FINAL REPORT

Interpretation and Use of the SPC Day 1 Outlook and Recommendations for Increasing Temporal and Spatial Resolution

September 2016

Abt Associates Inc.
Bethesda, Maryland

Written under contract for the
NOAA Office for Coastal Management
www.coast.noaa.gov

Abt Associates Inc.

Abt Associates is a mission-driven, global leader in research, evaluation and program implementation in the fields of health, social and environmental policy, and international development. Known for its rigorous approach to solving complex challenges, Abt Associates is regularly ranked as one of the top 20 global research firms and one of the top 40 international development innovators. The company has multiple offices in the U.S. and program offices in more than 40 countries.

Learn more at *www.abtassociates.com.*

NOAA's Office for Coastal Management

"Coastal management" is the term used by communities and organizations striving to keep the nation's coasts safe from storms, rich in natural resources, and economically strong. The national lead for these efforts is NOAA's Office for Coastal Management, an organization devoted to partnerships, science, and good policy. This agency, housed within the National Ocean Service, oversees major initiatives that include the National Coastal Zone Management Program, Coral Reef Conservation Program, Digital Coast, and National Estuarine Research Reserve System.

Table of Contents

Introduction and Background

The National Weather Service Storm Prediction Center (SPC) develops and issues several forecast products related to convective weather and associated threats. Among these products is the Day 1 Convective Outlook (Day 1 Outlook) (http://www.spc.noaa.gov/products/outlook/day1otlk.html) which provides information about the probability of convective storms and threats[1] for the current day. The Day 1 Outlook is first issued each day at 0600Z, which, during daylight savings time, is 2:00 am Eastern Time. It is then updated four times throughout the day.

The Day 1 Outlook consists of multiple related pieces of information, including:

- A map showing areas at risk for convective storms within the continental U.S.; these areas are assigned to ordinal risk categories based on the probability of individual threats;
- A map showing the probability of a tornado within 25 miles of a point and areas (if any on that day) that have 10% or greater probability of EF2 - EF5 tornadoes within 25 miles of a point;
- A map showing probability of damaging thunderstorm winds or wind gusts of 50 knots or higher within 25 miles of a point, as well as areas (if any on that day) that have a 10% or greater probability of wind gusts 65 knots or greater within 25 miles of a point;
- A map showing probability of one inch diameter hail or larger within 25 miles of a point and areas that have a 10% or greater probability of two inch diameter hail or larger within 25 miles of a point; and
- A detailed forecast discussion which provides information on factors influencing the forecast, characterization of uncertainty, a description of potential timing and other details.

Forecasts are, by their nature, uncertain. But as the science and modeling improves, meteorologists are able to provide more accurate (i.e., greater skill, reduced error) and/or more temporally and spatially precise forecasts about all kinds of natural hazards related to weather (e.g., flood, winds, severe storms, hurricanes).

The models used by SPC to forecast convective storms are now capable of providing useful information about the timing of predicted storm activity for the current day. Therefore, SPC is considering modifying the Day 1 Outlook to include more precise information about the timing of storms within the day. This information, if accurate, could be very useful for preparedness and response activity related to severe storms and tornadoes.

SPC initiated this study to gain a better understanding of how core partners and customers access, interpret and use the Day 1 Outlook. Core partners include Federal, state, and local emergency management professionals and broadcast meteorologists. In addition, SPC sought to understand how core partners and

[1] The term “hazard” was used to represent damaging weather phenomena (e.g., tornado, hail) on examples of the Outlook shown in 0 and Figure 3, and in interviews and focus groups in this study. The term “hazard” is commonly used in some segments of the risk analysis field, including in flood risk management. The term “threat” is commonly used by the National Weather Service and the emergency management field and is used throughout this report.

customers would interpret and use additional temporal and spatial detail in the Day 1 Outlook. SPC's specific objectives for the study include the following:

- Assess current perceptions of graphics in the forecast, without bias of seeing any new potential changes;
- Assess perceptions of potential changes, both temporal and spatial, with corresponding rationales; and
- Determine current usage of graphics by each partner group. Does each partner group use the graphics in different or similar ways? What rate of update cycle is needed for each partner group? What impact will these changes have on partner groups in regard to displaying higher resolution products?

Background: Communication of Weather Forecasts

Investigating how customers interpret and use the Day 1 Outlook and how they might interpret and use a modified version is important. Research on human risk perception and decision-making clearly shows that there are myriad biases and cognitive tricks that people employ when processing and using complex information, especially information fraught with uncertainty (e.g., see Kahneman et al, 1982; Kahneman and Tversky, 1979; and Slovic, 1987). This manner of processing complex information is often labeled "heuristic thinking" as opposed to systematic thinking and it can greatly influence how people interpret and use probabilistic information (Visschers et al, 2009). Providing more detailed information does not automatically lead to better decision-making, and the way information is presented can influence how it is interpreted and used (Spiegelhalter, 2011). These are important issues for SPC to consider as it works on adding more detail to the Day 1 Outlook.

The risk literature is replete with findings that people do not understand or accurately interpret risk, largely because of these heuristic biases noted above (see Kousky and Shabman, 2015 for a summary in the context of flood risk). However, the risk field typically deals with environmental, technological, and health risks that are controversial (e.g., nuclear power plants, government plans to build flood management infrastructure). Weather forecasts do not elicit the same controversy. In fact, research (Morss et al, 2010; Gigerenzer et al, 2005) shows that many people generally understand probabilities associated with weather forecasts (e.g., a 30% chance of rain) well enough to apply them or act accordingly. The reasons for this may include the fact that people are very familiar with weather and weather forecasts—i.e., most people encounter weather forecasts regularly and quickly experience whether the forecast materializes. In addition, probabilities associated with weather forecasts, including those from SPC, are larger, and so they may be more tangible and intuitive for people than those associated with many other environmental or health risks. Issues such as nuclear plant failure risk or health risk associated with exposure to pollutants may involve minute probabilities such as one in a million and they involve changes in relative risk, which can be very complex and abstract topics.

SPC's ultimate concern is perception and resulting responses among the general population. However, SPC's forecast products are just as likely to impact the public by the manner that they inform the decisions of local emergency managers, other local officials, first responders, and, crucially, broadcast meteorologists. We hypothesized that the Day 1 Outlook is a key input to local preparedness activity. Brotzge and Donner (2009) describe an "integrated warning system" for tornadoes that includes forecasting, detection, warning decision, dissemination, and public response. The Day 1 Outlook and *changes* to the Day 1 Outlook could interact with multiple phases of this system. It is clearly a forecast tool, but how it is structured and communicated can influence how it is disseminated and how the public responds. Research shows that emergency managers do use forecast information (Hoss and Fischbeck, 2016), but the manner in which forecasts are structured and communicated can impact the effectiveness of resulting decisions.

Another crucial component in the "integrated warning system" is broadcast media, especially television. Lazo et al (2009) showed that the top sources for weather forecasts among the general public are 1) local TV

stations, 2) cable TV stations, 3) commercial or public radio, and 4) websites other than from the National Weather Service (e.g., weather.com). Local TV stations were by far the most frequent source. The manner in which broadcasters use and communicate the Day 1 Outlook (or similar forecasts from other sources) will be crucial in how the public responds to these threats.

This study was designed to determine how core partners and customers, especially local emergency managers, staff from the Federal Emergency Management Agency (FEMA), and weather broadcasters, interpret and use the Day 1 Outlook. It was also designed to determine whether the changes SPC is considering would affect interpretation and use of the tool. The study sought to determine how each audience uses storm forecasts (including the Day 1 Outlook as well as other forecasts that may be in use). Specifically, we sought to understand the types of decisions each audience segment makes and how forecast information supports those decisions. In addition, the study aimed to assess how users interpret the current version of the Day 1 Outlook and collect feedback about the existing version. Most importantly, we investigated whether additional detail in the Day 1 Outlook would be useful to SPC's customers and how it might improve their operations and decisions.

Throughout this project we sought to understand whether audiences appropriately interpret and use the Day 1 Outlook, and whether they would appropriately interpret examples of how additional timing information could be added to the Day 1 Outlook. We looked for evidence of heuristics or biases and whether those heuristics might hamper use of the existing Day 1 Outlook and proposed modifications to the Outlook. While we did not survey the general public, we did gather input from emergency managers and broadcasters about how the public might interpret and act on the Day 1 Outlook.

Methodology

Mock-ups of the Modified Day 1 Outlook

On August 11, 2015, two Abt Associates staff traveled to Norman, Oklahoma to meet with SPC personnel. The purpose of the meeting was to discuss in more detail how the Outlook is developed, is communicated, and options for modifying the Day 1 Outlook to include more timing information. SPC was unsure whether timing information could effectively be shown on the map, though several options were discussed. It was agreed that for this study we would assume that timing and other new information would be presented in a sidebar to the main map graphic. The additional information would be presented for a user-selected location. The meeting resulted in several concepts for Abt designers to use in creating mock-ups of a modified Day 1 Outlook.

Abt designed several examples of how the Day 1 Outlook could be modified to include location-specific timing information. All of the examples created represent two key features that were presented to study participants as potential new design features for the Outlook:

1. Ability for the user to select a specific location on the map, either with point-and-click or by entering a city/state or a zip code in a search field.
2. A sidebar showing additional details for the selected location, including information about when during the day SPC believes the risk is highest for the location.

Several drafts were shared with SPC for review and discussion (see 0). Version 3 was used for initial interviews with broadcast meteorologists. Initial feedback prompted Abt to modify the graphical display of timing information. Version 4 was used for all remaining interviews and focus groups.

It is important to note that the modified version of the Day 1 Outlook used in this study was not meant to represent a draft version that might eventually be implemented by SPC. Instead, it was presented to participants as a mock-up that allowed more concrete discussion about changes that SPC is considering. We believed it more effective to ask participants to react to a visual example, rather than ask for input in the abstract.

Selecting and Adjusting Target Cities

The following criteria were used for selecting five cities to target for focus groups and interviews:

- At least one metro area from each of the broad regions outlined by SPC should be included. These regions are listed below.
    1. Northern Plains and Midwest: North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana, Ohio
    2. Southern Plains: Kansas, Oklahoma, Texas, Missouri
    3. Southeast: Arkansas, Louisiana, Kentucky, Tennessee, Mississippi, Alabama, Georgia
- Selected metro areas should be large enough that personnel from multiple municipal and regional agencies can be included, as well as potentially draw in personnel from outlying smaller communities.
- Selected metro areas should have multiple media outlets (television and radio stations) so that several broadcasters[2] could be included.
- Selected metro areas should have recent history with severe/damaging storms and/or a general high risk for severe storms so that we could be reasonably confident that emergency personnel and broadcasters have focused on storm risk in their response and communication planning and that they would be familiar with the Day 1 Outlook.
- Selected metro areas should differ at least slightly in their characteristics so the resulting set represents a range of city types. For example, we should not pick only very large metro areas (e.g., Dallas, Atlanta, Minneapolis) or only smaller metro areas.

Abt used readily available economic, demographic, and media data to compare metro areas against these criteria. Based on the analysis and discussion with SPC, five metro areas were selected: Birmingham, AL; Dallas/Ft. Worth, TX; Minneapolis, MN; Wichita, KS; and Washington, DC. To increase recruitment of participants, additional metro areas were added: Kansas City, MO; Memphis, TN; and Raleigh, NC.

Recruiting Participants

Abt Associates coordinated with American Meteorological Society staff to conduct outreach to their broadcast meteorologist members who would be attending the Society's Annual Meeting in New Orleans, LA in January and their Broadcasters Conference in Austin, TX in June.[2] Abt drafted an email that was sent by American Meteorological Society staff to a list of broadcaster attendees. This email included a description of the background and purpose of the study, as well as information on how to contact Abt staff to schedule an interview during the conferences. An Abt staff member coordinated interview times with the participants and secured space in which to hold interviews at the conferences.

The process for recruiting emergency management personnel was laid out in the Information Collection Request approved by the White House Office of Management and Budget. First, the National Weather Service task lead reached out to local Weather Forecast Office personnel in the targeted cities to request their assistance in identifying key partners and customers in their geographic areas who could be recruited for participation in focus groups. Abt drafted an email for local forecast office personnel to send out to their

[2] The initial study plan was to conduct focus groups with broadcasters. For various reasons, we opted to conduct individual interviews with broadcasters during two separate American Meteorological Society conferences.

regional emergency management contacts. The email explained the purpose of the study and asked individuals to contact Abt staff to express interest in participating. Abt coordinated directly with all emergency managers who expressed an interest in participating.

FEMA personnel were recruited by working with SPC's FEMA Liaison. A list of regional and Headquarters FEMA contacts was provided to Abt. An email explaining the study and requesting participation was sent by Abt to each FEMA Contact.

Focus Groups and Semi-Structured Interviews

While the study was originally proposed to use focus groups, Abt chose to conduct semi-structured individual interviews with broadcast meteorologists per the suggestion of SPC. Focus groups were conducted with local emergency managers in Dallas, Minneapolis, and Kansas City. In order to maximize the sample, Abt conducted individual interviews with several emergency managers who were unable to participate in those focus groups, as well as phone interviews with interested participants in cities where the overall response was too low to justify a focus group. Finally, we conducted phone interviews with FEMA staff from FEMA Headquarters and Regions 4, 5, 6, and 7 (covering the Southeast, Midwest, Central Plains, and Southern Plains, respectively).

Abt developed two interview protocols—one for broadcast meteorologists and a separate protocol for emergency managers and FEMA (see 0). The same line of questioning was used for focus groups and for individual interviews with emergency managers. The protocol served as an overall guide to the interviews, though each discussion differed slightly depending on the participants' input.

At each of the focus groups, Abt arranged for the audio to be recorded and for an outside vendor to produce a transcription of the discussion. These transcripts were used to analyze and synthesize the information gathered. In-person interviews with emergency managers were conducted by one person from Abt (in conjunction with travel to the focus group). These interviews were recorded, and the recordings were later transcribed and analyzed. For each of the phone interviews with local emergency managers, one Abt staff member led the questioning while another took detailed notes of participant responses. Two Abt staff traveled to the AMS conferences, so for each broadcaster interview, one person led the questioning while another took notes. For phone interviews with FEMA, one Abt staff member conducted the interview and also took notes.

Description of the Sample

A total of 26 meteorologists were interviewed—11 at the AMS Annual Meeting and 15 at the AMS Conference on Broadcast Meteorology. Of this group, 20 are on-air television meteorologists and five are from weather consulting firms or individual consultants that serve many areas nationwide. One interviewee publishes an educational weather blog and teaches weather lessons in schools.

Table 1: Summary of the Participants in this Study

Participant Category	Number
Broadcast meteorologists	26
Local emergency management personnel	42
FEMA personnel	9
Total	77

The on-air meteorologists in the sample hailed from various cities across the United States, including high weather risk areas such as Joplin, Missouri, Orlando, Florida, Laredo, Texas, and Mobile, Alabama. The largest TV viewership area (in number of households) represented by interviewees was Washington, DC, the lowest was Laredo, Texas, and the median was Memphis, Tennessee.

Abt gathered feedback from 42 emergency management personnel in the focus groups and interviews. The participants came from several metro areas: six from Birmingham, 13 from Dallas, eight from Kansas City, two from Memphis, eight from Minneapolis, and five from Raleigh.

The majority of EM participants were staff from county and city emergency management agencies. Others represented state emergency management agencies, and emergency preparedness divisions at universities, hospitals systems, fire departments, state tollway authorities, tribal organizations, and public school districts.

A qualitative study such as the one described here does not typically target a statistically representative sample. There are reasons to believe that the sample of emergency managers that were part of this study is biased in certain ways. Since emergency managers were recruited through local Weather Forecast Offices contacts, the sample likely includes primarily emergency managers who are well connected with their forecast offices. Recent work (see National Weather Service, 2014; Hoss and Fischbeck, 2016) suggests that not all emergency managers have a well-established relationship or line of communication with their local Weather Forecast Office and that resources, roles and capabilities vary widely among local emergency management agencies. The results reported here are most relevant to emergency management functions within larger communities where the EM role is more formal; the findings may not be applicable to smaller communities where emergency managers likely have fewer resources and multiple responsibilities (Hoss and Fischbeck, 2016).

Finally, Abt interviewed nine FEMA personnel: one from Headquarters, four from Region 4, one each from Regions 5, 6, and 7, and one FEMA Liaison to SPC.

Results and Findings

Broadcast Meteorologists

As described above, 26 broadcast meteorologists were interviewed, covering a variety of markets in multiple storm and tornado prone areas of the U.S. Broadcast meteorologists must use available forecast data and products to formulate their own forecast that they then deliver on the air. Their forecasts must be brief (three minutes is a typical duration) and must communicate information that is relevant, understandable, and actionable from the perspective of their viewers.

There is variation both in how broadcasters use the Day 1 Outlook and in their feedback on the current Day 1 Outlook and potential modifications. All broadcasters were familiar with the Day 1 Outlook and reported using it in some way. Many expressed great respect for the expertise of the SPC and described the Day 1 Outlook as being a crucial tool for awareness and preparedness for severe weather.

Below we detail several themes that emerged from interviews with broadcasters.

Audience and Communication Goals

Most of the sample was made up of broadcast meteorologists who target the general public as their audience. There were also several private sector meteorologists who provide services for broadcast entities; broadcasters are their immediate audience (i.e., their customers) but the ultimate audience for their work is also the general public.

In communicating to the public, broadcasters aim to keep information about severe weather as simple as possible. Most broadcasters repeated similar themes when asked what they aim to communicate. They aim to communicate what threats severe weather will bring, specifically focusing on whether viewers can expect heavy rain, flooding, hail, wind, tornadoes or some combination. Also, they communicate the timing of severe weather as much as possible. Finally, many broadcasters try to communicate how the forecasted weather will affect people. For example, they might mention whether people can expect hazardous driving conditions during the evening commute or whether outdoor activities have a chance of being cancelled. Many broadcasters pointed out that they do not have the time to explain the weather and they must stick to the key points of what, where, and when.

Use of the Day 1 Outlook in Formulating their Forecasts

All broadcasters reached for this study were familiar with the SPC Day 1 Outlook and reported being regular users of the Outlook. It is worth noting that many of them also use Day 2, Day 3, and Days 4-8 Outlooks,

building awareness of coming weather threats over several days. Further, on days with active severe weather in their region, many broadcasters reported using SPC's mesoscale discussions to get more detailed information.

There were two predominant patterns reported by broadcasters for how they formulate the severe weather forecasts that they communicate on the air. Some broadcasters start with the SPC Day 1 Outlook. They look at the Day 1 Outlook and if they see that the SPC is predicting a substantial risk for their region, they then pursue additional information and detail. This might be triggered by different categorical risks in different places; many reported that if the category for their area is "slight" or higher they will seek more information. See Table 2 for a list of other sources and tools used by broadcasters (and emergency managers). They review additional information to make sure they understand the conditions that are driving the weather risk. Based on their own interpretation of models and data, some broadcasters might change the SPC forecast slightly; in particular they might adjust the boundaries of different categorical risk zones. However, many broadcasters reported that they use the SPC Outlook and do not modify it.

Another pattern reported by many broadcasters was that they use more detailed models and monitoring data (see Table 2) to formulate their own forecast and then check the SPC Day 1 Outlook to compare. If SPC's forecast differs substantially from their own, they then review the Outlook discussion and revisit models and data to investigate further. They may adjust their forecast, but the key is that the Outlook serves as a check against their own thinking and forecast.

Most broadcasters reported that they use all portions of the Day 1 Outlook, including the categorical map, the tornado, hail and wind probability maps, and the discussion. Importantly for this study, many reported obtaining information on timing from the Outlook Discussion. Many also reported that they read the discussion to get a better understanding of SPC's scientific rational for the day's forecast.

Use of the Day 1 Outlook in Communicating a Forecast

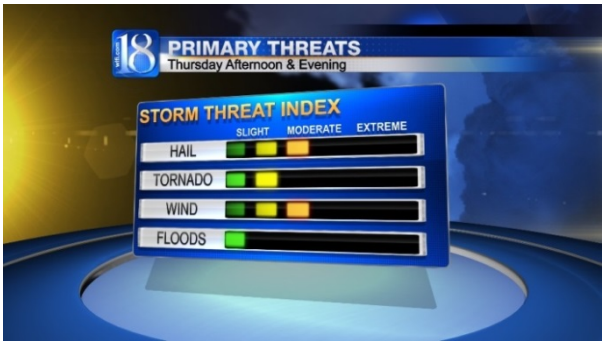
Many broadcasters interviewed said that they use some portion of the Day 1 Outlook on the air. Some reported that they show the national categorical map on the air; most reported that their station creates a local/regional map using KML or shapefile data from SPC. Creating a local/regional map allows broadcasters to include regional details (e.g., city locations, county boundaries) that help viewers interpret the map. In many cases, the process of downloading the KML or shapefile data is automated and in some cases through an outside vendor. Most broadcasters said they show the SPC's categorical risk scale along with the map (see below for a discussion of feedback on the terminology).

Some broadcasters prefer to create their own forecast and forecast maps, and many expressed discomfort with the SPC's categorical risk terminology (see next section). Broadcasters in this camp reported modifying the boundaries/shapes of areas at risk for storms or drawing them from scratch based on their own forecast. Some also reported simplifying the risk rating to three or four categories (e.g., low, medium, high). Others indicated that they use more descriptive terms in place of or in addition to the categorical terms. Descriptive terms could include "isolated storms," "widespread storms," or "major outbreak of storms." Some of this terminology is taken directly from SPC's "Understanding Sever Thunderstorm Risk Categories" diagram. While we did not ask interviewees for specific examples of their forecast maps or graphics, many examples can be found with a Google search (see Figure 1Figure **1**).

In addition to on-the-air broadcasts, most television meteorologists reported that they or their stations use social media to communicate weather forecasts. They often include the Day 1 Outlook categorical map (either SPC's version or their own version) when using social media to report on severe weather risk.

Figure 1: Examples of how local television stations communicate risk of severe thunderstorm and associated threats (Note: These examples were not taken from television stations represented by the interviewees from this study.)

Source: KAIT8, Jonesboro, Arkansas



Source: WLFI, Lafayette Indiana

Feedback about the Current Day 1 Outlook

Broadcasters see the Day 1 Outlook as an important tool for their work to develop and communicate local forecasts of severe weather. In fact, all of the interviewees were intimately familiar with the Day 1 Outlook and described in detail how they use it. They also offered feedback about elements of the Day 1 Outlook that they see as problematic or suggestions for changes. Almost all of them expressed a desire for the Day 1 Outlook to include more information on timing of severe storms; this is covered in detail below in the discussion about their response and feedback to the potential modifications of the Day 1 Outlook.

Categorical Risk Terminology

The interviews did not include formal questions about the categorical risk terminology, but it was one of the issues raised most frequently by broadcasters. In many cases, it was the first topic about which a respondent talked. Broadcasters offered several specific critiques.

Several of the broadcasters interviewed were adamant that the change from three risk categories to five was a bad idea because they see it as more confusing to the public. Their view is that a low-medium-high rating system is more intuitive to laypersons. They were not asked to provide specific data to support this assertion, but many communicated that they get feedback from the public via social media and other channels. Interestingly, a similar number of broadcasters supported the move to five categories because they feel it better represents the range of possible risk.

Many broadcasters offered some feedback on one or more of the specific terms, particularly “marginal,” “slight,” and “enhanced.” For “marginal,” several broadcasters suggested that it is a vague term that does not adequately communicate whether people should be concerned. Issues with “slight” and “enhanced” were brought up most frequently. Many broadcasters expressed concerns with the term “enhanced.” Generally, they reported that it is a vague and confusing term that signals to many people a higher risk than “moderate.”

Many broadcasters felt that probabilities underlying a designation of “slight” are high enough to warrant a state of alert among the public, but the word “slight” downplays the risk and might result in too many people ignoring the weather that day. Some suggested that when the term “slight” is used for rainfall chances, people generally discount it when planning their day, and they fear the same could happen with storm risk. While this argument may have merit, it is hard to know without specifically testing how the public responds to these terms. It also was not clear whether there is a threshold for when the public **should** remain alert; any given threshold will be arbitrary, and it may be preferred to provide forecast information that people can

use with their own criteria (Morss et al, 2010). Interestingly, a few broadcasters pointed out that since mobile technology makes it easy to get word out quickly about an impending threat, overplaying the risk at the forecast stage is unnecessary and may be harmful due to the "cry wolf syndrome." This is a serious concern, as research (Simmons and Sutter, 2009) has shown that false alarms can contribute to increases in loss of life.

Many of the broadcasters interviewed for this study suggested that the terminology is completely unnecessary. They suggested that SPC use only the numerical scale (e.g., 1-5) and abandon the categorical terms. This could avoid the potential for confusion over SPC's chosen terminology, but it would also leave interpretation in the hands of users of the Day 1 Outlook, including the public. This idea is discussed more fully in the section on recommendations.

Design and Appearance

Most of the feedback focused on the categorical terminology, but a few suggestions were offered about the design and appearance of the Day 1 Outlook. Some broadcasters pointed out that the color system used can be difficult for people with color blindness. While the green/yellow/red scale is very common for risk communication, it might be beneficial to offer an alternative Day 1 Outlook that can be read by those who cannot distinguish reds and greens. Further, some broadcasters suggested that green does not connote risk, so displaying marginal in green might be misleading. It is true that green is typically used to indicate very low risk or even safety, requiring no action on the part of an audience. Similar to the categories, some suggested only three colors should be used.

Some expressed concern with the implied precision of having fine boundaries between the risk zones. A person might find his/her city just outside a particular risk zone (e.g., if the city falls just outside an "enhanced" zone and is in "slight") and might underestimate the risk as a result. Finally, some pointed out that coordinated universal time is very confusing to the public and that the Day 1 Outlook should be presented in real time (see recommendations section for more on this).

Feedback about Potential Modifications to the Day 1 Outlook

Interviewees were presented with an example of how the Day 1 Outlook could be modified to show location-specific timing information (see Versions 3 and 4 in 0). Interviewees at the AMS Annual Meeting in January 2016 were shown Version 3, and interviewees at the AMS Conference on Broadcast Meteorology in June 2016 were shown Version 4. The switch to Version 4 was made because feedback quickly showed the timing graphic on Version 3 was confusing. The interviewer described the general functionality, asked interviewees to interpret what was presented, and posed a series of questions to gather feedback.

Feedback about Timing Information

Most broadcasters said that adding timing information for forecasted storms should be a high priority improvement to the Day 1 Outlook. Most reacted positively to the example presented, saying it represents a positive development that would address a frequent need among their audiences. They suggested that the timing information would be helpful for members of the public to plan their day.

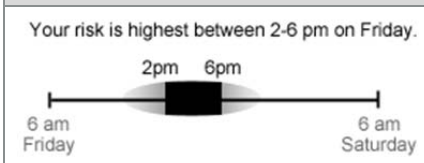
Most broadcasters interpreted the timing information accurately and said they find the graphical presentation to be understandable. Some interviewees suggested that Version 3 of the timing graphic would be confusing to some users (which prompted revision to Version 4); see Figure 2.

Most reported that Version 4 would be understandable. However, a number of broadcasters interpreted the graphic as showing maximum risk between 2 pm and 5 pm (the intent was to show maximum risk from 2 pm to 6 pm). This was likely due to the small size of the graphic and the difficulty of seeing how the grid lines up with the time labels.

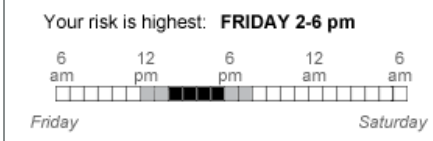
Most broadcasters interpreted the white grid cells as representing the hours with the lowest risk of the day or with very low risk in general. Some noted that the public might interpret the white grid cells as meaning zero risk. A few broadcasters said the inclusion of the gray ramp up and ramp down was good to capture the inherent uncertainty.

Some suggested that too much precision in the timing information was misleading, either with the words or with the graphic. With the example shown, some suggested that members of the public might conclude that there is no risk through 11:59 am. However, we know in other contexts that people tend to assume uncertainty in a weather forecast (Morss et al, 2010) and that predominant assumption probably would apply to interpretation of this timing information. Broadcasters who saw this as a problem suggested it would be better to use more general language, such as "risk is highest in the afternoon" or "risk is highest in the early evening." A few broadcasters said the graphic is unnecessary and that text description is sufficient.

Figure 2: Two versions of timing information were used through the course of this study.



This version was used for the first round of interviews.



This version was designed and adopted as early feedback showed the previous version to be confusing.

Interviewees were asked whether they would like to see timing information about the individual threats (e.g., tornado, wind, hail). Most respondents said this would be unnecessary and superfluous; they think it is sufficient to provide a general description of the overall storm risk. Some also pointed out that the timing of the threats will generally overlap in most situations and that forecast models may not be able to distinguish the timing to a degree that would be useful. Several broadcasters suggested that a narrower time window would be more helpful. The example presented showed a four-hour window, but since storms rarely last that long in any one location, they preferred to see a two-hour window if the models could provide that information with sufficient accuracy.

Many broadcasters pointed out that there should be a legend for the grid (Version 4) to explain the meanings of black, gray, and white. The timing information on the example modified Day 1 Outlook does not reference or use the categorical risk terminology or colors (i.e., it does not show different risk categories for different portions of the day). Most broadcasters indicated that this was acceptable or even preferred.

Some broadcasters would prefer to see the Day 1 Outlook segmented into smaller time frames, instead of reporting categorical risk for the entire day with location-specific timing information as shown on the example. In other words, instead of reporting risk for the entire day, they preferred to see the Day 1 Outlook report risk, for example, from 12:00 am to 6:00 am, 6:00 am to 12:00 pm, and so on.

Feedback about Selecting a Location

Broadcasters liked the possibility of selecting specific locations to get risk and timing information exactly for that location. They suggested this would be very useful for the public. Several broadcasters pointed out that the example does not provide any details about the selected location; when a user selects a location by clicking the map, it would be helpful if the sidebar updated with text to describe the location (e.g., "you have selected a point in or near Weld County"). Many broadcasters also pointed out that the location specific information would need to include the spatial context for the risk information (i.e., probability is for 25 miles within a given point).

Use of the Timing Information

Most broadcasters said they would use the timing information. Nearly all of them said it would inform their forecast and that they would communicate it in some form. Some said they would report it as it comes from SPC (e.g., "risk is highest from 2-6 pm"). Others said they might generalize it to say something like "risk is highest during the afternoon." Only a few said they would show the graphic in their broadcast.

Timing Information and Watches and Warnings

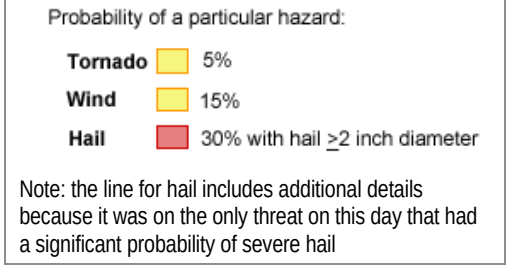
When asked about potential confusion between the Day 1 Outlook and Watches or Warnings, broadcasters did not express any concerns. They noted that occasionally Watches are issued in areas of relatively low risk on the Day 1 Outlook, but they acknowledged this to be the result of the inherent uncertainty of weather forecasting.

Broadcasters were asked whether additional timing information on the Day 1 Outlook would create any inconsistencies or confusion with Watches and Warnings. Generally, they did not see any potential problems. They see the Day 1 Outlook as a distinct product that serves a different purpose from Watches and Warnings (e.g., "once there is a Watch or a Warning, we do not use the Day 1 Outlook"). Some said that with the additional timing information the Day 1 Outlook would become a "watch for a watch." Many pointed out that if the Day 1 Outlook is modified to include the ability to select specific locations, it should be able to show if and when a selected location is in a Watch or a Warning.

Feedback about Threat Probabilities

Broadcasters were generally less positive about showing specific threat probabilities (see Figure 3) for a selected location. They expressed several concerns. First, many suggested that it is too much detail for the average member of the public and is not useful. Meteorologists would use the additional details, but they can already access it via the probability maps. Second, they said that members of the public would get confused about the different color designations for each threat (i.e., on the example provided, the overall categorical risk is red for "moderate" but the threats show yellow and red). Most people do not know how the overall risk category is assigned and would be confused by the information presented this way. Third, the graphic does not indicate that the probabilities are for 25 miles within a given a point, so it lacks spatial context. In addition, they viewed a five percent chance of a tornado as sufficient to warrant a heightened level of awareness, but they thought that members of the public might disregard that probability. In general, they are not confident that members of the public understand probability and risk well enough to properly interpret this information. Finally, if the specific threat probabilities are included, they suggested that each threat should include a physical description (this example includes a description for only hail, because on this day, there was a significant chance for severe hail). However, most broadcasters suggested that the public needs to know what threats to expect and that the Day 1 Outlook should incorporate this information.

Figure 3: Threat probabilities as shown on the example modified Outlook



Emergency Managers

We spoke to 42 emergency managers who work for local, regional, and state emergency management organizations, representing cities, counties, volunteer firefighters, hospitals, the American Red Cross, school districts, a Tribal police department, and universities. Participants were generally very familiar with the Day 1 Outlook and use it as part of their decision-making and communication. The following sections provide a synthesis of our findings from these interviews and focus groups.

Decisions Affected by Severe Thunderstorm Forecasts

As expected, a forecast of risk for severe thunderstorms and tornadoes leads to preparedness actions and a heightened state of awareness/alert. Severe convective weather can affect a multitude of local government operations and activities, including schools, student transportation, large special events, and hospital operations. When there is a forecast for severe weather, agencies and organizations involved in emergency management will enhance communications, alert relevant partners, notify staff and volunteers, check

equipment, and perform constructive actions to ensure that lines of communication are open and that the community is ready to take next steps if necessary.

Emergency managers make decisions in response to severe weather forecasts for the current day contingent on their individual role in their organization or department. For example, most state or regional-level organizations are not directly responsible for making closure or other operational status decisions. Instead, they perform a decision-support and facilitative role by communicating and translating the risk of severe weather. A severe weather forecast leads these emergency managers to communicate information or alerts to partner agencies, including state leaders, schools, public safety agencies, county emergency managers, local officials, hospitals, volunteer agencies, community groups, storm spotters, and other local and government agencies.

Local and county emergency managers perform similar activities by sharing information with event coordinators, fire departments, law enforcement and other first responders, schools, dispatchers, and others. In addition, county and local emergency management departments make decisions about adding staff, alerting on-call staff and volunteers, and activating communications systems/networks. For example, emergency managers will alert vendors or other participants who are scheduled to help with special events. They may decide to open or activate shelters and whether to close schools early or keep kids late to avoid students in transit when a storm hits. Emergency managers who represent hospitals might cancel elective surgeries, add staff, and discharge patients, if possible, to free up beds in case a major disaster leads to an influx of injured people.

Sources of Information

The emergency managers we interviewed rely on many sources of information for severe convective weather forecasts. In fact, some indicated that they want as much information from as many sources as possible. Table 2 presents the sources of information that emergency managers (and broadcasters) rely on for severe convective weather forecasts.

How Emergency Managers Use the Day 1 Outlook

Many emergency managers use the Day 1 Outlook (and longer-term outlooks on an ongoing basis) as a screening tool to alert them to severe weather for the current day and to allow them to plan and prepare accordingly. With some exceptions, the emergency managers in this study said they check the Day 1 Outlook first thing every morning, and if the risk is slight or higher, they continue to check it throughout the day. The Day 1 Outlook tells them whether they need to continue paying attention and whether they need to acquire more detailed information from sources such as the Day 1 Outlook discussion and the mesoscale discussion. As severe weather emerges, many emergency managers quickly turn to the local forecast office for more detailed, site-specific information. Other emergency managers, however, wait to receive alerts or Hazardous Weather Outlooks from the local office and then turn to the Day 1 Outlook to read the text discussion for more in-depth information. Most emergency managers we interviewed had a strong relationship with the local Weather Forecast Offices. Some said that if they notice any discrepancies between different data sources, which does not happen often, they will call their local Weather Forecast Office to clarify and provide additional insights.

Table 2: Summary of severe convective weather forecast data sources used by emergency managers and broadcasters

Source	Description	Provider/Administrator
Day 1 Outlook	Forecast product provides storm risk information for the entire current day.	SPC
Day 2, 3, and 4-8 Outlooks	Forecast product provides storm risk information for future days.	SPC
Mesoscale Discussion	Provides updates on regions where a severe weather threat is emerging, including the valid timing of the threat, the probability of a watch or warning, a summary of the weather threat, and a more detailed discussion of the weather threat.	SPC
Area Forecast Discussions	Provides a discussion of the meteorological thinking that supports the preparation of the Zone Forecast Product, including a list of all advisories, non-convective watches, and non-convective warnings.	Weather Forecast Office
Hazardous Weather Outlooks	Provides forecast information for the current day and days 2 through 7. Also includes a spotter activation statement alerting whether a particular region should prepare to activate storm spotters and emergency managers.	Weather Forecast Office
Weather briefing videos	Provides detailed information on severe weather forecasts for the current day. See, for example: http://www.weather.gov/mpx/videobriefing.	Weather Forecast Office
Situation Reports	Provides information on significant events, significant weather, disaster activity, and FEMA readiness.	FEMA
NWSChat	The use of Instant Messaging (IM) and chatrooms to provide a real time interactive communications system to improve decision support during high-impact events.[3]	Office of the Chief Information Officer; WFO authorizes new users
Mobile Decision Support Services (MDSS) interactive NWS (iNWS)	MDSS (iNWS) is an experimental service intended for National Weather Service core partners, including emergency managers, community leaders and other government agencies. [4] It provides text and email alerts about severe weather.	National Weather Service headquarters
SKYWARN® storm spotters	An organization established by the National Weather Service. SKYWARN® is a volunteer program with trained severe weather spotters to provide timely and accurate reports of severe weather to National Weather Service.	National Weather Service
National weather broadcast stations	Includes Weather Channel and Weather Nation.	Varies
Doppler Radar (NEXRAD)	Provides real time information on precipitation and movement from 160 Doppler radar stations around the U.S.	National Weather Service, Departments of Defense and Transportation
Specific weather forecast models	Examples include: Climate Forecast System (CFSv2) Ensemble Products, HopWRF-ARW Ensemble Model Output, NAMWrF model, GFS/Avn Model, European Center for Medium range Weather Forecasting (ECMWF) forecast model.	Varies
Other	High resolution radar software; locally installed and run sensors; local Mesonet (i.e., local mesoscale networks), local news/radio, internal agency meteorologists, local Weather Forecast Office webinars, local weather blogs, National Weather Service data on wind speed, direction and height.	N/A
Some emergency managers also discussed visiting the websites for the Hydrologic Prediction Center and the Weather Prediction Center.		

[3] https://nwschat.weather.gov/NWSChatSecurityWhitepaper.pdf

[4] See http://products.weather.gov/PDD/MDSS_National_SDD_Final_070710.pdf for more information.

In general, emergency managers use all aspects of the Day 1 Outlook: the categorical risk, individual threat probabilities, and text description. The categorical risk map, however, seems to drive whether emergency managers click on the individual threats or read the text description. If their area is in a slight or higher risk category, they are more likely to use the entire product. A few emergency managers conveyed that the text description is sometimes intimidating because of its technical content, so they are more likely to disregard it and rely more heavily on the categorical risk map.

Many emergency managers like and use the categorical risk map; they use it for briefings and share it with partner agencies, and, in some instances, with the public. The categorical risk terminology does trigger some emergency managers to take certain actions. For example, actions range from alerting partner agencies and the public about the weather forecast with instructions as to whether they should continue to monitor the situation, seeking additional data sources (e.g., mesoscale discussion, NWSChat), and calling the local forecast office for more information. Some emergency managers start taking action when their area is in a slight risk category; others take action starting with an enhanced or moderate risk category.

Feedback about the Current Day 1 Outlook

Many emergency managers expressed a high regard for SPC's Day 1 Outlook product and rely on it heavily to provide a high level summary of what to expect for severe weather for the current day. Importantly, most of those we talked to would like the Day 1 Outlook to include information about the timing of storms during the day. Emergency managers currently obtain severe weather timing information from the Day 1 Outlook text description, NWSChat, the local forecast office, and other sources.

Most emergency managers like and understand the categorical risk terminology and like the two recent additions. Some emergency managers, however, do not like the "enhanced" category because they think the term "enhanced" suggests more significant risk than the term "moderate." We also received feedback that some emergency managers do not disseminate the risk category information to the public because they fear the public does not understand the risk terminology and would not respond to it appropriately. For example, many of our participants assume the public will not take action if they see a slight risk even though past experience shows that a slight risk can lead to significant severe weather; the term slight diminishes the perceived potential severity of a storm. To avoid potential confusion, the Pleasant Hill Weather Forecast Office tends to remove the labeling and show the coloring to convey risk. While some emergency managers do not like "slight" or "enhanced," they are also sensitive to making too many changes to the terminology, which adds to the confusion.

Other specific feedback from individual emergency managers to improve the current Day 1 Outlook includes:

- Provide a link in the text description to define the airport codes.
- Divide the Day 1 Outlook into six- to 12-hour windows.
- Use local time instead of Zulu/UTC time (Note that the issue of using Zulu time did not arise until we presented the modified version of the Day 1 Outlook.
- Use patterns to display the categorical risk areas to help people who are visually impaired.
- Include a regional view option.
- Include information about the timing of the next update.
- Provide a visual indication about whether SPC expects squall lines and super cells.

Feedback about Potential Modifications to the Day 1 Outlook

In this section, we highlight findings about emergency management participant responses to the individual components of the new information, including the timing of severe weather, the ability to select a location, and the information on the individual threats (see 0, Version 4 for the version presented to emergency managers). We also convey whether they see a potential for inconsistencies in the modified Day 1 Outlook

and watches and warnings, as well as other feedback on the modified Day 1 Outlook.

Feedback about Timing Information

Largely, emergency managers said additional information on timing would be helpful. In particular, many said they would like the ability to retrieve information at the zip code level. Some emergency managers, however, suggested that the timing information is duplicative of what the Weather Forecast Offices already provide and that the local offices provide additional information on the level of confidence of timing information.

When we asked what they assumed about the level of risk in the boxes on the timeline—white, grey, and black—most either assumed that the white boxes conveyed no risk at all or low to very low risk. Some emergency managers had difficulty understanding the value of the timing information if the entire day is still in a moderate risk category. Their concern is that people will assume no risk for most of the day, and that could be misleading and possibly dangerous. Some emergency managers assumed that there was no risk in the white boxes, an elevated risk in the grey, and a high risk in the black boxes. Other emergency managers assumed that the black boxes corresponded to a moderate risk, the grey boxes to a slight/enhanced risk, and the white boxes a marginal/no risk. The current version of the Day 1 Outlook, including the potential modifications we tested, is meant to communicate the overall categorical risk for the entire day, while the additional information would point to the time of day when the risk of severe weather is greatest. There is a potential misinterpretation with what we heard from some emergency managers, and in a later section we offer recommendations to avoid this misinterpretation.

With the additional timing information, it became clear that reporting Zulu time created confusion for some emergency managers. They either did not know how to interpret the time zone for the greatest risk period because of the Zulu time stamp on the map graphic or they assumed it was local time. Some participants advocated for the time to show in local time.

Other comments emergency managers provided include:

- Add more color to the timeline graphic so that it stands out more.
- Use colors in the timeline to mimic those in the categorical risk scale.
- Provide a larger scale with more than three colors/shades.
- Consider changing the timing scale from a horizontal line into a circle, like a clock.
- Make the vertical line for 6 pm heavier.

Feedback about Selecting a Location

Most emergency managers understood and were excited about the new functionality of selecting a point on the map or entering city or zip code information in the search bar in order to view more specific timing information. Some, however, were confused about the black teardrop icon that was used to point to the selected location on the map. One questioned whether the black teardrop was meant to highlight the footprint of the area for which the timing information was presented. Another interpreted the teardrop icon as a tornado indicator and suggested that it would immediately put them on alert. Some participants made the following recommendations regarding the specific location:

- Consider using another icon that does not look like a tornado.
- Make the icon more transparent so people can still see the categorical risk color behind the icon.
- Add the footprint of area included in the location-specific forecast (e.g., 25 miles of a given point) for the categorical risk.
- Add the footprint of area included in the location-specific forecast (e.g., 25 miles of a given point) for the individual threats.

Feedback about Threat Probabilities

Many emergency managers liked seeing the individual threats on the new legend because it saves the step of having to look at the individual tabs, and it presents a more complete story in one snapshot. Some participants provided some feedback on whether to keep the percentages. For the emergency manager community, the percentages can be very useful because they understand the underlying definitions and the appropriate response. But there was concern that the public would interpret a five percent tornado probability as very unlikely to happen and ignore the risk. Other feedback regarding the threat probabilities included:

- Provide text descriptions for each of the individual threats (we showed a version with text for only hail because it was the only threat with a chance for significant severe on that day).
- Remove percentages if this product will be aimed at communicating to the public.
- Put the threats in descending order based on the probabilities in a particular area.

Emergency management participants provided a range of responses when we asked whether they would like to have timing information for the individual threats. Some emergency managers said that having timing for each threat would be beneficial; others said it would make things too complicated. The responses seemed to vary based on how the participants use forecast information. Those emergency managers directly involved in operational decisions want as much information as possible to inform their decisions. Those emergency managers who are focused primarily on dissemination of weather forecast information but are not directly responsible for decisions expressed concern that the new details would confuse people. Some questioned whether SPC's models could actually distinguish between the timing for the individual threats and whether that information would be very different between threats.

Timing Information and Watches and Warnings

Two of the emergency managers we interviewed work for agencies that have a meteorologist on staff to monitor and track severe weather. These two participants were the most concerned about the timing information provided in the modified Day 1 Outlook being inconsistent with timing information provided by Watches and Warnings. They both felt that if the Day 1 Outlook does not update at the same time SPC issues a Watch or the local Weather Forecast Office issues a Warning, then it could create a serious problem. Other opinions on this matter varied. Some emergency managers did not express any concern because they already deal with inconsistencies between the Watch/Warning and Day 1 Outlook products. Other emergency managers shared the view that the modified version would work only if the SPC continuously updates the Day 1 Outlook. Others simply believe that the Watch/Warning and Day 1 Outlook products are not comparable and that the Day 1 Outlook is a forecast while the Watches/Warnings are real time. And some expect consistency in the products and assume that SPC would issue a Watch or the local Weather Forecast Office would issue a Warning in the grey and black parts of the timeline.

Other Feedback

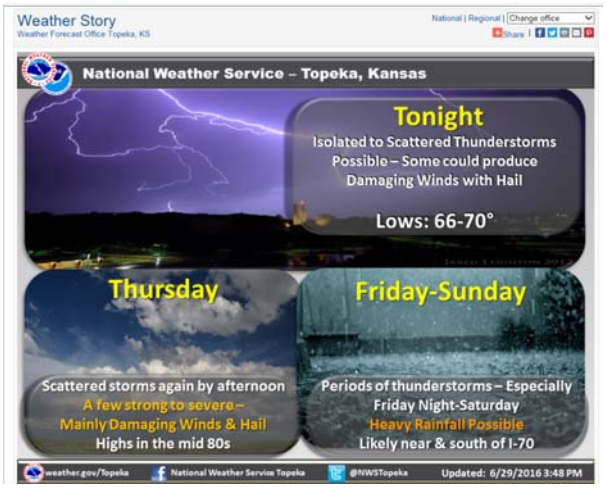
Several emergency managers provided additional feedback for the modified Outlook, including:

- Provide the ability to access gridded information, if available (e.g., via web link).
- Provide information on the confidence of the forecast.

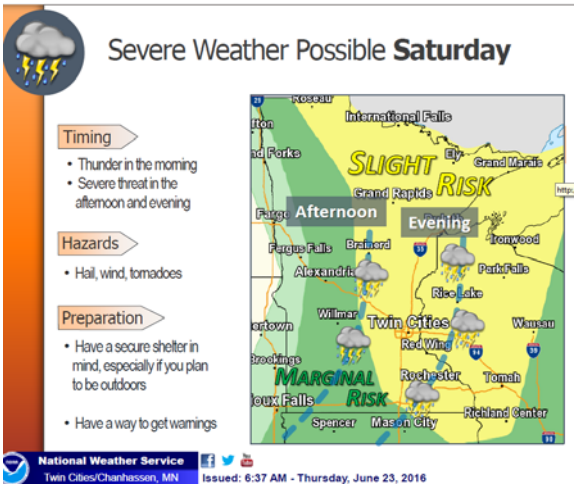
How Emergency Managers would Use the Timing Information

Many emergency managers indicated that they would use the information on timing in some way; however, two participants said that even if they were to use it, they would still compare it with what the local forecast office produces to ensure consistency in the products. Emergency managers stated that the local forecast office already provides information on timing. Figure 4 provides two examples of how local Weather Forecast Offices publish severe weather timing information for the current day.

Figure 4: Examples of how local Weather Forecast Offices provide severe weather timing information



Source: Topeka Weather Forecast Office website



Source: Twin Cities Weather Forecast Office email attachment

Some emergency management participants said they would use the additional information to alert partner agencies or organizations (e.g., first responders) who need to know about timing information to make decisions (e.g., how many dispatchers would be needed).

In general, emergency management participants said they would not necessarily make decisions differently. Some indicated that having the additional information on timing would save them time. Others feel like they already receive the information from their local forecast office and are concerned about inconsistencies (although they admit that there are currently inconsistencies). Some noted that they use multiple sources of information to make decisions and additional detail is helpful but would not change how they operate.

FEMA Personnel

Representatives from FEMA Headquarters and Regions 4, 5, 6, and 7 were interviewed, as well as the FEMA Liaison to SPC (total of nine interviewees from FEMA). These regions cover most of the U.S. areas typically at risk for severe convective storms. FEMA Headquarters and the regional offices have similar procedures for severe storms, and they tend to use the Day 1 Outlook in similar ways.

Decisions Affected by Severe Thunderstorm Forecasts

FEMA Headquarters and regional staff continuously monitor weather forecasts (as well as other information) to maintain awareness of developing threats and to initiate preparedness and response actions when needed. When severe weather is forecasted, affected FEMA regional offices will enhance their watch status. This entails alerting and eventually bringing in additional staff and advising field teams that a deployment may be necessary. In some cases they may start to move and pre-position their field teams in advance of an event. In addition, FEMA staff may increase their communications with state and other partner agencies, and they will brief senior leadership on the developing situation and FEMA's actions. FEMA increasingly prepares a threat assessment or threat analysis in advance of a severe weather event, which provides information on potential impacts of severe weather, including population and infrastructure that may be affected.

Sources of Information

FEMA Headquarters and regional staff rely heavily on all of SPC's Convective Outlooks, including the Day 1 Outlook. The Day 2 and Day 3 Outlooks are just as important to FEMA because each region covers a large area (several states), and they need lead time to mobilize teams or staff up. Some regional staff reported

getting information from Weather Forecast Offices, state emergency management agencies, and media forecasts as well.

How FEMA Uses the Day 1 Outlook

Similar to local emergency managers, the FEMA personnel interviewed use the Day 1 Outlook (as well as the Day 2, 3, and 4-8 Outlooks) as a screening tool and to support FEMA's decisions about enhancing its watch status, adding staff and deploying field teams. Generally, FEMA staff reported triggering their preparedness actions if the Day 1 Outlook shows moderate or higher risk in their region. It is also possible that they will initiate preparedness actions at lower risk levels if it might impact a major population center and/or impact at a particularly vulnerable time (e.g., evening rush hour). This may especially be true if the key threat is tornado (e.g., a category of "slight" driven by probability of tornado). One FEMA representative indicated that he/she does not rely solely on the Outlooks and prefers to get more detailed information from local Weather Forecast Offices and local media.

Feedback about the Current Day 1 Outlook

FEMA interviewees generally expressed appreciation for the Outlooks and other SPC products and indicated that the Outlooks are a crucial part of their decision-making processes. They did offer several suggestions about how they would like to see the Day 1 Outlook improved. Some of the feedback would apply to other Outlooks as well. As with other groups included in this study, FEMA staff expressed a desire for additional timing information.

Categorical Terminology

FEMA interviewees generally liked the shift to five categories of risk because they feel it provides more information and more granularity about the level of risk. They did not report any concern about the categorical terminology.

Appearance and Design

Several FEMA staff suggested that the underlying maps and graphics could be improved so that they are more visually appealing and impactful. However, they did not offer examples of maps or graphics that they like. In addition, there was one suggestion that the underlying maps and graphics should be standardized across all National Weather Service products to help with integrating spatial information into FEMA's mapping applications and enable consistency in briefings and other communications.

Improved Analysis

Several FEMA interviewees reported that they would like to see additional or improved analysis about potential impacts of forecasted storms. The Day 1 Outlook currently reports the area, population, and major population centers covered by each categorical risk (see Figure 5). Some FEMA staff suggested that this level of analysis is too general and crude to be useful. While the statistics accurately reflect how many people are located in each risk zone, far fewer people are likely to be impacted in a significant way. In other words, these statistics probably overstate the risk of impacts. Other staff suggested that regional analysis of potential impacts, perhaps at the state level, would be more useful.

Figure 5: Example of Day 1 Outlook information on area and population impacts (from 6/22/2016)

Day 1 Risk	Area (sq. mi.)	Area Pop.	Some Larger Population Centers in Risk Area
MODERATE	62,996	19,741,118	Chicago, IL...Indianapolis, IN...Columbus, OH...Fort Wayne, IN...Aurora, IL...
ENHANCED	73,316	12,269,942	Pittsburgh, PA...Toledo, OH...Cincinnati, OH...Akron, OH...Peoria, IL...
SLIGHT	171,827	35,383,998	Detroit, MI...Baltimore, MD...Milwaukee, WI...Washington, DC...Cleveland, OH...
MARGINAL	204,229	30,961,125	Philadelphia, PA...Charlotte, NC...Nashville, TN...Virginia Beach, VA...Norfolk, VA...

Simplify the Text Discussion

One FEMA respondent reported that the Forecast Discussion that accompanies the Day 1 Outlook (as well as the other SPC Convective Outlooks) is often too technical and complex for people who are not meteorologists. The respondent noted, however, the discussion can be useful because of the timing information and other details it presents. This interviewee suggested adding more layperson's terms, perhaps by expanding the introductory summary statements at the beginning of the discussion.

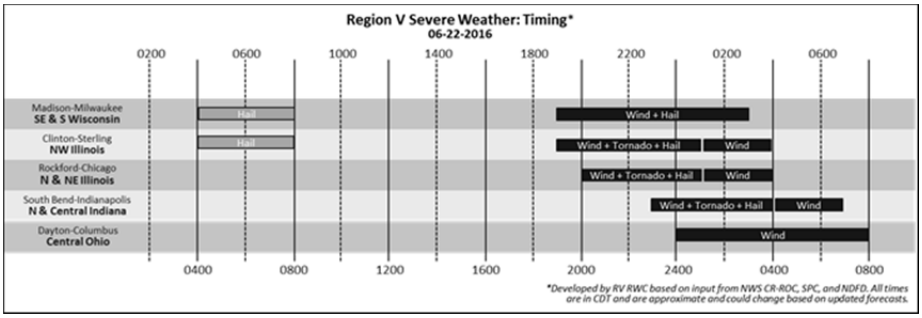
Feedback about Potential Modifications to the Outlook

In general, feedback from FEMA staff about the modified Outlook was positive. They felt the location selection function, timing information, and threat details would be useful additions, especially for local emergency managers. However, all FEMA interviewees pointed out that regional, rather than localized, information would be much more useful for them. The feedback is detailed below.

Feedback about Location Selection and Timing Information

Most FEMA interviewees reported that they would like to have additional information on timing of storms. In fact, one FEMA region produces a timing chart based on available information (Figure 6). This is the biggest gap the region faces with currently available forecast information. The example modified Day 1 Outlook would enable a user to access location-specific timing information. FEMA staff suggested that the approach depicted in the example would be useful and intuitive for local emergency managers. However, nearly all FEMA interviewees reported that it would be of limited use to FEMA because of FEMA's national and regional purview. Instead of location-specific information, FEMA requires regional information on timing of storm risk. For example, one suggestion offered by multiple FEMA interviewees is to map the timing of zones of highest risk, perhaps overlaying this information on the standard categorical risk map (see Figure 7 for relevant examples showing timing information on a map). Another option would be to break the Day 1 Outlook into shorter time segments within the day. These options are covered in more detail in the recommendations section. With the point-and-click function to select locations, some FEMA staff said they could scan across their regions to get a sense of timing, but it would be more useful if the information is presented on a regional basis.

Figure 6: Example of a timing chart produced by FEMA Region 5



In addition, there was feedback that SPC should include some indication of the level of confidence in the timing information. FEMA staff did not express interest in seeing timing information about the individual threats separately. Finally, some FEMA interviewees pointed out that the timing information should have a legend to describe what black and gray mean, as well as a general description of what the information is and how it can be interpreted.

FEMA staff also expressed interest in the Day 2 and Day 3 Outlooks being modified to include timing information.

Figure 7: Examples of mapping storm risk timing

Source: KOCO, Oklahoma City, Oklahoma

Source: WBRC, Birmingham, Alabama

Timing Information versus Watches and Warnings

FEMA interviewees generally view the Day 1 Outlook and Watches/Warnings as completely separate products. They view the Day 1 Outlook as a forecast product with a comparatively long lead time; they view Watches and Warnings as information about real time events. Therefore, they did not express any concerns between potential timing information on the Day 1 Outlook and how it would compare to Watches and Warnings. One FEMA interviewee suggested that timing information could be confusing for the public, especially once Watches or Warnings are issued.

How FEMA Would Use the Information on Timing

As discussed above, the FEMA interviewees said that the location-specific timing information represented in the mock-up example of the Day 1 Outlook would not be particularly useful to FEMA. Some said they would use it by scanning across multiple locations within their regions to get a sense of region-wide timing.

FEMA staff described several ways in which they could make use of timing information, particularly if SPC developed a way to display timing information on a regional basis. FEMA uses the Day 1 Outlook to initiate "enhanced watch" status, for which it calls in additional staff. Also, FEMA uses the Outlooks (Day 1, 2 and 3) to mobilize field response teams. With more detailed regional information about timing, FEMA could fine tune when and how it makes these decisions and avoid having additional staff when it is not necessary. Further, it could make better decisions about when to move field teams. For example, if the Day 1 Outlook projected that severe storms were most likely to hit between 4:00 pm and 8:00 pm on a particular day, FEMA would call in additional staff to cover only that time (with perhaps some cushion to cover the uncertainty of the forecast). FEMA could better decide when to mobilize field teams to maximize the chances that they are on-location as soon as possible after the event, but minimize the chance that these teams will be in transit during dangerous weather, which could place them at risk.

Further, FEMA staff suggested that timing information would help them better understand the potential consequences associated with a severe weather event. For example, they would have a better sense if severe weather might affect morning or evening commutes, or large events (e.g., outdoor professional sporting events). Finally, the timing information might help FEMA get a head start on planning response operations, such as mobilizing power generation equipment or getting water delivered to affected areas.

Conclusions

This section presents a synthesis of our findings across all three audiences (local emergency managers, FEMA, and broadcasters). We offer several conclusions about the Day 1 Outlook, how it is used, and how modifications might impact core SPC customers.

Appropriate Interpretation of the Outlook

Most emergency managers (including FEMA) and broadcasters interpret the current Day 1 Outlook appropriately and described ways of using it that are appropriate for the information it provides. Most participants understand that the Day 1 Outlook presents probability of severe weather and that there is inherent uncertainty in the underlying forecast. Broadcasters seek to communicate that information in a way that will make the public aware that it should monitor conditions and be prepared to take action if a watch or a warning is issued. And emergency managers use the Day 1 Outlook largely to enhance short-term preparedness. We did hear some examples of heuristic-based interpretation (e.g., enhancing preparedness when categorical risk is above "slight") but 1) these responses can be considered appropriate for the level risk and 2) most emergency managers reported that they review all of the available information before making any decisions.

General Concern about How the Public Interprets the Day 1 Outlook

Many participants expressed concern that the public does not adequately understand convective storm forecasts in general or the Day 1 Outlook in particular. This view was particularly common among local emergency managers and broadcasters. They expressed concern that the public would be confused by the categorical risk terms (see below) and would not understand the probabilities. Many seemed to suspect that the public would underestimate risk in many situations. We do not have data to test these assumptions, but other research suggests that few members of the public obtain storm forecasts from SPC and the Day 1 Outlook (Lazo et al, 2009) and that the public understands weather forecast probability better than is typically hypothesized (Morss et al, 2010). The extent to which these previous research findings apply to the Day 1 Outlook is not clear.

High Level of Trust for SPC

Trust in the source can affect how risk information is used (Wachinger et al, 2013). Though participants were not specifically asked, many volunteered that they see SPC as competent experts and have a high level of trust in the information provided. This is further supported by the fact that nearly all participants are familiar with the Day 1 Outlook and most use it as part of their professional responsibilities.

The Day 1 Outlook as a Screening Tool

While not universal, the Day 1 Outlook is widely seen and used as a screening tool, i.e., it is the first tool used by many emergency managers, FEMA personnel, and broadcasters to understand convective weather risk for the current day. Information provided by the Day 1 Outlook serves as a key input and decision factor that then triggers additional actions, potentially including acquisition of more information and operational decisions. Many local emergency managers and broadcasters tend to rely on multiple sources of information, and for those that do, the Day 1 Outlook is unlikely to serve as a sole factor in decision-making. The Day 1 Outlook is a particularly important tool for FEMA, which relies on it heavily to make decisions about watch status, staffing, and other operations. Rather than as a screening tool, a few broadcasters use the Day 1 Outlook as a way to check their own interpretation of forecast models.

Concerns with the Categorical Risk Terminology

While the details varied widely, there was concern with categorical risk terminology. Most of the concerns were specifically geared toward how members of the public might interpret the terminology, especially the terms "marginal," "slight," and "enhanced." Some broadcasters indicated that they avoid the SPC's terminology and use their own terms.

Widespread Interest in Timing Information

FEMA personnel and broadcasters were highly supportive of SPC adding timing information to the Day 1 Outlook. FEMA staff would prefer timing information presented on a regional basis and would be able to make use of that information in their operational decisions. In addition, FEMA staff believe that timing information would be highly useful to local emergency managers. In contrast, the local emergency managers

we reached expressed mixed views. Most were supportive of additional timing information and could imagine ways that they would use it to support preparedness decisions. However, some emergency managers expressed concern about potential inconsistencies with information provided by local Weather Forecast Offices. FEMA also expressed interest in seeing timing information added to the Day 2 and 3 Outlooks (if feasible).

The Importance of the Local Weather Forecast Offices

Local emergency managers rely heavily on their local Weather Forecast Offices. While many do access SPC's website, most of the emergency managers we reached have close working relationships with their local Weather Forecast Office and rely on forecasts and hazardous weather outlooks from them. When they have questions or concerns, many emergency managers contact their Weather Forecast Office directly.

Recommendations

The Day 1 Outlook is widely used throughout the emergency management and broadcast meteorology fields. Consequently, it is important to periodically evaluate how the tool can be changed to better communicate storm risk and support the decisions of partners and customers. Several recommendations are offered below, including how SPC can proceed with increasing the temporal details of the Day 1 Outlook and adding more spatial functionality on the map. These recommendations are based on findings and conclusions from the interviews and focus groups, but not all of these ideas were expressly suggested by a study participant. Some were developed from our interpretation of the findings. Further, not all of the suggestions we received are offered as a recommendation here. We focused on ideas we heard recurrently, as well as recommendations that would enable SPC to successfully modify the Day 1 Outlook to incorporate greater detail about timing of storm risk.

Display the Outlook with Local Time Instead of Zulu Time

Many participants reported that Zulu time makes interpreting and using the Day 1 Outlook more difficult. Most said that they have become comfortable with Zulu time but it would be more intuitive to see the information in local time. An added complication is that daylight savings time does not apply to Zulu time, requiring users to adjust their translation of Zulu time twice a year. This issue will become even more important to users if SPC opts to increase the temporal resolution of the Day 1 Outlook. It is possible to design a website so that it detects the IP of the user and adjusts the display and information to the time zone of the user. There may be restrictions against this approach for government agencies. If so, an alternative is to have the Day 1 Outlook default to one U.S. time zone and provide an option (via toggle or radio button) for the user to change that time zone. This user control would update the Day 1 Outlook to the user-set time zone and would update information on the time the Day 1 Outlook was issued, timeframe that is valid, and, eventually, any information about within-day timing of storm risk.

Abandon the Categorical Terms in Favor of a Numerical Scale

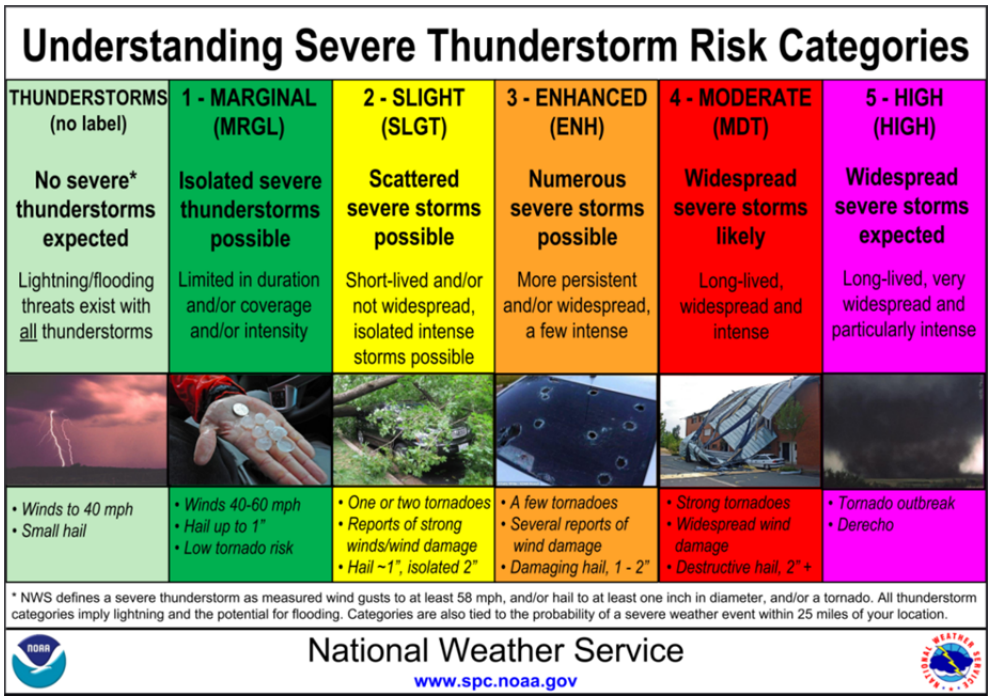
SPC should consider dropping the categorical terms and simply use a numerical scale with descriptors. In short, this means removing the terms from the current definitions (see Figure 8) and referring to each risk category as "category X" or "level X." The different zones of risk on the map would be labeled as such. We make this recommendation because many broadcasters and emergency managers communicated dissatisfaction with the terminology and significant concern that the terms are confusing and potentially misleading for the public. Further, it is quite likely that users interpret those terms to indicate both the probability and severity of weather from a meteorological perspective as well as the potential consequences of hazardous weather conditions. But consequences vary depending on local circumstances, time of day that weather hits a particular location, and other factors. It may be better for SPC to target its communication about convective storm forecasts to the meteorological factors (probability and severity). Making this change would be consistent with standard risk management approaches in which risk is defined as the product of the probability of an adverse event and the expected consequences of that adverse event. SPC's products

focus primarily on probability.

There are many examples of using a numerical scale for natural hazards. Perhaps the most salient for SPC's purposes is the Saffir-Simpson Hurricane Scale. Hurricanes are typically described and reported in the media by its category (1, 2, etc.) and not by the additional labels ("moderate," "catastrophic," etc.). These numerical hurricane categories are used in forecasts, watches, and warnings that are issued a day or more in advance.

Figure 8: Current and Proposed categorizations of severe convective weather risk

Current labeling of risk categories	Thunderstorms	1 – MARGINAL (MRGL)	2 – SLIGHT (SLGT)	3 – EHNANCED (ENH)	4 – MODERATE (MDT)	5 – HIGH (HIGH)
Proposed numerical labeling of risk categories	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6



If SPC does maintain the terminology, another potential revision is to use the full terms (e.g., marginal) on the map legend rather than the abbreviations. While we did not hear any feedback about this issue, it is quite possible that the abbreviations are confusing to new users and/or the general public.

In addition, SPC should consider modifying the Day 1 Outlook so that the "marginal" (i.e., proposed level 2) category is shown as something other than green. Green is often used in a risk and/or decision context to indicate good or normal conditions, and in weather forecasting it is often used in rainfall scales, with the dark green sometimes indicating a lot of rain. While "marginal" does include a very low level of severe thunderstorm probability, it may be better to represent it with another color, such as light beige, so that it does not give the false impression of "safe" or "normal" conditions. The same can be considered for the "Thunderstorms" (proposed level 1) category. It is shown in Figure 8 as light beige (lighter than level 2).

Make the Update Schedule for the Outlooks More Readily Available

Several participants noted that it would be helpful if they could easily find information on when the Outlooks are updated and released each day. The Outlook discussions include a note about when the next update is scheduled. A graphic summarizing when each Outlook (including Days 2, 3, and 4-8 Outlooks) is issued would help users understand the overall workflow of these forecast products and more easily access information about when updates can be expected.

Add Within-Day Timing Information to the Day 1 Outlook

Most participants expressed interest in seeing additional temporal information on the Day 1 Outlook, though some concerns were expressed. SPC has begun to conduct research and development to make the Day 1 Outlook (and other Outlooks) report storm risk at the hourly scale. We recommend that SPC revise the Day 1 Outlook to include location-specific and regional timing information, and we present three separate options below.

Option 1 – Add Timing Information Separate from the Map

The interest in more temporal information was high enough that SPC should consider adding this information as soon as possible. SPC has communicated that output from forecast models would enable it to include timing information in a simple format, such as that demonstrated in the mock-ups in 0. If more complex changes to the Day 1 Outlook (see below) are expected to require more than a few months of research, development, and testing, we recommend that SPC work to add a simplified version of timing information in the near future. This would serve as an interim product, but would meet a need in the broadcast and emergency management fields and could potentially provide valuable information to the public. Based on the input received, there are several specific design recommendations that should be considered if SPC proceeds with Option 1:

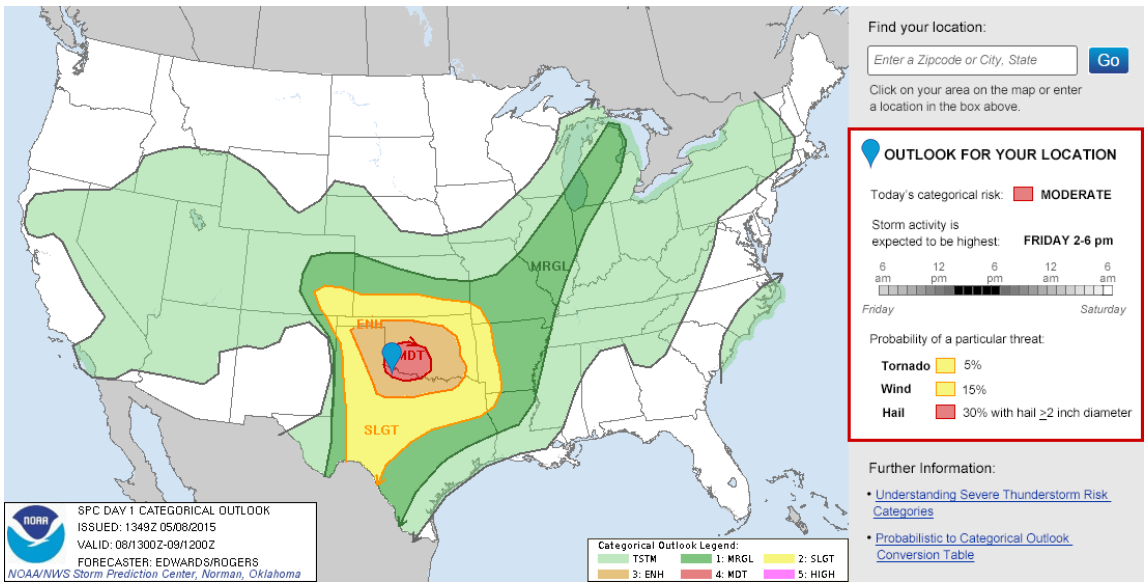
- Use the point-and-click and search bar features for selecting a location, as shown in the mock-up.
- Consider adding location information to the sidebar so that a user has detailed information on the counties or cities included in the point on the map they have selected. For example, the sidebar could update with text such as “You have selected a point in Weld County.”
- Use local time, not Zulu time, as described above (this is reflected in the timing information shown on the mock-up but not in time stamp or valid times shown in the lower left; however, it is recommended that those times be shown in local time as well).
- Ensure that graphical representation of timing (whether the grid shown in Version 4 of 0 or another graphic) does not imply zero risk for any portion of the day (unless the forecast models do in fact suggest zero probability of storms during that time), e.g., for the timing grid shown in the appendix, color all cells gray with a continuous fading from the highest risk time.
- Instead of using the phrase “Your risk is highest,” which was used on the mock-ups for the interviews and focus groups, use a phrase that focuses on storm activity, such as “Storm activity in your area is expected to be highest.” Since the timing information as envisioned under this option does not use the risk terminology of the Day 1 Outlook, using the phrase “storm activity” will avoid confusion with the risk terminology and designations on the map.
- If feasible, indicate the level of confidence in the timing information, perhaps using a simple high/medium/low rating.
- Select another icon as the location pointer (currently the black tear drop)—one that less resembles a tornado—to avoid potential confusion. We used a blue teardrop in the new mock up below.
- To avoid confusion with Watches and Warnings, the Day 1 Outlook should automatically show if a selected location is in a current Watch or Warning **versus** showing the forecast timing information.

Instead of showing the timing graphic, the Day 1 Outlook would indicate that the selected location is in a Watch/Warning and provide a link to the relevant webpage for more detail. The Watch/Warning information would supersede the timing information.

A revised mock-up reflecting some of these recommendations is shown in Figure 9.

It is not clear whether the Day 1 Outlook should include individual threat probabilities for a selected location, as is shown in Figure 9. Many of the broadcasters and emergency managers said that the display of location-specific threat probabilities would make accessing that information a little easier. However, many also expressed reservations about how that information would be interpreted by the public. They fear that probability information will be confusing to the public, or that the public will discount the risk associated with, for example, a five percent chance of tornadoes. As discussed above, there is evidence that laypersons do understand the probabilities associated with weather, but we do not have any information about how the public views, interprets, and acts on probability of tornado and other threats of severe convective weather. Moreover, we do not have evidence that large segments of the general public access and use the Day 1 Outlook. In fact, available research suggests this may be unlikely (Lazo, 2009).

Figure 9: Mock-Up of Option 1 Recommendations for the Day 1 Outlook



Perhaps emergency managers and broadcasters are more risk averse than many segments of the public and would prefer that information be presented in ways that maximize the chances that the public will take precautions, whatever those precautions may be. However, at the same time, SPC, emergency managers and broadcasters must be careful to avoid the cry-wolf syndrome—overstating risk on a regular basis and leading the public to trust forecasts and warnings less, ultimately leading to insufficient public response when risk is particularly high (Simmons and Sutter, 2009).

Option 2 – Display Timing Information as an Overlay on the Existing Map

FEMA in particular, as well as some broadcasters, expressed a preference for seeing timing information on a regional basis, as opposed to specific 25 kilometer grid locations. These participants reported that they would more effectively use regional timing information. One possibility is to produce the Day 1 Outlook for time spans that are less than a day and map and disseminate those results (see Option 3, next section). A simpler

approach, which likely can be supported by the existing models and processes, would be to overlay timing information on the existing map. In this approach, polygons representing areas of highest storm activity for different time segments of the day would be shown over the existing polygons for the categorical risk areas.

Figure 10: Timing information overlaid on the existing Day 1 Outlook Map

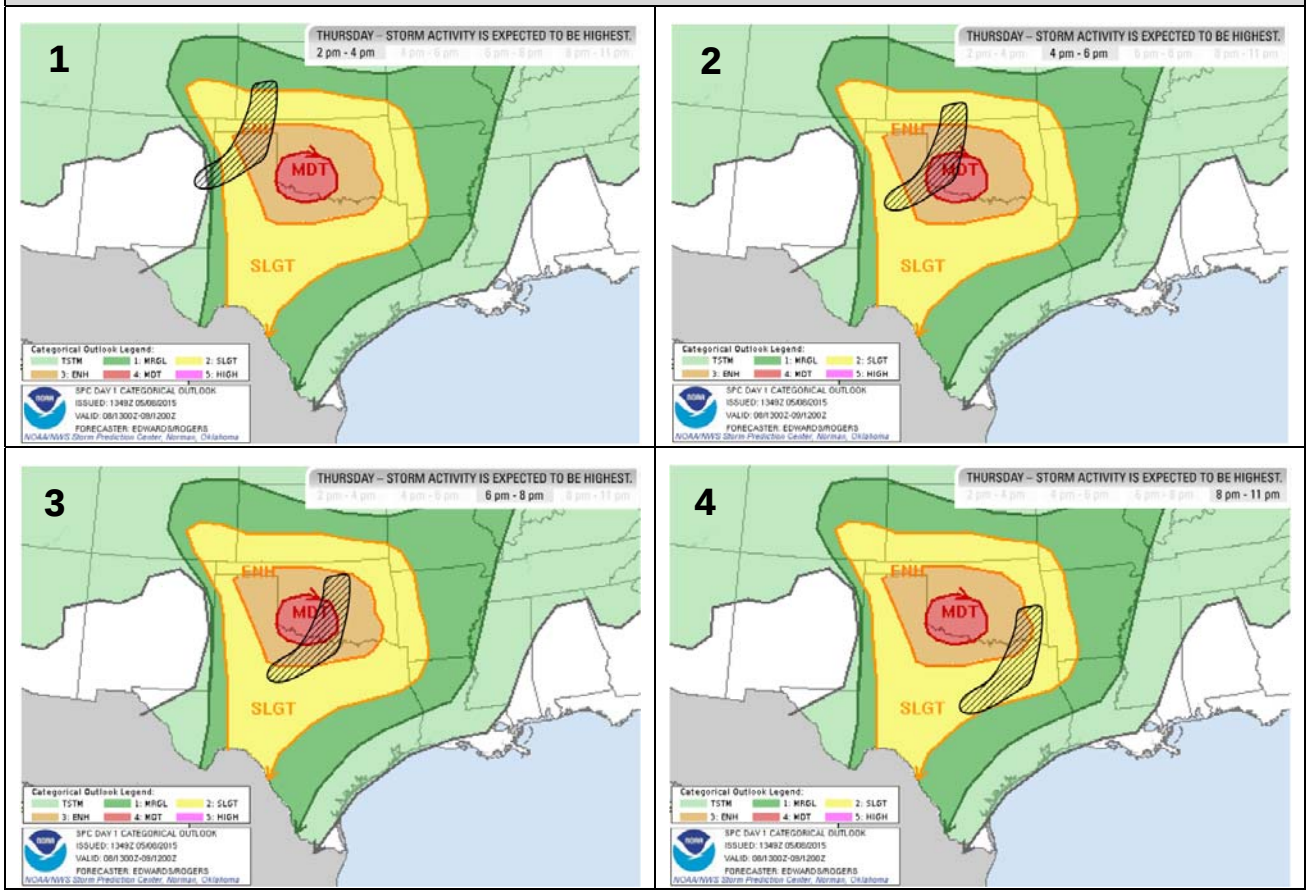


Figure 10 shows an example of how timing information could be overlaid on the Day 1 Outlook map. The information represented would be the same as what is represented in Option 1, i.e., it would communicate only the time of day that storm activity is expected to be highest and would not categorize the risk on an hourly basis. But with this option, the information would be presented for larger regions. In addition, we recommend animating these timing overlays, similar to how the Day 4-8 Outlooks automatically animate. Finally, this functionality would be most effective as a user-controlled option, similar to the additional layers that are offered in the current Day 1 Outlook (e.g., population, cities). As a user-controlled option, those who need regional timing information could access it, but it would prevent cluttering the Day 1 Outlook for users that are not interested.

This option presents some challenges. First, it may clutter the map if timing information for all categorized risk areas is shown on the national map. Risk areas on the Day 1 Outlook often cover a large portion of the country, and the timing of storm activity across those areas may differ (e.g., storms may be expected to initiate in the early afternoon in the Southeast, but not initiate until early evening over the Great Plains). Displaying all timing information for all mapped risk areas at once could be confusing and chaotic.

There are at least two ways to deal with this problem. One, SPC could limit this option to only those days

and those areas that exceed a certain risk category. For example, SPC could map timing for "moderate" and above, which FEMA reported as triggering its preparedness actions. Other respondents reported that they take action starting at "slight." SPC could provide timing information for only those areas above the threshold. Second, it would simplify the map to show timing polygons and animation only when the user zooms into a particular region (as shown in Figure 10). This would require that SPC also add zoom-in functionality to the Day 1 Outlook (covered below).

Another challenge is that this option would likely increase the workload and/or complicate the workflow for producing the Day 1 Outlook. Forecasters would need to produce polygons to show how timing of storms will evolve throughout the day, and on many days they would have to do that for several regions of the country.

Option 3 – Sub-Daily Outlooks

Several participants expressed strong interest in having the Day 1 Outlook reformulated to show forecast information for multiple time periods within each day, in place of or in addition to an outlook for the entire day. For example, instead of an outlook for the entire day, some people would prefer to see four outlooks for each of the six-hour periods in a day. Under this approach SPC would redefine the categorical risks by changing the probability thresholds so that they can be applied to periods less than a day. These new definitions would be used with forecast model output for each six-hour period of the day to designate risk categories for each period separately. This would result in outlooks for 12:00 am to 6:00 am, 6:00 am to 12:00 pm, 12:00 pm to 6:00 pm, and 6:00 pm to 12:00 am of each day. As SPC updates its forecast, it would update only those time periods remaining in the day.

This approach would be fundamentally different than Option 1 or 2. Options 1 and 2 use the categorical risk designations as they exist now (i.e., for the entire day). Option 3 would rate the risk separately for different time periods in the day. A given location might be projected in the Day 1 Outlook to have a "slight" risk in the morning and "high" risk in the afternoon.

Option 3 would provide a greater level of detail than Option 1 or 2, but it would also create a potential problem. The Day 2 and Day 3 Outlooks use the same categorical definitions as the Day 1 Outlook. Changing the categorical definitions to support sub-daily time segments would create a discontinuity between the Day 2 and Day 3 Outlooks and this new version of the Day 1 Outlook. There could be many situations in which categorical risks shift spatially from Day 2 to Day 1, leading users to view the products as inconsistent and potentially diminish the value of the Outlooks. In addition, as discussed earlier, more information does not automatically lead to better decisions. This more detailed version of the Outlook may prove to be too complex for those emergency managers and broadcasters that use the Day 1 Outlook as a screening tool. If SPC elects to go this route, it will be important to structure the Day 1 Outlook so that summary, higher level information is presented first, with the option for users to drill into more temporal or spatial detail if they want. This will allow the Day 1 Outlook to continue serving as a high-level screening tool, while providing enough detail to support some of the decisions identified in this study.

In recent discussions with SPC, we understand that it is working to develop new definitions for the categories that would apply for Days 1, 2 and 3 and that these new definitions would support sub-daily outlooks. This would enable SPC to meet the need for more detailed timing information on Day 1, while maintaining consistency in risk categorization across the Outlooks.

Add Timing Information to the Day 2 Outlook

Some participants, particularly those from FEMA, indicated that when severe weather is forecasted one to two days out, they begin to plan preparedness actions, such as alerting on-call staff. The Day 1 Outlook is first issued for the current day at about 0600Z or about 2:00 am Eastern Daylight Time, 1:00 am Central Daylight Time and 12:00 am Mountain Daylight Time. If the Day 1 Outlook is modified to include more detailed timing information, that means the earliest FEMA and local emergency managers could have access to detailed timing information would be in the pre-dawn hours of a day projected to have severe weather. It could be useful for FEMA's operations if it had timing information earlier on the prior day. Therefore, SPC

should consider adding graphical timing information to the Day 2 Outlook (and potentially the Day 3 Outlook). The Day 2 Outlook discussion currently provides timing information in the text discussion, so the supporting data from forecast models is already produced. Three options for structuring and graphically presenting timing information were discussed above. Those same options could be applied to the Day 2 Outlook. For example, the Day 2 Outlook could be modified to support location-selection functionality that would then present a timing graphic similar to that shown in Figure 9Figure 10. However, timing information should be added to the Day 2 Outlook only if SPC believes the skill of forecast models can support it.

Add Capability to Zoom in for Regional Views

Many participants expressed interest in being able to zoom in and out on the Day 1 Outlook map so that they can view risk mapping at a higher resolution. In fact, some TV stations produce their own regional maps using the KML or shapefile data provided by SPC. This would be particularly beneficial when users elect to add the optional layers available on the Day 1 Outlook (e.g., counties, highways). This capability would be more conducive to Option 2 for timing information presented above. There are two ways that SPC could proceed to add this functionality.

A simple approach would be to define a limited number of regions and structure the Day 1 Outlook so that users can navigate to those regional views by clicking on the map. The U.S. Drought Monitor is designed with this approach (see Figure 11). This approach could be implemented in conjunction with the timing information recommended under Option 2 above—regional timing information would be presented only when a user navigates to view a particular region. The regions could be FEMA regions or states.

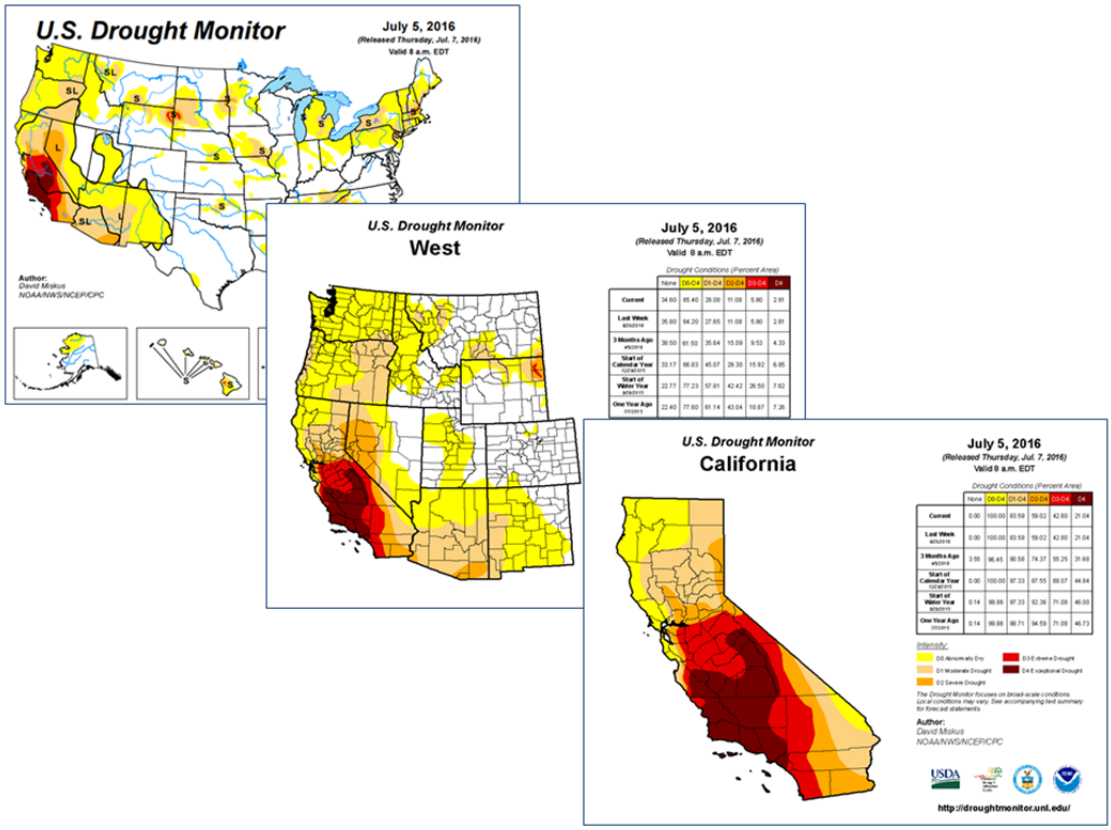
Another approach would be to provide the Day 1 Outlook on a mapping web app that enables continuous zoom in and out, such as on Google, Bing, or ESRI base maps. Other National Weather Service products use such base maps. This approach would provide the familiar means for zooming in and out using the mouse wheel and/or icons on the map interface. And it would provide other geographic information (e.g., cities, roads, water bodies) to provide context. Of note, zooming in should be limited so that users do not get a false sense of spatial precision from high resolution views.

Coordinate Outlook Changes with Weather Forecast Offices

SPC should work closely with Weather Forecast Offices as it researches and develops new versions of the Day 1 Outlook (or other Outlooks). Local emergency managers rely heavily on their local Weather Forecast Offices to help them access, interpret, and act on severe weather forecast information. Most Weather Forecast Offices issue hazardous weather outlooks, which often include information from the SPC. Weather Forecast Offices in the regions targeted for this study tend to have close working relationships with the emergency management community, often in association with National Weather Service Integrated Warning Teams. As a result, local forecast office personnel will have a more detailed understanding of local needs and challenges and how those needs and challenges can be met with changes to the Day 1 Outlook.

This study did not include any formal data collection from personnel from local Weather Forecast Offices. Going forward, we recommend that SPC engage with these offices in different regions to understand how they use the SPC Outlooks and how changes to the Outlooks would affect those uses. Collecting this information could provide valuable insight to support decisions about future revisions to the Outlooks, including whether and how to provide more detailed information on timing, and how to make the Day 1 Outlook flexible enough to support a variety of established local communications processes among Weather Forecast Offices and emergency managers. Engaging Weather Forecast Offices could be accomplished through interviews similar to those conducted for this study, or, if feasible, a workshop (or series of workshops) hosted by SPC.

Figure 11: U.S. Drought Monitor Regional Views



Assess How the Public Uses Severe Weather Forecast Information

The ultimate goal of severe weather forecasting, including the SPC Convective Outlooks, is to provide information that can help protect people and property from dangerous weather. The professionals interviewed for this study are a pivotal link in the forecast communication chain for severe weather (Brotzge and Donner, 2013). Broadcasters use information from SPC and many other sources to communicate forecasts to millions of people. Local emergency managers, as well as FEMA staff, use information from SPC and other sources to initiate preparedness actions and provide support in the wake of disastrous events. We do not yet know how the public obtains, interprets, and acts on forecasts of severe convective weather. There is some literature on public response to tornado warnings (e.g., for an overview see Lindell et al, 2012) and other research about how the public accesses and interprets weather forecasts in general (e.g., Lazo et al, 2009; Handmer & Proudley, 2007; Gigerenzer et al, 2005; Morss et al, 2010). However, we have comparatively little understanding of how the public obtains or uses forecasts like the Day 1 Convective Outlook. There may be lessons from research on other natural hazards, such as flood risk (see Kousky and Shabman, 2015) or the extensive literature on hurricane evacuation decision-making (Lindell et al, 2005; Dash and Gladwin 2007 for a literature review). But the key threats associated with severe convective weather, especially tornadoes, have unique characteristics compared to other natural hazards. They generally have smaller, more localized impact than hurricanes or most floods. They emerge and evolve quickly, leaving comparatively little time for warning and response, and they can be extremely dangerous and damaging when they do touch down.

Broadcasters and emergency managers expressed concerns about certain elements of the current or potentially modified Day 1 Outlook being confusing or misleading to the public. There were concerns that the timing information might lead members of the public to assume some parts of the day are "safe." There were concerns that the public would not understand probability information, or that it would downplay the typical probabilities of tornado (e.g., 5% or 10%). These concerns may have merit and may deserve additional research. The first issue for any new research is to investigate the extent to which the public obtains forecasts from SPC and any determinants of where it obtains severe weather forecasts. It is entirely possible that most of the public obtains severe convective forecast information from other sources, not SPC; Lazo et al, 2009 shows that most people get forecasts in general from TV, radio, and websites other than from the National Weather Service. And regardless of where the public obtains convective forecasts, it is important to know what, if anything, members of the public do with this information. To what extent do members of the public take precautionary actions such as changing plans, alerting their families and friends, and/or take the time to monitor weather forecast information sources throughout the day?

Such research can help SPC make decisions about modifying the Outlook(s). For example, if relatively few people obtain forecast information from the SPC Outlooks, then concerns about the impacts of additional probability details may be unfounded. However, if people are confused by multiple threat probabilities and how those are combined to designate a categorical risk, it may be worthwhile to limit such details to features/functions that are likely to be accessed only by professional EM or meteorology audiences.

References Cited

Brotzge, J., & Donner, W. (2013). The tornado warning process: A review of current research, challenges, and opportunities. Bulletin of the American Meteorological Society, 94(11), 1715-1733.

Dash, N. and Gladwin, H. (2007). "Evacuation Decision Making and Behavioral Responses: Individual and Household." Nat. Hazards Rev., 10.1061/(ASCE)1527-6988(2007)8:3(69), 69-77.

Gigerenzer, G., Hertwig, R., Van Den Broek, E., Fasolo, B., & Katsikopoulos, K. V. (2005). “A 30% chance of rain tomorrow”: How does the public understand probabilistic weather forecasts?. Risk analysis, 25(3), 623-629.

Handmer, J., & Proudley, B. (2007). Communicating uncertainty via probabilities: The case of weather forecasts. Environmental Hazards, 7(2), 79-87.

Hoss, F., & Fischbeck, P. (2016). Increasing the Value of Uncertain Weather and River Forecasts for Emergency Managers. Bulletin of the American Meteorological Society, 97(1), 85-97.

Kahneman, D., P. Slovic and A. Tversky, Eds. (1982). Judgment under Uncertainty: Heuristics and Biases. Cambridge University Press. Cambridge, UK.;

Kahneman, D. and A. Tversky (1979). Prospect Theory: An Analysis of Decision Under Risk. Econometrica, 47(2): 263-292.

Lazo, J. K., Morss, R. E., & Demuth, J. L. (2009). 300 billion served. Bulletin of the American Meteorological Society, 90(6), 785.

Lindell, M. K., Lu, J. C., & Prater, C. S. (2005). Household decision making and evacuation in response to Hurricane Lili. Natural Hazards Review, 6(4), 171-179.

Lindell, M. K., D. Sutter, and J. E. Trainor (2012). White paper 4: Individual and household responses to tornadoes. Proceedings of Workshop on Weather Ready Nation: Science Imperatives for Severe Thunderstorm Research, Birmingham, AL. Available at: http://www.nws.noaa.gov/com/weatherreadynation/files/WRN_FinalReport120917.pdf

Morss, R. E., Lazo, J. K., & Demuth, J. L. (2010). Examining the use of weather forecasts in decision scenarios: results from a US survey with implications for uncertainty communication. Meteorological Applications, 17(2), 149-162.

National Weather Service (2014). Service Assessment: The Record Front Range and Eastern Colorado Floods of September 11-17, 2013. Available at: http://www.nws.noaa.gov/om/assessments/pdfs/14colorado_floods.pdf

Simmons, K. M., & Sutter, D. (2009). False alarms, tornado warnings, and tornado casualties. Weather, Climate, and Society, 1(1), 38-53.

Slovic, P. (1987). Perception of Risk. Science, 236(4799): 280-285.

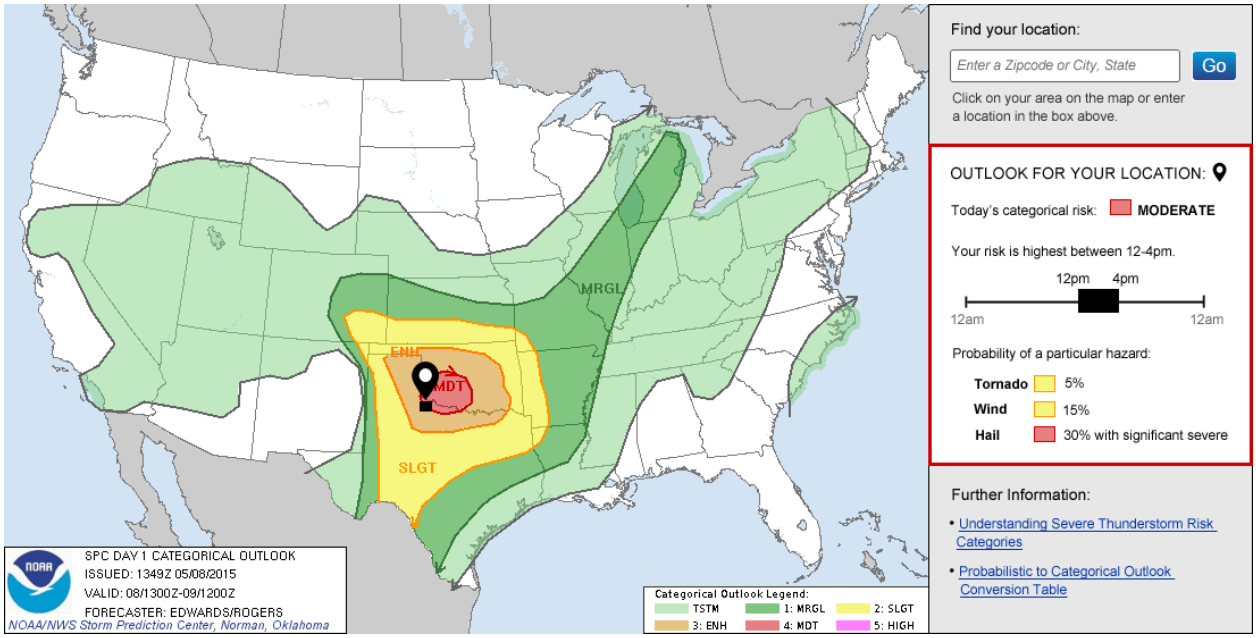
Spiegelhalter, D., Pearson, M., & Short, I. (2011). Visualizing uncertainty about the future. science, 333(6048), 1393-1400.

Visschers, V. H., Meertens, R. M., Passchier, W. W., & De Vries, N. N. (2009). Probability information in risk communication: a review of the research literature. Risk Analysis, 29(2), 267-287.

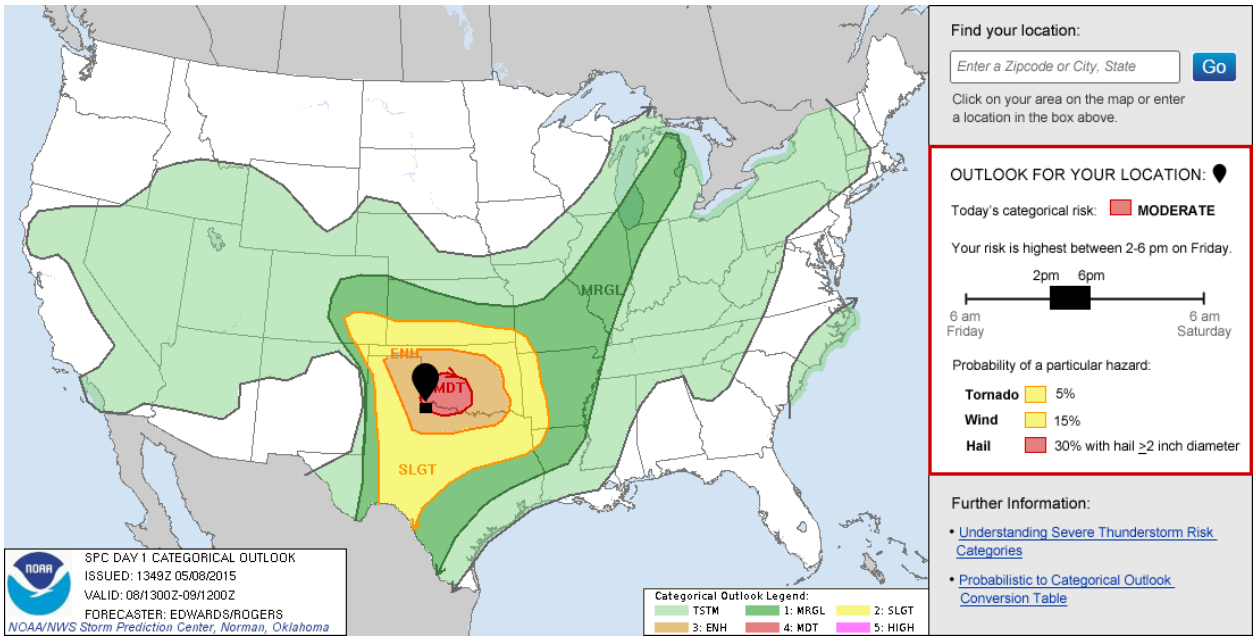
Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox – implications for governance and communication of natural hazards. Risk analysis, 33(6), 1049-1065.

Appendix A – Outlook Modifications

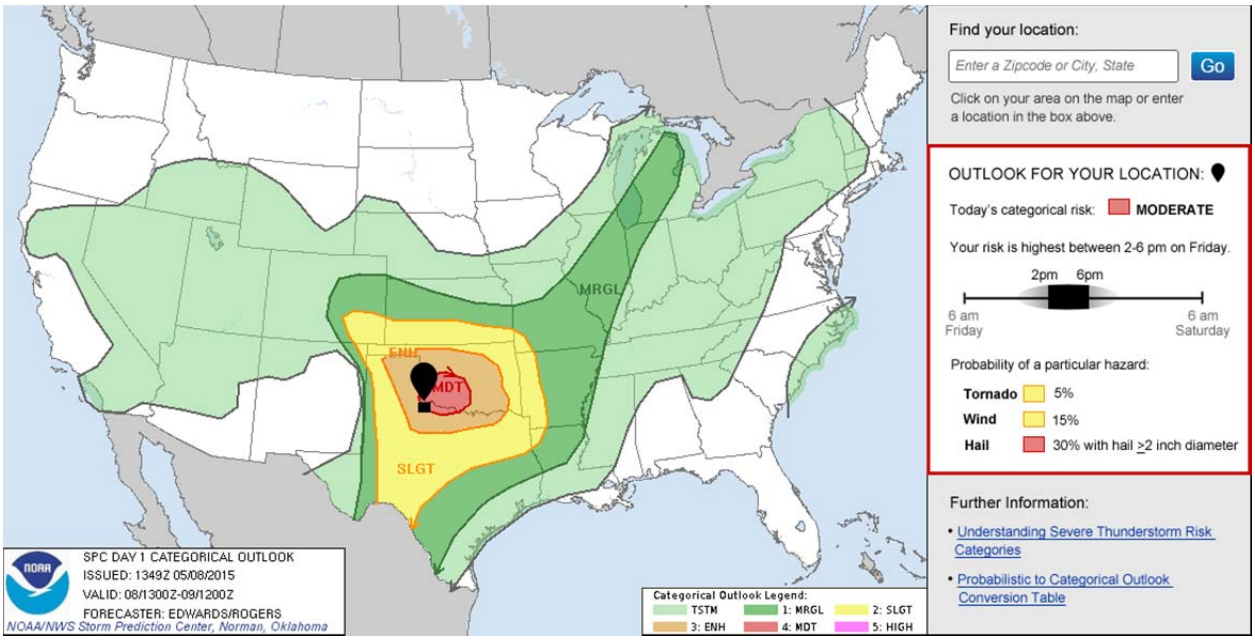
Outlook Mock-Up Version 1: This version was shared with SPC on October 20, 2015.



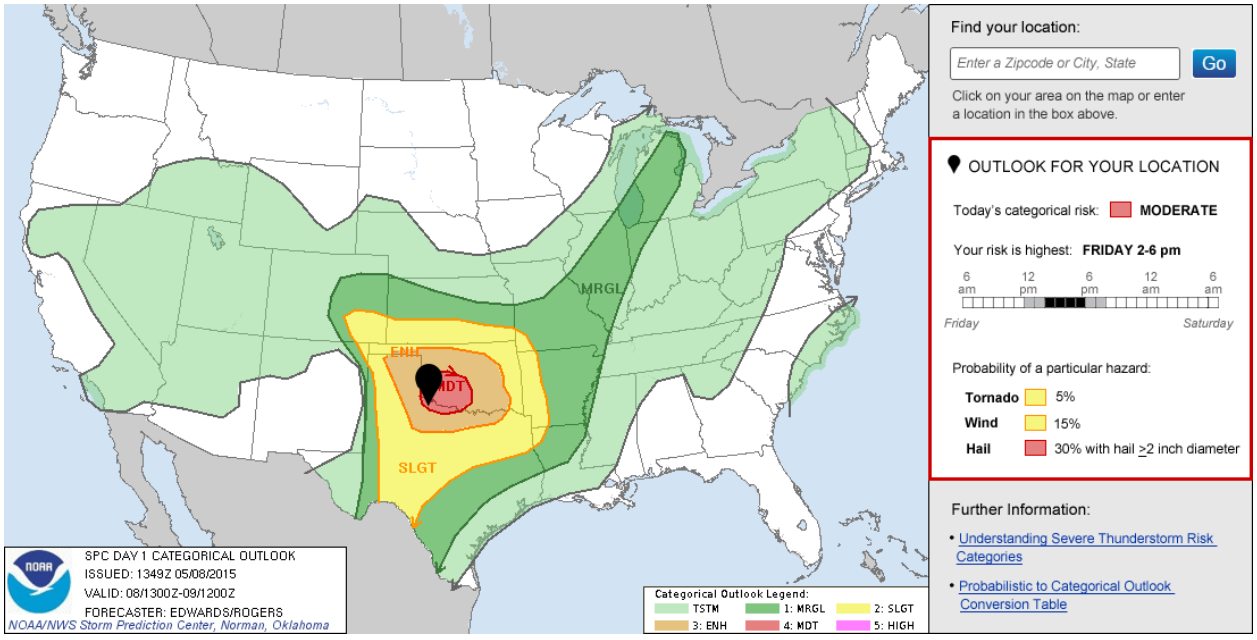
Outlook Mock-Up Version 2: This version was shared with SPC on December 29, 2015. Several changes were made to Version 1 in response to feedback from SPC, including changing the location marker, adding day of the week to the timing information and showing time span as 6:00 am to 6:00 am, which better reflects applicability of the Outlook for U.S. time zones. In addition, the term "significant severe" was removed from the threat probabilities and replaced with descriptive terms.



Outlook Mock-Up Version 3: Version 2 was modified to add the grey oval to the timeline to indicate that risk ramps up and down before and after the highest risk period.



Outlook Mock-Up Version 4: Feedback during initial interviews showed that the timeline with black box and gray oval was confusing. Abt experimented with several alternative graphical representations of timing and selected that shown in Version 4. This version was used for all remaining interviews and focus groups.



Appendix B – Focus Group and Interview Protocols

Protocol for State and Local Emergency Management Personnel

Paperwork Reduction Act Statement

Public reporting burden for this collection of information is estimated to average 60 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to Jennifer Sprague, NOAA National Weather Service, jennifer.sprague@noaa.gov .

Abt Associates will not release your name or information that could identify you as part of this focus group process or in our subsequent reports to NOAA's Storm Prediction Center. Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

Begin with short introduction of the project (5 min)

- I am _____ from Abt Associates, which is a contractor to the Federal Government and is helping SPC with this study. During this meeting, I will ask questions about how you use weather forecast information in your work.
- The National Weather Service's Storm Prediction Center, or SPC, produces a "Day 1 Outlook", which provides forecast information about severe thunderstorms, tornadoes, other wind gusts and hail for the current day. By the current day, we mean that the Outlook provides forecast information for the same day on which it is produced.
- SPC is planning to modify or add to the Day 1 Outlook to include more detail on the timing of forecasted hazards and possibly more spatial detail. We will describe the kinds of changes they are considering later in this discussion.
- SPC would like to gather input from core partners and customers, including the emergency response community, to help guide future changes to the Outlook. They want to know how local personnel make emergency preparedness decisions with regard to severe thunderstorms, tornadoes, hail and other hazards. They want to know if and how the current Day 1 Outlook is used to support decisions for the current day, what other information would be useful in the Day 1 Outlook and whether and how increased detail about timing and location of risks would help.
- With better knowledge about how emergency preparedness decisions are made, SPC will be able to design a more useful version of the Day 1 Outlook.

Questions

- How does risk of severe thunderstorms and tornadoes affect your operations and activities?
- What kinds of decisions, if any, do you make based on forecasted storm risk for the current day? By current day, we mean starting in the early morning, for potential storms that day or night.
    - Probe: When do you make these decisions?
    - Probe: What kind of information do you use to make these decisions?
    - Probe: Why do you use these sources of information?

  - Probe: Where and how do you obtain this information?
  - Probe: Do you think the storm, tornado and other hazard forecast information available for making these decisions is sufficient? If not, what is missing?
- Do you communicate severe weather forecast information to other agencies or organizations or to the public?
  - Probe: In what way do you communicate information to other agencies or organizations or to the public?
  - Probe: What kind of information do you communicate to other agencies, organizations or the public?
  - Probe: Are there kinds of severe weather forecast information for the current day that other agencies or organizations or members of the public request from you that you do not have available?
- *[Bring up Day 1 Outlook on screen or hand out hard copy(TBD)]* Are you familiar with the SPC Day 1 Outlook? Do you use the Day 1 Outlook?
  - [If anyone is not familiar with Day 1 Outlook, describe the example (on screen and/or in hard copy)]
  - Probe: Please describe what the Day 1 Outlook tells you about risk of severe weather for the current day. Describe what you think the categorical risk categories mean.
  - Probes: How do you use the Day 1 Outlook? When and how often do you check it? Do you have formal decision rules about how to use information in the Outlook?
  - Probes: Which portions of Day 1 Outlook do you use? The Categorical Outlook? The text portion? Specific hazard (i.e., the tornado, wind, hail) probability forecasts?
  - Probe: How does the Day 1 Outlook compare to other sources of information that you use to make decisions related to storm/tornado risk?
  - Probes: How does your use of the Outlook compare to your use of storm and tornado watches and warnings issued by the National Weather Service? Do you think that the information provided by these products is consistent?
  - Probes: What do you think about the format and layout of the current Day 1 Outlook? Is it user-friendly and easy to navigate and use?
  - Probe: Is there anything that could be improved about Day 1 Outlook to better meet your needs?
- [Bring up example #1 of modified Day 1 Outlook on screen and/or hand out hard copy (TBD). Point out the primary changes from the current Outlook]
  - This example shows a possible modification of the Day 1 Outlook.
  - Probes: Could you tell me how you interpret the additional information that is provided here? Is there anything that is unclear or confusing?
  - Probes: Is the additional information on the timing of risk understandable?
  - Probes: Is it useful to have additional information on timing for each of the hazards (tornado, wind, and hail) or just for the overall categorical risk?
  - Probes: Would you use the additional information on timing? How? Would it change the way you make decisions or help you make better decisions?

- Probes: The information about timing does not use the categorical risk terminology. Does that fact affect how you would interpret and use this information? If so, how?
- Probes: Would you communicate the additional information on timing to partner agencies/organizations? To the public?
- Probes: How do you think your use of this modified version of the Outlook would compare to your use of watches and warnings issued by the National Weather Service?
- Do you have any other comments or suggestions?

Conclude by thanking them for their participation, providing contact information if they have any questions, and letting them know that the study will be concluded by Spring (2016).

Protocol for Private Sector Meteorologists (small group or individual interviews)

Paperwork Reduction Act Statement:

Public reporting burden for this collection of information is estimated to average 60 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to (name), NOAA Line office, (address).

Abt Associates will not release your name or information that could identify you as part of this interview process or in our subsequent reports to NOAA's Storm Prediction Center. Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

Begin with short introduction of the project (5 min)

- I am _____ from Abt Associates, which is a contractor to the Federal Government and is helping SPC with this study. During this meeting I will be asking you questions about your use of various thunderstorm forecast products.
- The National Weather Service's Storm Prediction Center, or SPC, produces a "Day 1 Outlook", which provides forecast information about severe thunderstorms, tornadoes, other wind gusts and hail for the current day. By the current day, we mean that the Outlook provides forecast information for the same day on which it is produced.
- SPC is planning to modify or add to the Day 1 Outlook to include more detail on the timing of forecasted hazards and possibly more spatial detail. We will describe the kinds of changes they are considering later in this discussion.
- SPC would like to gather input from core partners and customers to help guide future changes to the Outlook. They want to know how broadcast and other private sector meteorologists use and communicate forecasts of severe thunderstorms, tornadoes, hail and other hazards for the current day. They want to know whether and how the current Day 1 Outlook is used to support broadcast forecasts, what other information would be useful in the Day 1 Outlook, and whether and how increased detail about timing and location of risks would help.
- With better knowledge about how broadcasters and other private sector meteorologists use and

communicate this information, SPC will be able to design a more useful version of the Day 1 Outlook.

Questions

- /Bring up Day 1 Outlook on screen or hand out hard copy(TBD)] Are you familiar with the SPC Day 1 Outlook?
- [if they are not familiar with the SPC Day 1 Outlook, describe the example]
- I'm interested to know how you interpret the information presented in the Outlook: can you tell me how you interpret the information in the Outlook?
- Do you use other tools for forecasting and communicating severe storm risk for the current day? If so, which ones?
    - Probe: If so, how is the Day 1 Outlook similar to or different from other sources of weather information that you use?
- What is your primary audience for broadcasting/disseminating forecasts? The public? Specific customers?
- How do you use severe weather forecasts for the current day in preparing the forecast that you deliver on broadcasts or on websites? What do you aim to communicate to your audience?
- Do you use the Day 1 Outlook for preparing your forecast? Why or why not?
    - Probe: How do you use the Day 1 Outlook, if at all?
    - Probes: Which portions of the Outlook do you use? The Categorical risk? The text discussion? The tornado, hail, or wind forecast probabilities?
    - Probe: Do you use the Outlook map/graphic?
    - Probes: If not, why? Do you use other map/graphics of risk?
    - Probes: How does the Outlook compare to watches and warnings issued by the National Weather Service? Do you think that the information provided by these products is consistent?
- Is there anything that could be improved about the Day 1 Outlook to better meet your needs?
- How do you report/relay/interpret different levels of forecast risk (Slight, Moderate, etc.)?
    - Probe: Do you use the same terminology? If not, why, and what terminology do you use?
- [Bring up example #1 of modified Day 1 Outlook on screen and/or hand out hard copy (TBD)]
    - This example shows a possible modification of the Day 1 Outlook.
    - Probes: Could you tell me how you interpret the additional information that is provided here? Is there anything that is unclear or confusing?
    - Probe: Is the additional information on the timing of risk understandable?
    - Probe: Is it useful to have additional information on timing for each of the hazards (tornado, wind, and hail) or just for the overall categorical risk?
    - Probes: Would you use the additional information on timing? How? Would it change the way you communicate forecasts via your broadcast or website?
    - Probe: The information about timing does not use the categorical risk terminology. Does

that fact affect how you would interpret and use this information? If so, how?

- Probe: How do you think your use of this modified version of the Outlook would compare to your use of severe thunderstorm and tornado watches and warnings issued by the National Weather Service?
- Do you have any other comments or suggestions?

- What do you think the public needs to know about severe weather risk for the current day? How did you learn about what the public needs? Do you have research about how the public receives and understands this type of information?

Conclude by thanking them for their participation, providing contact information if they have any questions, and letting them know that the study will be concluded by Spring (2016).