014

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Table of Contents

| | <u>Page</u> |
|---|-------------|
| I. Introduction..... | 3 |
| II. Methodology and Approach..... | 3 |
| III. Focus Groups and Survey Instruments..... | 5 |
| IV. Focus Group Results and Discussion..... | 7 |
| V.1. Survey Results..... | 16 |
| V.2. Survey Discussion..... | 23 |
| VI. Conclusion..... | 24 |
| VII. References..... | 26 |
| Appendix A: IBW Warning Product Example..... | 28 |
| Appendix B: Focus Group Questions for NWS Weather Forecasters..... | 29 |
| Appendix C: Focus Group Guide for Emergency Managers and Broadcast Media..... | 30 |
| Appendix D: Survey Instrument..... | 34 |

I. INTRODUCTION

A number of large and damaging tornadoes have struck U.S. cities in recent years. One of the most dramatic was the tornado that struck Joplin, Missouri, on May 22, 2011, when 159 people were killed and over 1000 injured (NWS 2011). The extraordinary number of casualties during the tornado in spite of multiple and early-issued warnings was puzzling. The National Weather Service (NWS) made several recommendations after the disaster based on a service assessment (NWS 2011), including a non-routine impact-based warning mechanism to prompt immediate action. Subsequently, the NWS developed the impact-based warning (IBW) product designed to support the decision-making needs of NWS partners, namely emergency managers and broadcast media. The IBW product is an enhancement of the traditional tornado watch and warning product.

The Great Lakes Sea Grant Social Science Network evaluated the IBW product throughout the NWS Central Region in 2013. The evaluation study builds off previous work commissioned by the NWS (Galluppi et al. 2013). Galluppi's study assessed the product in 2012, when five Weather Forecast Offices (WFOs) piloted the IBW product. The study we conducted reveals the product's effectiveness throughout the NWS Central Region, which includes 38 WFOs. Our evaluation data was collected using focus groups, interviews, and surveys of NWS weather forecasters, emergency managers, and broadcast media to assess the product's effectiveness.

II. METHODOLOGY AND APPROACH

Three audiences, NWS weather forecasters, emergency managers, and broadcast media, were targeted to evaluate how the IBW product functions within the risk paradigm. The risk paradigm is composed of three components: risk characterization, risk communication, and risk management (Galluppi et al. 2013; NRC 2009). Risk characterization involves describing the hazard, while risk communication entails creating a mutual understanding of the situation, and risk management refers to the decisions and actions made to protect lives and property. The three audiences all play a critical role in the risk paradigm. Forecasters issue the IBW product, while emergency managers and broadcast media interpret and disseminate information to the public and use it to make local decisions. Essentially, forecasters characterize the risk and then communicate it to the emergency managers and broadcast media who then reinterpret that risk, communicate it and make management decisions based on the characterized risk. The focus group, interview, and survey instruments were designed to tease out how helpful the IBW product was at communicating risk in a way that the user groups', emergency managers and broadcast media, perceptions of risk would lead them to take action based on the tool.

Differences between traditional NWS tornado watches and warnings and the IBW product include information added about the relative risk of damage, impacts to lives and property, the source of tornado information (e.g., storm spotter), and more detailed information about hail and wind speed. The damage threat tag, a key element of the IBW product, uses the words "considerable damage" and "catastrophic damage" to indicate the increased probability of significant damage from a tornado. The threat tags communicate the relative risk of potential damage from a tornado. Previous NWS watches and warning products did not clarify how people would be impacted if they did not seek shelter or other protective actions. Impact information is especially grave and graphic. Table 1 displays the threat tags and associated impact statements with each threat tag level. The base threat tag is associated with the traditional tornado warning, whereas the considerable and catastrophic damage threat tags indicate increased risk relative to the traditional warning product. Appendix A provides an example of a tornado

warning with the enhanced IBW product; portions that differ from traditional watches and warnings are highlighted in yellow.

Table 1. Threat tags and their associated impact statements

| <i>Threat tag</i> | <i>Impact statement</i> |
|---------------------|--|
| Base | MOBILE HOMES WILL BE DAMAGED OR DESTROYED. DAMAGE TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. TREE DAMAGE IS LIKELY. |
| Considerable damage | YOU ARE IN A LIFE THREATENING SITUATION. MOBILE HOMES WILL BE DESTROYED. CONSIDERABLE DAMAGE TO HOMES...BUSINESSES AND VEHICLES IS LIKELY AND COMPLETE DESTRUCTION POSSIBLE. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. EXPECT TREES TO BE UPROOTED OR SNAPPED. |
| Catastrophic damage | YOU COULD BE KILLED IF NOT UNDERGROUND OR IN A TORNADO SHELTER. COMPLETE DESTRUCTION OF NEIGHBORHOODS...BUSINESSES AND VEHICLES WILL OCCUR. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. |

In evaluating the use of the IBW product with NWS partners, we were not only interested in the new information being provided by the IBW product, but also the platforms by which the message is disseminated. Emergency managers and broadcast media serve as the gatekeepers to a majority of the public’s severe weather information. Television and air raid sirens work in tandem and are the primary means from which the public learns about tornado warnings (Golden and Adams 2000; Lazlo et al. 2009; NWS 2011; Sherman-Morris 2013). For example, while television was an important means of tornado communication in Joplin, it was the sirens that signaled residents to turn on their televisions (NWS 2011). The sirens are the main communication tool that emergency managers have to alert the public to the presence of a tornado (League et al. 2010).

Our study takes into account the use of the IBW product by the wider emergency management community, not solely county or city emergency managers. The emergency management community includes supporting roles from the transportation sector, hospitals, school administrations, and firefighters, among others. The Federal Emergency Management Agency’s National Response Framework (FEMA 2008) describes 15 distinct emergency support functions that are most frequently needed in a disaster response. For example, a manufacturing plant manager needs to make decisions about when severe weather conditions make production unsafe or a school official needs to make a school closing or delay decision. In what follows, the term emergency manager or emergency management refers to the wider emergency management community.

One of the emerging tools for hazard communication is social media. Increasingly, social media is used to disseminate severe weather information by the NWS, emergency managers, and broadcast media. A recent report from the International City/County Management Association highlighted six case studies of how social media is used to improve preparedness for emergencies (Chavez et al. 2010). For example, in the City of Moorhead, Minnesota, emergency managers used social media to coordinate a response strategy to the spring 2010 floods. The city provided real-time updates on all city disruptions

and response, and solicited volunteers to fill sandbags. In Johnson County, Kansas, emergency managers host two Twitter feeds, one that offers ongoing information related to hazards and another with real-time updates from the emergency management office.

The public disseminates information via social media as well. Individuals communicate on-the-ground weather information on platforms like Twitter and Facebook. For example, during the spring 2009 floods of the Red River region near Fargo, North Dakota, government agencies sent about 44% of flood-related tweets, while the general public issued the rest (Starbird et al. 2010). It is unclear how social media communication from the public affects agency decision making, or other members of the public. Because social media plays a critical, and relatively unstudied, new role in disseminating information about severe weather, study participants were asked to describe the communication platforms they use, including social media, and the role they serve when the IBW product is deployed.

III. FOCUS GROUPS AND SURVEY INSTRUMENT

The focus group and survey instruments were developed in collaboration with the NWS Central Region leadership and relied heavily on the Galluppi et al. (2013) pilot evaluation study in 2012. The focus group data provides a rich description of how the IBW tool is used and perceived, while the survey data provides generalizable findings about satisfaction levels with the tool.

In the focus groups, a consistent set of questions was asked to forecasters, emergency managers, and broadcast meteorologists in order to facilitate comparison across locations. Participants were asked to consider a day of severe weather in June and describe the communication platforms and preparedness actions that are typically taken. Questions specific to the IBW product differed slightly between (1) forecasters and (2) emergency managers and broadcast media. Forecasters were asked to describe how and when they issue the IBW product, their comfort with deploying the product, and training they received related to it. Emergency managers and broadcast meteorologists were asked to describe how the damage threat tags and impact statements might affect their decision making and whether the tool prompted them to change their typical course of action when a tornado warning is issued. The focus group instrument was pretested by NWS staff at the Milwaukee/Sullivan WFO. The focus group questions for forecasters are provided in Appendix B. The questions for emergency managers and broadcast meteorologists are in Appendix C.

Focus groups took place in five WFO regions: Grand Forks, ND, Quad Cities, IA, Chicago, IL, Northern Indiana (North Webster), IN, and Louisville, KY. The WFO regions chosen represent a mix of urban and rural areas and a variety of typical weather patterns for the NWS Central Region. Evaluation of the IBW product already took place in 2012 in the tornado-prone states of Kansas and Missouri. WFO regions in Colorado and Wyoming were not chosen due to their low incidences of tornadoes. Figure 1 displays a map of the WFOs and the areas they represent. The focus group locations are marked with a red star.

Figure 1. National Weather Service Central Region Weather Forecast Offices



Source: NWS 2014

The forecasters and emergency managers participated in focus groups, however the broadcast meteorologists were frequently interviewed alone or with one other meteorologist. This approach with broadcast meteorologists was used because they were from different stations with conflicting work schedules. The forecasters and emergency managers participated in separate focus groups to keep the groups occupationally similar. Typically, 7–10 people participated in each focus group. The emergency manager focus groups had more participants than the weather forecaster groups. In total, 28 weather forecasters, 50 emergency managers, and 16 broadcast meteorologists participated in the focus groups and interviews. The 50 emergency managers comprised a range of emergency management support functions, from traditional county emergency managers to manufacturing plant operators to school officials. The WFO Meteorologist-In-Charge was responsible for inviting participants to the focus groups and interviews. Hence, the participants are those with a relationship with the WFO. Emergency managers and broadcast meteorologists who do not actively stay in touch with their WFO may not be well represented in the data. A facilitator and a note taker convened each focus group and interview session. The focus groups and interviews were audio recorded. Those recordings were transcribed and then coded to discover important themes that arose from the data.

The survey instrument was developed to determine satisfaction by forecasters, emergency managers, and broadcast media with the IBW product. Questions were posed to find out how well the product conveys storm magnitude, timing, location, history, and duration, as well as forecaster confidence. These were the most important factors identified in the Gallupi et al. (2013) study in terms of assisting the emergency managers and broadcast media with understanding the severe weather threat. The instrument is in Appendix D. A modified Dillman (2000) approach, consisting of multiple email messages with a web survey link, was used to maximize response to the survey. The NWS Meteorologist-In-Charge for each WFO sent an email with a survey link to their region's list of emergency managers and broadcast media. A follow-up email was sent two weeks later. The survey was

distributed to about 5,000 people, with 833 surveys completed for a response rate of 17%. Respondents included 194 (27%) weather forecasters, 424 (59%) emergency managers, and 102 (14%) broadcast media.

Limits to the methods arise from two concerns. First, the emergency managers and broadcast media involved in the study are those connected to the WFO. Personnel in the WFOs may not have relationships with a representative sample of the emergency managers and broadcast media in their service region. The perceptions and use of the IBW product could vary significantly from those who are and who are not connected to the WFO. The second concern is that some forecasters may have been less forthright due to the focus group location. Forecaster focus groups were held in a conference room of the WFO due to logistical issues. Even though WFO supervisors did not participate in the focus group, forecasters may have felt some pressure to conform with colleagues' or supervisors' opinions due to the location. In addition, due to federal rules related to the Paperwork Reduction Act and the study's timeline, both the focus group guide and survey instrument had to be submitted to the Office of Management and Budget concurrently. This prevented the research team from including additional questions in the survey based on the input from the focus groups and interviews.

IV. FOCUS GROUP RESULTS AND DISCUSSION

In the focus groups, the forecasters, emergency managers, and broadcast meteorologists consistently brought up themes related to: (1) the effectiveness of the IBW product, (2) limits to the product's use, (3) changes suggested for the product, (4) the importance of social media in communicating severe weather information, (5) drawbacks to using social media to communicate severe weather information, and (6) other recommendations to improve NWS communication more generally.

Each theme includes a group of subthemes, which clarify how IBW is effective or what the limits to IBW are. Tables of the subthemes reveal how many weather forecasters (WF), emergency managers (EM), and broadcast meteorologists (BM) indicated a particular subtheme, as well as the total number of respondents in each group. Although the number of references to a given subtheme is an indication of the importance of the subtheme, it should be emphasized that the lack of a reference does not indicate disagreement or opposition to the subtheme. For instance, 11/28 weather forecasters indicated that the IBW product helps emergency managers and broadcast meteorologists take appropriate action. It cannot be inferred that 17 forecasters disagreed, only that they did not make any statements indicating agreement. The number of focus group locations where a theme was cited is also indicated.

1) Effectiveness of the IBW Product

Approximately half of all focus group respondents indicated that the IBW tags and impact statements add new, helpful information. A smaller proportion of weather forecasters (one-third) than emergency managers (one-half) and broadcast meteorologists (every broadcast meteorologist except for one) considered the tool to offer useful information that did not exist previously. The difference between the three groups reveals how vital NWS partners, i.e., emergency managers and broadcast meteorologists, perceive NWS products quite distinctly from NWS employees. Weather forecasters expressed a great deal of skepticism about the need for IBW, while emergency managers and broadcast meteorologists viewed IBW as something novel and effective. Themes related to the effectiveness of the IBW product are displayed in table 2.

Table 2. Themes related to the effectiveness of the IBW product

| Theme | Number of WF references | Number of EM references | Number of BM references |
|---|-------------------------|--|-------------------------|
| IBW product helps EMs and BMs take appropriate action (5/5 locations) | 11 | 8 | 9 |
| IBW product adds new, helpful information (5/5 locations) | 9 | 26 | 15 |
| IBW product is useful for the public (4/5 locations) | 1 | 4 + general consensus in one focus group | 6 |
| Total respondents | 28 | 50 | 16 |

Respondents who viewed IBW positively cited the differentiation between severity levels, the efficiency of impact statements to understand a threat, its simple, concise language, information on locations impacted, wind speed, and information source, and its attention-grabbing appeal. A Louisville emergency manager described the product, “The communication looks cleaner, less jargon.” The easy-to-understand language allows information to be digested more quickly. Phrases like “tornado possible” and “weather spotters confirmed” add vital information to the warning. Because of the number of small, short-lived tornadoes in most of the WFO regions, some weather forecasters found that the “tornado possible” tag helped them to communicate the threat of the smaller, short-lived tornadoes. About one-third of all focus group respondents indicated that the IBW tags and impact statements help emergency managers and broadcast meteorologists take appropriate action to prepare for severe weather. A Chicago broadcast meteorologist explained how the product adds value, “The language is a lot more descriptive, urgent. It makes things easier for me because I can give this information out to the public in a clearer way.”

Examples of how the IBW product might spur action on the part of emergency managers and broadcast meteorologists included stronger rationale for television station cessation of normal programming and rapid message dissemination. The strong and humanized language motivates a more urgent response. Emergency managers and broadcast media can simply copy and paste the simple and clear wording directly into their social media feeds, or repeat the warnings verbatim over the dispatch radio or television broadcast. No longer do they need to spend time digesting and translating the information. Especially for emergency managers who are unlikely to have a weather background, they don’t have to worry about misinterpreting the warning information. The IBW product requires less training to understand than previous NWS products. The enhanced language gives more confidence to emergency managers and broadcast meteorologists to make decisions. Some emergency managers reported that they would make additional calls, heighten their level of preparedness, and distribute resources more efficiently if the IBW product was deployed.

Although the ultimate aim of the IBW product is to better communicate severe weather threats, data was not collected to evaluate the public’s satisfaction with or response to the product. Almost half of the broadcast meteorologists and some emergency managers suggested that the IBW language would

benefit the public. The usefulness and applicability for the public is an area that warrants further research.

2) Limits to the Use of IBW

The majority of statements about the limits to the IBW product came from weather forecasters. Only a small number of emergency managers and broadcast meteorologists held reservations about the product. Table 3 describes themes related to the limits of the IBW product. Forecasters (almost one-half) were primarily concerned that the tags cannot be used correctly, either by themselves or by emergency managers and broadcast meteorologists. Almost one-third of forecasters described inconsistency in how the tags are issued.

Table 3. Themes related to the limits of the IBW product

| Theme | Number of WF references | Number of EM references | Number of BM references |
|--|-------------------------|-------------------------|-------------------------|
| Inconsistency in WF decision making framework to issue tags (2/5 locations) | 8 | 0 | 0 |
| Disbelief/concern that tags can be used correctly either by WFs, EMs, and BMs (4/5 locations) | 13 | 3 | 2 |
| IBW does not change actions taken by EMs/BMs (4/5 locations) | 3 | 3 | 2 |
| IBW language may cause public to discount tornado warning/advisory (4/5 locations) | 4 | 3 | 0 |
| IBW language too long (3/5 locations) | 0 | 3 | 2 |
| The public is confused and/or needs education (about warnings, tornadoes, actions to take during severe weather) (4/5 locations) | 11 | 10 | 0 |
| IBW not appropriate for common weather patterns in certain WFO regions (5/5 locations) | 6 | 9 | 6 |
| Total respondents | 28 | 50 | 16 |

Forecasters frequently disagreed with one another about the triggers that would cause a forecaster to issue a particular IBW tag. They were concerned about subjectivity in issuing the tags. Issuing a tag is not a strict science – population size, personal experience with tornadoes, and office culture all play a role. A Chicago forecaster worried, “There is so much uncertainty with our events that it would be very difficult to decide to use these tags.” Forecasters discussed whether use of the tags should be a group or office-wide decision. Many forecasters critiqued the IBW training they had received as inadequate. The IBW product was perceived by many as adding unneeded complexity to the warning decision. Even some broadcast meteorologists questioned how forecasters would determine a tornado is catastrophic. Some WFOs need additional training to feel comfortable issuing tags in a systematic decision framework.

Some focus group participants critiqued the IBW product for not reflecting the diversity in weather patterns and community types in WFO areas. Some WFO regions have weather patterns and landscapes where big tornadoes are not likely to form. Forecasters felt that the IBW product responded to a problem particular to the Southern Plains, and was not as useful in the High Plains, Mississippi River Valley or near Lake Michigan, where straight-line winds and short-lived tornadoes were more common. Because tornadoes are infrequent in many of the WFO regions, forecasters do not always have personal experience to rely on when contemplating whether a tag is appropriate. Emergency managers in four out of the five WFOs expressed more concern about winter weather than summer weather. When walking through scenarios, emergency managers, especially, would ask questions for clarification regarding winter weather. The scenarios clearly stated that it was “mid-June,” but emergency managers would either state that winter weather was a bigger concern, or ask if they should consider winter storms. A Grand Forks emergency manager stated, “It’s funny, you say it is mid-June. I would do less in mid-June than I would in mid-December . . . You have to do a lot more planning for a snow event.” Concerns about the IBW language were also raised about how applicable the IBW product was for rural areas. Modifications may be needed for rural areas so that impact statements are relevant. For example, adding language about destruction of crops or dangerous conditions for livestock would be more motivating to a farming area.

One theme that emerged in the focus groups, which may be outside of the scope of what the IBW product can address, was public apathy towards tornado warnings. A Chicago emergency manager gave a personal example, “My dad is the person we’re trying to get to. I called him on the phone. He’s outside. I can literally hear the siren going off in the background. I asked, ‘What are you doing?’ He said, ‘I’m looking for the tornado.’” Emergency managers and forecasters expressed the most concern with the public’s understanding of tornado warnings. Almost a quarter of the forecasters expressed concern that the public is complacent and does not take warnings very seriously. Emergency managers have the same concern, and some feel that the public needs education about tornado warnings and what to do when the warnings are issued. Although the overwhelming concern expressed by both emergency managers and forecasters was over-warning and desensitizing the public to severe weather warnings, there was also concern about the public’s confusion about what action to take when a warning is issued.

Forecasters questioned the public’s ability, as well as that of the media and emergency managers, to discern the difference between a considerable and catastrophic tag. Forecasters were concerned that the IBW product adds new terms that will confuse the public, or cause the public to discount the terms watch and warning. “People are getting numbed,” was a concern raised by a weather forecaster from Chicago.

3) Changes Suggested for the IBW product

A number of changes were suggested to improve the IBW product; they are described in table 4. Almost half of weather forecasters emphasized the need for ground-truthing for the IBW product to be effective. Many forecasters concluded that trained spotter confirmation is critical to have the confidence to use a tag. For example, a Northern Indiana forecaster suggested, “Helicopters and real-time spotter reports would be helpful in making considerable or catastrophic decisions.” Emergency managers and broadcast meteorologists want to know the type of spotter that confirmed the tornado. They will take the message more seriously if the spotter was trained. A Chicago emergency manager suggested that a database of spotters with unique identification numbers would be useful. Forecasters would know whether the spotter was trained and who were trustworthy spotters based on past interaction. Reliable spotter reports are critical in rural areas and areas with poor radar coverage.

Table 4. Themes related to changes suggested for the IBW product

| Theme | Number of WF references | Number of EM references | Number of BM references |
|---|---------------------------|-------------------------|-------------------------|
| Ground truthing needed for IBW to be effective. Spotters are an important source of ground truth information. (4/5 locations) | 23 | 18 | 4 |
| Order of tag and impact statement info needs to be rearranged/greater emphasis needed on weather radios (4/5 locations) | 8 | 9 | 3 |
| In-person training needed for IBW (like radar school) (1/5 locations) | 4 | 0 | 0 |
| Tag info should be modifiable by forecaster (3/5 locations) | 3 | 11 | 5 |
| Make warnings more social media friendly, shorter and mixed-case (2/5 locations) | 0 | 0 | 3 |
| Impact statement is too strong for actual threat (i.e., 60 mph winds will not damage siding and 3/4 –inch hail will not damage roofs) (1/5 locations) | 0 | 1 | 1 |
| Flexibility in tags needed for rural regions (3/5 locations) | Consensus in several WFOs | 0 | 0 |
| Training suitable to a WFO region’s weather patterns and communities needed (3/5 locations) | Consensus in several WFOs | 0 | 0 |
| Spotter training needed for specific populations like contractors or schools in order to recruit spotters (2/5 locations) | 0 | 2 | 0 |
| More in-person spotter trainings needed (2/5 locations) | 0 | 9 | 0 |
| Total respondents | 28 | 50 | 16 |

Some forecasters and emergency managers suggested format changes to emphasize the key messages of the IBW product. Emergency managers want it to read like a press release with the most important information first. A Louisville emergency manager explained, “Just like in a press release, you want your most urgent message to be first.” The quicker the key messages are read, they quicker they can be acted upon. The damage threat tag should be at the top of the IBW product, or as a title in bold font. The most important information such as location, source, and impact should follow. Emergency managers and broadcast meteorologists would also like the IBW product to be mixed-case to improve readability. A difference in voice inflection on NOAA weather radios would alert listeners to the weather severity. Bullet points were suggested.

A number of emergency managers and broadcast meteorologists desired added or altered content to the IBW product. To simplify the message, a Louisville forecaster suggested color coding or a

number system instead of the terms “considerable” and “catastrophic”. Forecasters and emergency managers wanted the impact statements modified to be relevant to their communities. Rural areas especially warrant different types of impacts. A Quad Cities emergency manager suggested differentiating outdoor safety hazards from indoor safety hazards. Many forecasters expressed a desire to be consulted about IBW product development, to ensure the product made sense for their region. Chicago emergency managers described a need for a greater range of tornado impacts and differentiation between super cells, long track tornados, and a line of thunderstorms. Broadcast meteorologists wanted more information on storm history. They feel that the public will take the storm more seriously if the storm’s recent impacts are known. Emergency managers and broadcast meteorologists desired more detailed information on location – including the name of a city will get the sirens going and be more useful to travelers unfamiliar with the county name.

IBW trainings for forecasters and spotter trainings for the public were suggested to improve the effectiveness of the IBW product. The consensus in several WFOs was that forecasters would like IBW training specific to their environment (e.g., smaller, short-lived tornadoes) and training for the application of the tags in rural areas. They felt that the tags were meant for large urban areas, and areas with large long-track tornadoes. A suggestion was made by several forecasters to hold in-person trainings, similar to radar school, where they could ask questions in real-time and work with the scenarios with trainers. A Chicago forecaster critiqued his IBW training, “From the scientific side, we used to have big organized training efforts for radar stuff, for winter storms, severe storms. And now, it's like well check out this Google doc. Maybe there is a quick webinar. And sometimes you don't even hear about it.”

Emergency managers asked for additional training for spotters, as well as training to read the radar. Many emergency managers reported using sources of information other than the NWS and were concerned that they did not necessarily know how to read the radar or adequately use some of the commercially available products (e.g., Weather Underground, Radarscope). Emergency managers requested additional, in-person training for spotters. Especially in the Northern Indiana WFO, emergency managers reported that after switching to webinar-based trainings, the number of spotters participating declined.

4) The Importance of Social Media

Social media was addressed by some focus group respondents as they discussed how they receive and send information found in the IBW product among themselves and the public. Table 5 describes the themes about the importance of social media. Over half of broadcast meteorologists, and a smaller proportion of emergency managers and forecasters described NWS Chat as an important communication tool to share information with one another. This private social media platform facilitates real-time dialogue between forecasters, emergency managers, and broadcast meteorologists. Chat communication is quicker than printed-out warnings. Emergency managers and broadcast meteorologists benefit from being able to ask follow-up questions after a warning has been issued. They can also share weather information, giving forecasters greater access to on-the-ground reports. NWS Chat can be accessed from smart phones, which allows emergency managers away from their offices or a computer to stay up to date on weather developments.

Table 5. Themes related to the importance of social media

| Theme | Number of WF references | Number of EM references | Number of BM references |
|--|-------------------------|-------------------------|-------------------------|
| NWS Chat plays important role in disseminating severe storm information to EMs and BMs (5/5 locations) | 5 | 8 | 9 |
| Social media relays needed info from public to WF, EMs, and BMs (3/5 locations) | 5 | 3 | 8 |
| Social media allows WFs, EMs, and BMs to get correct messages out to public (4/5 locations) | 6 | 3 | 8 |
| Total respondents | 28 | 50 | 16 |

Broadcast meteorologists (one-half) described how social media is used to relay needed information from the public, as well as a platform for delivering information to the public. Fewer forecasters and emergency managers rely on social media in this manner. Broadcast meteorologists are the most visible to the public due to their television persona and generally have more active social media presences. Many meteorologists constantly update Facebook and other social media platforms like Twitter with weather news and links to NWS products. The IBW product is especially conducive to social media because of the simple, public-ready language. Chicago meteorologists post screen shots of weather radar and solicit feedback from the public on their experience with a storm. More popular meteorologists have the greatest social media reaches. Popularity stems from length on air and personality. A Quad Cities broadcast meteorologist explained that it’s necessary to use the same communication platforms that young people use if warning messages are to be received and action taken. Keeping up with communication trends is also key to receiving the latest information.

Forecasters use public social media platforms inconsistently. Some WFOs use the tool a great deal, while others do not find it useful or feasible. Few emergency managers reported a reliance on public social media platforms to share or receive information. WFOs that have embraced social media typically dedicate a staff person to monitor and send information on the WFOs social media platforms. Forecasters and emergency managers that use social media benefit from storm pictures sent through social media channels. The public’s description of a weather phenomenon may lead to incorrect conclusions, however a picture can be interpreted by trained spotters and weather forecasters and meteorologists. A Northern Indiana forecaster gave an example of how social media posts from the public can supplement information from trained spotters, “We might not be getting any calls from trained spotters, but the next thing you know, you have 20 comments [on Facebook] – ‘I have quarter-sized hail at my house.’”

5) Social Media Drawbacks

Two major drawbacks to social media in relation to the IBW product were noted by respondents. First, the public sends faulty and incomplete information through social media channels.

Forecasters described the problems that could arise from using social media information to make a considerable or catastrophic damage tag decision. Some forecasters described examples of the public sending incorrect information on platforms like Facebook and Twitter. Only a couple of emergency managers and broadcast meteorologists brought up this issue. The quality of public reports from social media is inconsistent and requires sorting out good information from bad information. A Northern Indiana forecaster explained, “A lot of weather information comes in from social media, regardless of whether it’s right or wrong.” Table 6 describes the themes related to the drawbacks of social media.

Table 6. Themes related to social media drawbacks

| Theme | Number of WF references | Number of EM references | Number of BM references |
|---|-------------------------|-------------------------|-------------------------|
| Incorrect information coming from public via social media (4/5 locations) | 5 | 2 | 3 |
| Internet/social media not accessible by everyone (3/5 locations) | 1 | 4 | 0 |
| WFO social media protocols still in development (5/5 locations) | 6 | 0 | 1 |
| Total respondents | 28 | 50 | 16 |

Second, social media is not accessible by everyone. Especially in rural areas and for emergency managers on the road, internet and broadband coverage is not reliable. Also, some emergency managers don’t have a mobile device or access to a computer; so they have no way of keeping up with social media communication. Even some WFOs do not have enough bandwidth to stream videos. A slow internet connection prevents forecasters at the Northern Indiana WFO from live streaming weather spotter videos. A Quad Cities emergency manager shared, “We have problems being in a rural area. We lose our internet connection so we don’t have NWS Chat available to us in a storm situation.”

While NWS Chat was used extensively in 4/5 WFOs, the Chicago WFO region emergency managers and broadcast meteorologists relied more on conference calls and the phone. The reliance on the phone was repeated through all of the focus groups and interviews for that forecast office. One forecaster reported calling an emergency manager when spotting something of concern on radar. A Chicago-based broadcast meteorologist said when asked if he used the NWS Chat, “The other communication that we have with the Weather Service that I partake in, whenever possible, is if they have some sort of severe weather briefing that they will do via a call in center and they will have all of the emergency managers and any other TV/radio meteorologists are able to call-in.” Participants in the Chicago WFO region focus groups did not make it clear why they use the phone and conference calls over NWS Chat.

Because social media protocols are still in development for WFOs, the use of social media varies greatly among offices. Some forecasters are concerned about the time sink that social media requires. “Social media is creeping deeper and deeper into operations and I’m concerned that it becomes a distraction,” related a Quad Cities forecaster. Not all WFOs have the resources and capacity to keep up

with social media communication. During an extreme weather event, forecasters have many pressing duties. Without sufficient personnel, some WFOs choose not to spend precious staff resources on social media communication, which drives inconsistent social media use.

6) Other Recommendations for NWS

The primary focus group recommendations that were not IBW-related fell in three categories: warning improvements, emergency manager trainings, and requests for uniform siren policies. Table 7 describes the themes related to these recommendations. The requests for warning improvements came mostly from emergency managers, but from broadcast meteorologists as well. These user groups suggested that NWS products be more social media friendly (i.e., shorter, easier to share, mixed-case) and that warnings are more accurate and regularly and clearly updated. Emergency managers would also benefit from regular trainings to read radar and interpret weather polygons, as well as networking opportunities and opportunities to give targeted feedback to the NWS. Because emergency managers are geographically dispersed and work for a variety of agencies and organizations, they have limited opportunities to get together to share ideas related to weather preparedness.

Table 7. Themes related to other recommendations for NWS

| Theme | Number of WF references | Number of EM references | Number of BM references |
|--|-------------------------|-------------------------|-------------------------|
| Would like to see more specific flood warnings, like polygons for the rivers where flooding expected (1/5 locations) | 0 | 0 | 1 |
| Need tiered approach to severe thunderstorm warnings (1/5 locations) | 2 | 0 | 0 |
| Need uniform warning siren activation guidelines and promotion of the guidelines, public education and/or automatic activation of sirens (linked to the warnings) needed (4/5 locations) | 0 | 19 | 1 |
| Working groups needed to facilitate active communication and feedback between weather forecasters and emergency managers (1/5 locations) | 0 | 1 | 0 |
| Requests for emergency manager trainings to improve uptake of weather information (1/5 locations) | 0 | 5 | 0 |
| Technical assistance on warnings needed – integrate into EM training above (1/5 locations) | 0 | 2 | 0 |
| Would like a way to connect spotters to their report - like an ID number (1/5 locations) | 0 | 2 | 0 |
| Consistent warnings from WFOs needed for whole region (There is a media market that has counties covered by 3 WFOs - they are concerned because there are three different criteria for heat & winter weather advisories) (1/5 locations) | 0 | 0 | 2 |

| | | | |
|---|---|----|---|
| Continue with WFO communications with user groups and the public: i.e., please put the winter weather video on FB (request from Chicago WFO), continue with Power Point presentations on weather conditions (from Quad Cities) (2/5 locations) | 0 | 3 | 1 |
| Email/text alerts & alerts for warnings in surrounding counties (as in more advanced warnings) needed (1/5 locations) | 0 | 3 | 0 |
| Advanced warnings for prescribed fires needed (1/5 locations) | 0 | 1 | 0 |
| Requests to generally improve warnings: improve accuracy, regular updates, estimated storm length, radar image, add storm history, make products social media-friendly (including mixed-case), color-coding to indicate forecaster confidence in threat (5/5 locations) | 2 | 11 | 4 |

NWS guidance was requested on siren policy standardization. Siren use was a concern of emergency managers in every WFO. In Northern Indiana, sirens dominated almost half of the focus group time. In almost every group, the emergency managers cited different policies for neighboring communities as a source of confusion for residents. In the Northern Indiana focus group, an emergency manager reported that his community activates sirens for severe thunderstorm warnings. An emergency manager in the Grand Forks region said that they activate their sirens for severe thunderstorms with winds over 70 miles per hour. Yet another emergency manager in the Grand Forks area said that the sirens result in panic in his community because of the memory of the Red River flooding in 1997, when the sirens were active for days without shutting off. A Chicago emergency manager concluded, “The NWS should either develop or endorse a warning siren activation guideline and promote it like they promote weather radio.”

V.1. SURVEY RESULTS

Surveys to determine satisfaction levels with the IBW product, as well as suggested modifications, were sent to NWS weather forecasters, emergency managers, and broadcast media throughout the NWS Central Region. The survey results were similar to the focus group findings, but provide greater confidence in generalizability. The key themes that arose in the survey results are: (1) greater satisfaction among emergency managers and broadcast media compared to weather forecasters with the IBW product, (2) the positive relationship between satisfaction with forecaster training and satisfaction with the IBW product, and (3) no difference in IBW satisfaction between WFO regions that did or did not deploy the IBW product.

1) Greater satisfaction among emergency managers and broadcast media

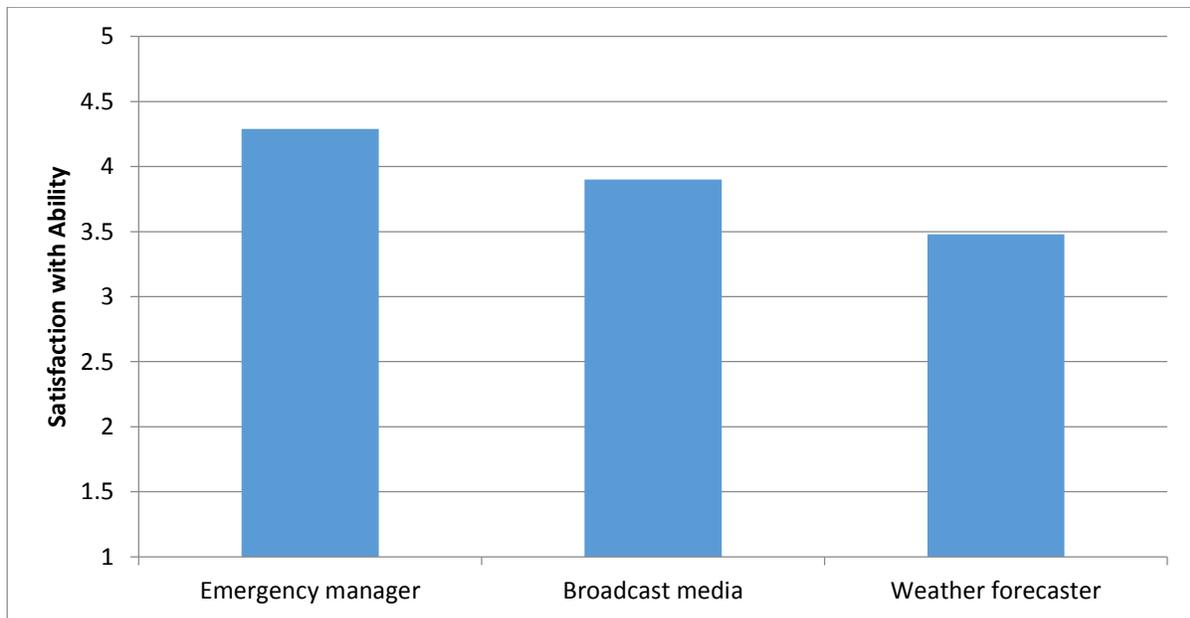
A univariate analysis of variance (ANOVA) test with an alpha level of 0.05 was performed to compare means for items measuring satisfaction with the IBW product among emergency managers, broadcast media, and weather forecasters. The ANOVA test helps us understand if the groups’ mean responses are statistically different from one another. On a scale of 1 (not at all satisfied) to 5 (extremely satisfied), emergency managers were most satisfied with the ability of the product to convey needed

information about thunderstorm and tornado impacts (Ability; Table 8), with a mean of 4.29 (Figure 2). Average ratings for the same satisfaction item were 3.90 for broadcast media and 3.48 for weather forecasters. Table 8 presents a list of attributes for which survey respondents were asked to rate their level of satisfaction.

Table 8. IBW survey items abbreviated as IBW satisfaction items

| IBW satisfaction item | IBW survey item |
|-----------------------|--|
| Ability | The ability of NWS threat tags and impact statements to convey needed information about thunderstorm and tornado impacts |
| Severity | The addition of the words "CONSIDERABLE" and "CATASTROPHIC" to convey increased severity of impacts during a NWS tornado warning |
| Magnitude | Ability of NWS impact statement to convey magnitude (potential size) |
| Confidence | Ability of NWS impact statement to convey confidence (how confident is the NWS forecaster) |
| Alignment | Alignment of NWS impact statement with tornado damage threat tag |
| Timing | Ability of NWS impact statements to convey timing (when storm will hit my area) |
| Location | Ability of NWS impact statement to convey location (where storm will hit) |
| History | Ability of NWS impact statement to convey storm history (what damage/impacts has the storm had so far) |
| Duration | Ability of NWS impact statement to convey duration (how long storm will last) |

Figure 2. Satisfaction with IBW's ability to convey necessary information about storms by job type

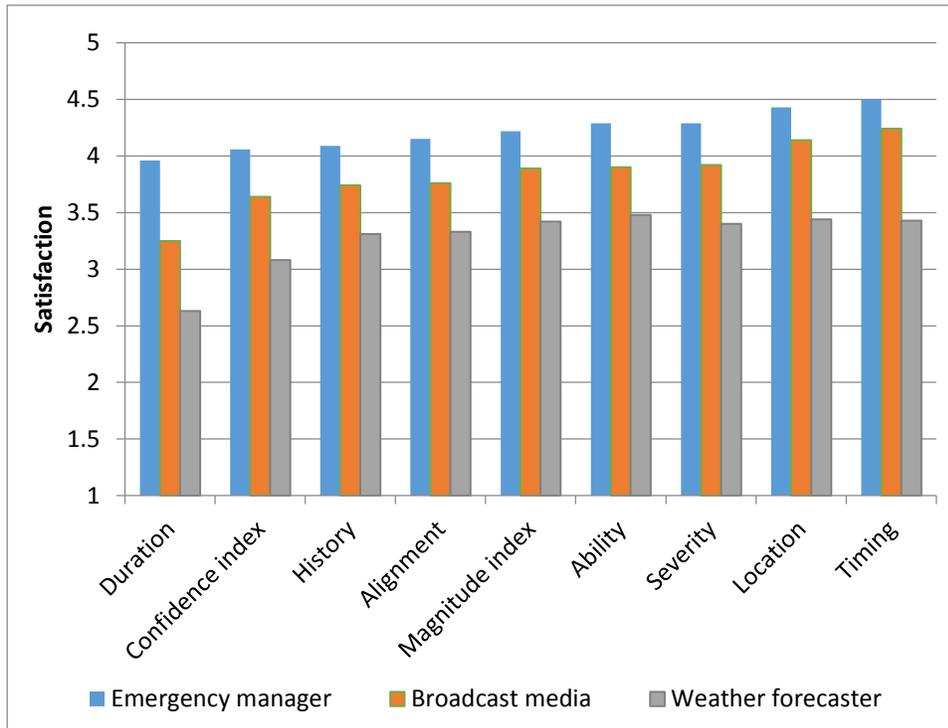


The ANOVA test comparing job type-specific means produced statistically significant results: $F(2, 717) = 51.38, p < 0.001$. The post-hoc comparison test Bonferroni showed that each job type was significantly different from the other two at $p < 0.05$. This pattern was consistent across all IBW satisfaction items, including severity, confidence index, magnitude index, alignment, timing, location, history, and duration (Table 9; Figure 3). While ANOVA tests look for a difference among any of the means, a post-hoc test, such as Bonferroni, examines differences between each group in the test. We chose Bonferroni for our post-hoc test as it is suitable for groups with unequal sample sizes.

Table 9. ANOVA results for IBW satisfaction items by job type

| IBW satisfaction item | Job type | Mean | df, n-df | F | Sig. |
|-----------------------|-------------------------|------|----------|-------|--------|
| Ability | Emergency manager | 4.29 | 2, 717 | 51.38 | <0.001 |
| | Broadcast meteorologist | 3.90 | | | |
| | Weather forecaster | 3.48 | | | |
| Severity | Emergency manager | 4.29 | 2, 717 | 46.25 | <0.001 |
| | Broadcast meteorologist | 3.92 | | | |
| | Weather forecaster | 3.40 | | | |
| Magnitude index | Emergency manager | 4.22 | 2, 702 | 51.49 | <0.001 |
| | Broadcast meteorologist | 3.89 | | | |
| | Weather forecaster | 3.42 | | | |
| Confidence index | Emergency manager | 4.06 | 2, 701 | 61.04 | <0.001 |
| | Broadcast meteorologist | 3.64 | | | |
| | Weather forecaster | 3.08 | | | |
| Alignment | Emergency manager | 4.15 | 2, 700 | 49.89 | <0.001 |
| | Broadcast meteorologist | 3.76 | | | |
| | Weather forecaster | 3.33 | | | |
| Timing | Emergency manager | 4.50 | 2, 695 | 88.87 | <0.001 |
| | Broadcast meteorologist | 4.24 | | | |
| | Weather forecaster | 3.43 | | | |
| Location | Emergency manager | 4.43 | 2, 696 | 76.15 | <0.001 |
| | Broadcast meteorologist | 4.14 | | | |
| | Weather forecaster | 3.44 | | | |
| History | Emergency manager | 4.09 | 2, 695 | 26.45 | <0.001 |
| | Broadcast meteorologist | 3.74 | | | |
| | Weather forecaster | 3.31 | | | |
| Duration | Emergency manager | 3.96 | 2, 697 | 77.87 | <0.001 |
| | Broadcast meteorologist | 3.25 | | | |
| | Weather forecaster | 2.63 | | | |

Figure 3. IBW aspect results for IBW satisfaction items by job type, arranged in increasing order



A repeated measures ANOVA test with an alpha level of 0.05 was performed to compare means for items measuring satisfaction with the ability of the IBW product to convey confidence of the weather forecaster when different threat tags (base, considerable, and catastrophic) were used. The test produced statistically significant results— $F(2, 725) = 25.65, p < 0.001$ —indicating that respondents scored satisfaction differently across threat tags. The Bonferroni test showed that each threat tag response was significantly different from the other two at $p < 0.05$. These results were also true for the threat tags regarding the magnitude of a storm (Table 10).

Table 10. Repeated measures ANOVA results for confidence and magnitude threat tags

| Confidence | Mean | df, n-df | F | Sig. | Partial Eta Squared |
|-------------------------|------|----------|-------|--------|---------------------|
| Base threat tag | 3.63 | 2, 725 | 25.65 | >0.001 | 0.04 |
| Considerable threat tag | 3.78 | | | | |
| Catastrophic threat tag | 3.84 | | | | |
| Magnitude | | | | | |
| Base threat tag | 3.79 | 2, 730 | 45.95 | >0.001 | 0.06 |
| Considerable threat tag | 4.03 | | | | |
| Catastrophic threat tag | 4.09 | | | | |

However, the ANOVA tests for confidence and magnitude had a small effect size, with partial eta

squared equaling 0.03 and 0.06, respectively. As an effect size of 0.10 and below is considered minimal, the statistical significance of the test may be due to the large sample size rather than meaningful differences among the means. Therefore, we created an index for each variable to measure respondents' collective attitude toward magnitude and confidence. Reliability results indicated sufficient internal consistency for the creation of two indices (Table 11). This means that respondents scored similarly enough for each confidence and magnitude threat tag that we can average the tag responses to create holistic index variables for these two items. These indices are used to represent IBW product satisfaction for the aspects confidence and magnitude in Table 11.

Table 11. Reliability results for confidence and magnitude indices

| Magnitude | Cronbach's alpha | Confidence | Cronbach's alpha |
|-------------------------|-------------------------|-------------------------|-------------------------|
| Magnitude index | 0.85 | Confidence index | 0.91 |
| Base threat tag | 0.89 | Base threat tag | 0.93 |
| Considerable threat tag | 0.70 | Considerable threat tag | 0.80 |
| Catastrophic threat tag | 0.78 | Catastrophic threat tag | 0.86 |

The job type pattern previously described held true for satisfaction with the IBW product to properly communicate the damage threat for wind and hail (Table 12). A paired samples *t*-test with an alpha level of .05 was performed to compare means for the entire sample between satisfaction items for wind and hail. A paired samples *t*-test helps us understand if there is a statistically significant difference between a person's responses to two items on a survey. The *t*-test produced statistically non-significant results— $t(713) = -0.50$, $p = 0.62$ —indicating that respondents scored satisfaction for wind and hail similarly.

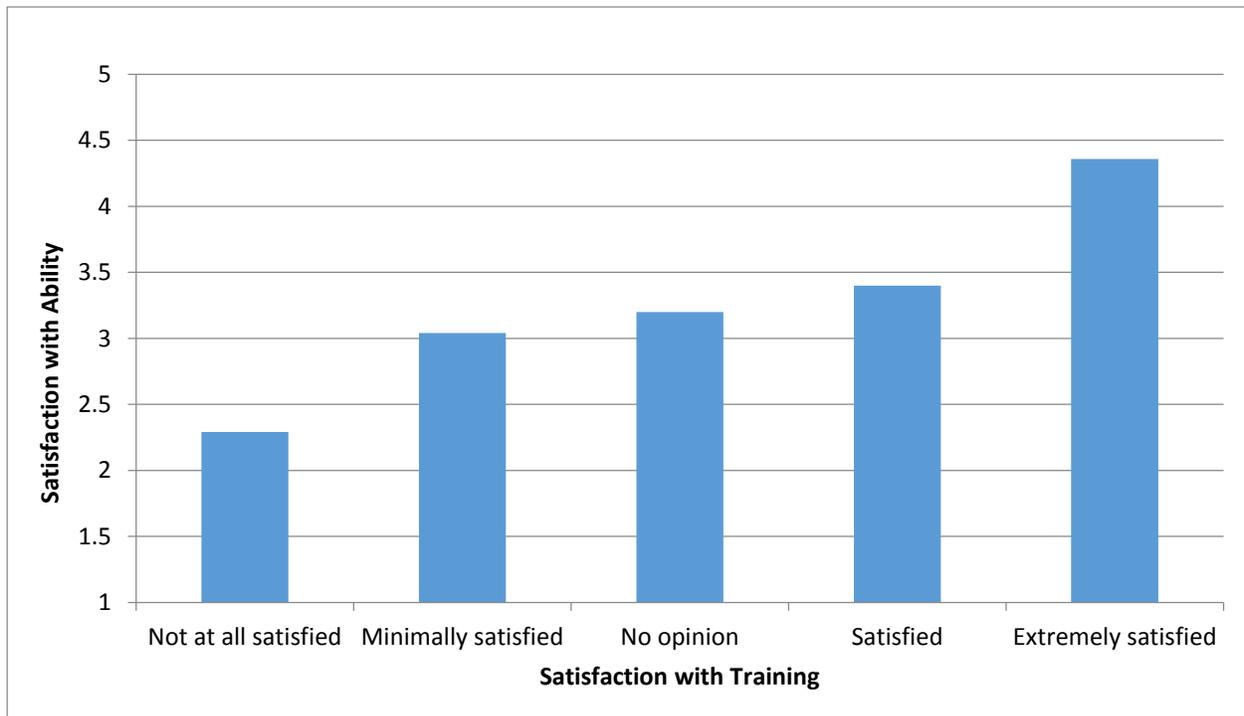
Table 12. ANOVA results for IBW satisfaction regarding wind and hail items by job type

| IBW satisfaction item | Job type | Mean | df, n-df | F | Sig. |
|------------------------------|-------------------------|-------------|-----------------|----------|-------------|
| Wind | Emergency manager | 4.36 | 2, 696 | 49.40 | <0.001 |
| | Broadcast meteorologist | 4.03 | | | |
| | Weather forecaster | 3.5 | | | |
| Hail | Emergency manager | 4.3 | 2, 696 | 33.359 | <0.001 |
| | Broadcast meteorologist | 4.16 | | | |
| | Weather forecaster | 3.61 | | | |

2) Positive relationship between forecaster training satisfaction and IBW product satisfaction

Weather forecasters indicated various levels of satisfaction with their IBW training. An ANOVA test with an alpha level of 0.05 was performed to compare satisfaction with IBW's ability to convey needed information about thunderstorm and tornado impacts among weather forecasters. As satisfaction with training increased, satisfaction with IBW's ability to convey necessary information also increased (Figure 4).

Figure 4. Satisfaction with IBW’s ability to convey necessary information about storms by satisfaction with IBW training



The ANOVA test comparing mean satisfaction with IBW ability by satisfaction with IBW training produced statistically significant results: $F(4, 169) = 11.74, p < 0.001$. The Bonferroni test showed that ‘extremely satisfied’ responses differed with all responses and ‘not at all satisfied’ responses differed with ‘satisfied responses’ at $p < 0.05$.

The majority of weather forecasters (105 of 175) were either satisfied or extremely satisfied with their level of comfort using IBW threat tags and impact statements. Fifty-nine were either minimally or not at all satisfied with their comfort level. Here, the mean was 3.29. From those minimally or not at all satisfied, no comments or suggestions were offered. The mean for WFOs that deployed the tags was higher at 3.75, with almost 75% (29 out of 40) indicating that they were satisfied or extremely satisfied.

A majority of emergency managers and broadcast media indicated a preference for pathcasts that list storm arrival times over ones listing affected cities. Forecasters responded similarly when they were asked how they thought emergency managers and broadcast media would respond regarding pathcasts. Mean responses for emergency managers, broadcast media, and weather forecasters were 3.87, 3.65, and 3.65 respectively.

3) No difference in IBW satisfaction between WFO regions that did or did not deploy the product

Of the 38 offices, only 11 deployed IBW tags during the study period: Wichita, Sioux Falls, Hastings, St. Louis, Detroit, Duluth, Topeka, Paducah, Central Illinois, Chicago, and Indianapolis. Wichita and Sioux Falls were the only two to use the catastrophic threat tag. WFOs that deployed tags rated IBW satisfaction items consistently slightly higher, but results were insignificant at $p > 0.05$ (Table 13).

Table 13. T-test results for IBW satisfaction items by WFO IBW tag deployment

| IBW satisfaction item | WFO IBW deployment | Mean | n | t | Sig. |
|-----------------------|--------------------|------|-----|--------|-------|
| Ability | Did not deploy | 4.02 | 681 | -1.255 | 0.21 |
| | Deployed | 4.12 | | | |
| Severity | Did not deploy | 4.03 | 681 | -0.811 | 0.418 |
| | Deployed | 4.10 | | | |
| Magnitude Index | Did not deploy | 4.00 | 680 | -0.827 | 0.408 |
| | Deployed | 4.06 | | | |
| Confidence Index | Did not deploy | 3.76 | 679 | -0.905 | 0.366 |
| | Deployed | 3.84 | | | |
| Alignment | Did not deploy | 3.88 | 678 | -1.853 | 0.064 |
| | Deployed | 4.02 | | | |
| Timing | Did not deploy | 4.21 | 678 | -0.255 | 0.799 |
| | Deployed | 4.23 | | | |
| Location | Did not deploy | 4.11 | 679 | -1.937 | 0.053 |
| | Deployed | 4.26 | | | |
| History | Did not deploy | 3.85 | 678 | -0.552 | 0.581 |
| | Deployed | 3.90 | | | |
| Duration | Did not deploy | 3.51 | 679 | -1.69 | 0.092 |
| | Deployed | 3.69 | | | |
| Wind | Did not deploy | 4.07 | 681 | -2.399 | 0.017 |
| | Deployed | 4.27 | | | |
| Hail | Did not deploy | 4.11 | 681 | -1.083 | 0.279 |
| | Deployed | 4.19 | | | |

Open-ended survey questions asked emergency managers and broadcast media to identify useful impact information that could be provided by NWS. Some comments indicated satisfaction with the IBW tool as is. Information desired, as well as modifications to the IBW product message, is listed below:

- Include recommended actions for people to take (e.g., stay inside, seek shelter).
- Provide information on expected threat, locations impacted, timing and duration of expected impacts, and storm damage history.
- Include a list of larger communities in the path as well as smaller communities that may be impacted.
- Provide frequent updates during the course of a severe weather event.
- Make a clear distinction between actual confirmed and observed threats and those based on

radar observation.

- Indicate where information is coming from (e.g., storm spotter, law enforcement, public, radar, on-the-ground observations).
- Do not overstate impacts.
- Use Plain language and brevity to communicate impacts.

Weather forecasters were asked to provide open-ended comments and suggestions on the IBW product. A few forecasters suggested the IBW product is useful and should be expanded nationwide with pathcasts. Yet, seventy-seven responses were provided, and less than 10% were positive. Most comments communicated concerns about the product and provided suggestions for improvement. Some forecasters felt the weather science and technology available does not allow for precision or accuracy in determining an appropriate IBW threat tag. Concerns were raised that there are too many unknowns to accurately communicate path, timing, and duration for specific areas. Ideas for IBW product improvement included the following:

- Product should be regionalized to better fit each part of the country and WFOs should be given greater flexibility to change wording to fit their communities' needs.
- Critical information should go at the top of the IBW product (e.g., what, where, when).
- Impact statements should not be overly strong in their wording. Language used to convey confidence in messages may be too strong. For example, words like "will" or "confirmed" should be replaced with "could," "may," "possible," or "indicated."
- Additional training is needed to effectively use IBW product. More clarification is needed to determine if and when "considerable" vs. "catastrophic" is appropriate.
- More peer reviewed research is needed before implementation of the IBW product.

V.2. SURVEY DISCUSSION

Because the survey sample was large, many results were statistically significant. This discussion explores the practical significance of statistical results and provides management implications for NWS. Survey results revealed that emergency managers, broadcast media, and weather forecasters are overall satisfied with the IBW product, which suggests that the product improves communication between NWS and their constituents. The product provides emergency managers and broadcast media with more information, especially on recommended actions, and both groups indicated that this is positive. More information can be used to make better decisions locally regarding severe weather. Emergency managers are most satisfied with the system, followed by broadcast media and weather forecasters. This trend may be due to formal education in severe weather. In our sample, emergency managers included a broad range of emergency responders, such as policemen and fire chiefs, who may have no severe weather education. Broadcast media and weather forecasters are likely to be more familiar with severe weather issues, which may make them more likely to critically analyze the tool and pinpoint shortfalls. Weather forecasters were able to provide many suggestions for improvement. This trend may also be due to accountability for providing accurate information. Broadcast media may feel highly accountable for false alarms by the public, while weather forecasters feel accountable as the scientific experts or purveyors of the information.

The fact that respondents reported being less satisfied with more severe threat tags may reflect a higher level of uncertainty with more severe storms and an anxiety over false reporting. While the trend is intellectually interesting, the differences among threat tags were too small to have practical management implications. Respondents scored fairly similarly on the impact statements' ability to communicate damage threats for wind and hail, suggesting that respondents perceive them similarly. If NWS alters the IBW product, they may be able to make holistic changes to wind and hail items.

Perhaps the result with the largest management implication for NWS is the relationship between the weather forecasters' satisfaction with IBW training and their satisfaction with the product's ability to communicate necessary information about storm impacts. The results suggest that raising satisfaction with IBW training would increase forecasters' satisfaction with the tool. Assuming that satisfaction with IBW training related to training quality, NWS should consider methods to improve trainings. For example, trainings could include in-person interactions, hands-on activities, and live IBW deployment drills.

A possibly surprising result was the lack of a significant difference in the ability of the IBW product to communicate storm impacts in WFOs that had deployed the product vs. those that had not. This implies that NWS should not expect satisfaction levels with the product to increase or decrease as a result of deployment. It seems that respondents' expectations about the usefulness of and comfort with the product are similar to the perceptions of those respondents with experience.

NWS should consult the open-ended responses section of the results for suggestions from emergency managers, broadcast media, and weather forecasters on how to improve the IBW product. Emergency managers did not display the same concerns with strong language, false alarms, and reliability as did broadcast media and weather forecasters. Emergency managers instead emphasized the need for plain language and additional information about potential impacts as well as the importance of timing, location, and duration. Broadcast media suggestions were varied; no major themes besides those already described were present. Most weather forecaster suggestions related to altering the product to reduce the number of false alarms. Many forecasters complained that the language was inflexible and might be too strong for their constituents.

VI. CONCLUSION

The primary purpose of the study was to help NWS improve communication efforts between forecasters and their constituents, emergency managers and broadcast media, through an evaluation of the IBW product. In particular, our interest was in exploring how the IBW product is used and perceived as well as identifying satisfaction levels with the product. Information collected in this investigation expands what we know about perceptions of severe weather communication and provides NWS with recommendations for the IBW product. We used a combination of focus group, interview, and survey methodologies, and our methods were informed by past IBW research (Galluppi et al. 2013). Although the methods examined different aspects of the IBW product, the results can be combined to enhance NWS efforts to improve severe weather communication.

From the survey and focus group data, we conclude that end users of the IBW product, emergency managers and broadcast media, are more satisfied regarding both the need for and operation of the tool than those charged with implementing the product and using the tool: weather forecasters. Survey responses and focus group data show that some forecasters felt that their opinions

were not solicited during the development of the IBW product and that the science available is not sufficient to reliably use the tool. Improvements to the forecaster IBW training will likely increase their satisfaction with the product.

The IBW product was commended for differentiating between severity levels and the efficiency of impact statements to understand a threat. Its simple, concise language makes the product easy to digest and disseminate. Modifications suggested for the product include making it relevant and modifiable for regions with diverse weather patterns and community types. Involving weather forecasters from a variety of WFOs to improve the product would be beneficial given their concern about not having input in the original development. Creating a decision making framework for when to use the tags could be beneficial as many forecasters disagreed about the triggers needed to issue a damage threat tag.

Additional severe weather risk communication themes that arose included the benefits of and drawbacks to social media as well as the need for a uniform siren policy. Inadequate budgetary resources drive inconsistent use of social media by WFOs, potentially limiting important communication pathways between NWS and the public. The fractional nature of the media landscape requires additional resources to stay abreast of and be part of the public's conversation, whether it occurs through a Facebook newsfeed, Twitter deck, or traditional news media. Finally, inconsistent siren policies by local governments cause confusion. Emergency managers suggested that NWS move towards a uniform siren policy and provide national leadership to encourage consistent response to sirens.

An issue that deserves study and attention is the need for user feedback and evaluation of new NWS communication products. Studies like this one will help weather forecasters understand how the recipients of IBW information react to the damage threat tags and impact statements once the results are reported back to the region. Another potential area of future research is how the IBW information affects the public's response to a severe weather event. Many of the respondents in the focus group setting stated their belief that the public would benefit from the tool. However, there is no evidence—from this study—that this would be the case. Some respondents in the emergency manager community stated that the public would need more instruction about what they should do and not just the risks. Further studies such as these could illuminate severe weather communication limitations and determine how we can alter this communication to improve risk management.

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Appendix A: IBW Warning Product Example

WFUS53 KXYZ 192045
TORICT
KSC173-192115-
/O.NEW.KXYZ.TO.W.0005.130619T2030Z-130619T2115Z/

BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE SOMEWHERE ST
330 PM CDT WED JUN 19 2013

THE NATIONAL WEATHER SERVICE IN SOMEWHERE HAS ISSUED A

* TORNADO WARNING FOR...
YOUR COUNTY IN YOUR STATE...

* UNTIL 415 PM CDT

* AT 345 PM CDT...A CONFIRMED LARGE...VIOLENT AND EXTREMELY DANGEROUS
TORNADO WAS LOCATED ON THE SOUTHWEST SIDE OF YOUR CITY...AND MOVING
NORTHEAST AT 30 MPH.

THIS IS A TORNADO EMERGENCY FOR YOUR CITY.

HAZARD...DEADLY TORNADO.

SOURCE...WEATHER SPOTTERS CONFIRMED TORNADO.

IMPACT...YOU COULD BE KILLED IF NOT UNDERGROUND OR IN A TORNADO
SHELTER. COMPLETE DESTRUCTION OF NEIGHBORHOODS...BUSINESSES
AND VEHICLES WILL OCCUR. FLYING DEBRIS WILL BE DEADLY TO
PEOPLE AND ANIMALS.

* LOCATIONS IMPACTED INCLUDE...
SEVERAL TOWNS AND CITIES THROUGHOUT YOUR COUNTY.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

THIS IS AN EXTREMELY DANGEROUS TORNADO WITH COMPLETE DEVASTATION
LIKELY. YOU COULD BE KILLED IF NOT UNDERGROUND OR IN A TORNADO
SHELTER. DO NOT DELAY...SEEK SHELTER NOW! IF NO UNDERGROUND SHELTER
IS AVAILABLE SEEK SHELTER IN AN INTERIOR ROOM OF THE LOWEST LEVEL OF
A STRUCTURE...OR IF TIME ALLOWS...CONSIDER MOVING TO AN UNDERGROUND
SHELTER ELSEWHERE. MOBILE HOMES AND OUTBUILDINGS WILL OFFER NO
SHELTER FROM THIS TORNADO

&&

LAT...LON 3748 9773 3778 9751 3779 9715 3765 9715
3748 9743
TIME...MOT...LOC 2047Z 233DEG 27KT 3765 9738

TORNADO...OBSERVED
TORNADO DAMAGE THREAT...CATASTROPHIC
HAIL...2.75IN

\$\$

Appendix B: Focus Group Questions for NWS Weather Forecasters

1. Can you talk us through your warning decision process? What are your key data points and triggers?
2. How comfortable would you feel in using the considerable enhanced tag and text? Why would you feel that way?
3. How comfortable would you feel in using the catastrophic enhanced tag and text? Why would you feel that way?
4. What would be the trigger(s) that might lead you to decide to use or not use the “considerable” tag?
5. What would be the trigger(s) that might lead you to decide to use or not use the “catastrophic” tag?
6. If you issued a warning or statement with the enhanced tag, what is your perception of what it would mean to the emergency manager? The broadcast meteorologist?
7. How else does your office communicate the warning information during events?
8. As a final question and separate from what we have discussed today, have you heard any feedback from your user community on the warnings or statements that you have issued this year?

Appendix C: Focus Group Guide for Emergency Managers and Broadcast Media

I am going to give you some weather scenarios. I am interested in how you would typically respond to each scenario.

1. This is the first scenario:

It's Tuesday afternoon in mid-June and you hear that your area has a chance of severe weather tomorrow.

- How do you learn about the threat of severe weather?
- Can you tell me what that communication looks like?
- What actions or decisions are you making at this time?
- Who are you talking/working with?
- Is it operationally useful to know there is a threat the day before, or is it just good to know?

2. This is the second scenario:

It's 11 AM on Wednesday in mid-June, and a tornado watch has been issued which includes your location.

- What does a watch mean to you?
- How is your decision making affected when a watch is issued?
- What actions or decisions are you making at this time?
- Who are you talking/working with? And why, what do these people need to know?
- What do you really need to know to take your action?
- Why do you need to know this piece of information?
- What information is a major influence on your decision making?

3. This is the third scenario:

Its 3:30 PM and a tornado warning has been issued for your county. Your town is listed in the warning and the sky is looking incredibly dark and green despite being in the middle of the afternoon. Storm spotters have reported a tornado earlier with this storm, but it has since lifted. The warning is in effect until 415 PM.

- What does a warning mean to you?
- What actions or decisions are you making at this time?
- Who are you talking/working with?

4. I am passing out an example of the type of communication you may receive from the National Weather Service for a tornado warning. [Hand out warning example #2 w/o highlights]

- Does the communication look different than it has in the past?

- Is there anything that stands out as particularly useful or informative?
 - If there was, how would it change how you respond to a potential threat?
5. Since around April of this year, have you noticed differences in the warnings being issued by the NWS? If so, what did you notice?
6. I am passing out the same communication warning I passed out previously. This time it is highlighted to show how it differs from last year's communication. I am also passing out last year's communication. [Hand out warning example #2 w/highlights and warning example #1]
- Does the highlighted text help you to make decisions? If so, how?
 - If not, what might be more useful?
 - Can you talk more about that?
7. For our last question, I would like each person to go around the room and answer it. Is there other information from the NWS that you would like to receive? Please explain how this information would support your work.

Appendix D: Survey Instrument

Survey introduction

Thank you for agreeing to participate in this survey. The purpose of this research study is to evaluate the impact-based warning (IBW) communication tool that the National Weather Service has recently implemented. The questions will ask your opinion about the IBW communication tool. Your answers will help the National Weather Service evaluate the current use and usefulness of the IBW tool.

If you agree to participate, you will be asked to complete an online survey that will take approximately 10 minutes to complete.

Your risks for participating in this survey are minimal. Your responses will be collected and kept anonymous. Identifying information such as your name, email address, and the Internet Protocol (IP) address of this computer will not be asked or available to the researchers. Data will be retained on the Qualtrics website server for 1 year and will be deleted by the research staff after this time. However, data may exist on backups or server logs beyond the timeframe of this research project. Data transferred from the survey site will be saved on a password-protected computer for 2 years. Only study staff will have access to the data collected by this study. However, the National Weather Service, the Institutional Review Board at the University of Wisconsin or appropriate federal agencies like the Office for Human Research Protections may review this study's records.

Your participation in this study is voluntary. You may choose to not answer any of the questions or withdraw from this study at any time without penalty. Your decision will not change any present or future relationship with the University of Wisconsin.

For more information about the study or study procedures, contact Jane Harrison at janeharrison@aqu.wisc.edu.

By entering this survey, you are indicating that you have read this consent form, you are age 18 or older and that you voluntarily agree to participate in this research study.

Thank you!

Question 1:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Don't know |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| The ability of NWS threat tags and impact statements to convey needed information about thunderstorm and tornado impacts | <input type="radio"/> |

Question 2:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Don't know |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| The addition of the words "CONSIDERABLE" and "CATASTROPHIC" to convey increased severity of impacts during a NWS tornado warning. | <input type="radio"/> |

During a NWS tornado warning, threat tags may be issued. Read through the list of threat tags and associated impact statements. Use this language to rate the statements in questions 3-5.

Impact statements for Tornado Warning

Weak tornado (seldom used, mostly high plains or very rural areas, or with landspouts)
 SPORADIC DAMAGE TO MOBILE HOMES...ROOFS AND VEHICLES.

Tornado (base)
 MOBILE HOMES WILL BE DAMAGED OR DESTROYED. DAMAGE TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. TREE DAMAGE IS LIKELY.

Impact statement for TORNADO DAMAGE THREAT...CONSIDERABLE tornado warning
 YOU ARE IN A LIFE THREATENING SITUATION. MOBILE HOMES WILL BE DESTROYED. CONSIDERABLE DAMAGE TO HOMES...BUSINESSES AND VEHICLES IS LIKELY AND COMPLETE DESTRUCTION POSSIBLE. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. EXPECT TREES TO BE UPROOTED OR SNAPPED.

Impact statement for TORNADO DAMAGE THREAT...CATASTROPHIC tornado warning (Tornado Emergency)
 YOU COULD BE KILLED IF NOT UNDERGROUND OR IN A TORNADO SHELTER. COMPLETE DESTRUCTION OF NEIGHBORHOODS...BUSINESSES AND VEHICLES WILL OCCUR. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS.

Question 3:

Ability of NWS impact statement to convey magnitude (potential size)

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| When base threat tag is issued | <input type="radio"/> |
| When considerable damage threat tag is issued | <input type="radio"/> |
| When catastrophic damage threat tag is issued | <input type="radio"/> |

Question 4:

Ability of NWS impact statement to convey confidence (how confident is the NWS forecaster)

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| When base threat tag is issued | <input type="radio"/> |
| When considerable damage threat tag is issued | <input type="radio"/> |
| When catastrophic threat tag is issued | <input type="radio"/> |

Question 5:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Alignment of NWS impact statement with tornado damage threat tag. | <input type="radio"/> |

During a NWS tornado warning, the attribution section (3rd bullet) of the warning will contain enhanced information. Read through the example below. Use this language to rate the statements in questions 6-9.

* AT 724 PM CDT...A CONFIRMED LARGE AND EXTREMELY DANGEROUS TORNADO WAS LOCATED NEAR HINTON...AND MOVING NORTHEAST AT 40 MPH.

THIS IS A PARTICULARLY DANGEROUS SITUATION.

HAZARD...DAMAGING TORNADO.

SOURCE...WEATHER SPOTTERS CONFIRMED TORNADO.

IMPACT...YOU ARE IN A LIFE THREATENING SITUATION. MOBILE HOMES WILL BE DESTROYED. CONSIDERABLE DAMAGE TO HOMES...BUSINESSES AND VEHICLES IS LIKELY AND COMPLETE DESTRUCTION POSSIBLE. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. EXPECT TREES TO BE UPROOTED OR SNAPPED.

* THE TORNADO WILL BE NEAR...
LE MARS AROUND 740 PM CDT.
REMSEN AROUND 750 PM CDT.

Question 6:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Ability of NWS attribution section to convey timing (when storm will hit my area) | <input type="radio"/> |

Question 7:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Ability of NWS impact statement to convey location (where storm will hit) | <input type="radio"/> |

Question 8:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Ability of NWS impact statement to convey storm | <input type="radio"/> |

...ity (what damage impact has the storm had so far)

Question 9:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Ability of NWS impact statement to convey duration (how long storm will last) | <input type="radio"/> |

Read through the wind speeds and associated NWS impact statements.

Winds of 60 MPH will generate the following Impact Statement:
EXPECT DAMAGE TO ROOFS...SIDING AND TREES.

Winds of 70 MPH will generate the following Impact Statement:
EXPECT CONSIDERABLE TREE DAMAGE. DAMAGE IS LIKELY TO MOBILE HOMES...ROOFS AND OUTBUILDINGS.

Winds of 80 MPH or greater will generate the following Impact Statement:
MOBILE HOMES WILL BE HEAVILY DAMAGED. FLYING DEBRIS WILL BE DANGEROUS TO PEOPLE AND ANIMALS. EXPECT CONSIDERABLE DAMAGE TO ROOFS...WINDOWS AND VEHICLES. EXTENSIVE TREE DAMAGE AND POWER OUTAGES ARE LIKELY.

Winds of 90 MPH or greater will generate the following Impact Statement:
YOU ARE IN A LIFE THREATENING SITUATION. MOBILE HOMES WILL BE HEAVILY DAMAGED OR DESTROYED. HOMES AND BUSINESSES WILL HAVE SUBSTANTIAL ROOF AND WINDOW DAMAGE. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. EXPECT EXTENSIVE TREE DAMAGE AND POWER OUTAGES.

Winds of 100 MPH or greater will generate the following Impact Statement:
YOU ARE IN A LIFE THREATENING SITUATION. MOBILE HOMES WILL BE DESTROYED. EXPECT CONSIDERABLE DAMAGE TO HOMES AND BUSINESSES. FLYING DEBRIS WILL BE DEADLY TO PEOPLE AND ANIMALS. EXPECT EXTENSIVE TREE DAMAGE AND POWER OUTAGES.

Question 10:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| NWS Impact statements for wind properly communicate the damage threat | <input type="radio"/> |

Read through the list of hail sizes and associated NWS impact statements.

Hail up to Half Dollar/Walnut Size (1.25 Inches) will generate the following Impact Statement:
DAMAGE TO VEHICLES IS EXPECTED.

Hail Ping Pong Ball Size (1.50 Inches) to Tennis Ball Size (2.50 Inches) will generate the following Impact Statement:
PEOPLE AND ANIMALS OUTDOORS WILL BE INJURED. EXPECT DAMAGE TO ROOFS...SIDING...WINDOWS AND VEHICLES.

Hail Baseball Size (2.75 Inches) and larger will generate the following Impact Statement:
 PEOPLE AND ANIMALS OUTDOORS WILL BE SEVERELY INJURED. EXPECT SHATTERED
 WINDOWS...EXTENSIVE DAMAGE TO ROOFS...SIDING AND VEHICLES.

Question 11:

Please rate the statement below.

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| NWS Impact statements for hail properly communicate the damage threat | <input type="radio"/> |

Question 12:

Please rate the statement below

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| The level of training you have received to issue NWS threat tags and impact statements. | <input type="radio"/> |

Question 13:

Please rate the statement below

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Your personal comfort level in issuing NWS threat tags and impact statements. | <input type="radio"/> |

Question 14:

Do you have any specific comments or suggestions about the IBW communication tool?

Question 15:

Please rate the statement below

| | Not at all satisfied | Minimally satisfied | No opinion | Satisfied | Extremely satisfied | Not applicable N/A |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Your comfort level in issuing pathcasts in NWS tornado warnings for a defined, persistent feature. | <input type="radio"/> |

Question 16:

Please rate the statement below

| | Strongly Disagree | Disagree | No opinion | Agree | Strongly Agree | Not applicable N/A |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| In your opinion, emergency managers and broadcast meteorologists would prefer to see pathcasts instead of city lists in NWS tornado warnings for a defined, persistent feature. | <input type="radio"/> |

Question 17:

What is your primary job classification?

- Lead Forecaster
- General Forecaster
- Intern
- WCM
- SOO
- MIC
- HMT
- DAPM
- OPL
- ITO
- Other

Question 18:

How long have you been in your current position?

- Less than one year
- 1-5 years
- 6-10 years
- 11-20 years
- 20+ years

Question 19:

What is your primary National Weather Service Office (listed in alphabetical order by state)?