Winter Storm Severity Index:

Improving Storm Readiness through Severity and Social Impact Forecasting

Nurture Nature Center:
Rachel Hogan Carr (PI), Dr. Kathryn Semmens, Keri Maxfield

East Carolina University Professor Emeritus:
Dr. Burrell Montz (co-PI)

Potential Winter Storm Impacts

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Contents

Partners

NOAA Weather Prediction Center:
Dr. Joshua Kastman, James Nelson, Dr. Kirstin Harnos, Dr. Dana Tobin (CIRES)

NWS Weather Forecast Offices:
Grand Rapids, MI - Daniel Cobb, James Maczko, Walt Felver, Brandon Hoving
Omaha, NE - Suzanne Fortin, Brian Smith, Brian Barjenbruch, Cathy Zapotocny
Boulder, CO - Jennifer Stark, Paul Schlatter, Gregory Hanson
Boston, MA - Andy Nash, Rodney Chai, Andrew Loconto
Jackson, MS - Chad Entremont, Eric Carpenter, Thomas Winesett
San Joaquin/Hanford, CA - Kristian Mattarochia, William South

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List of Figures and Tables

FIGURES

TABLES

Executive Summary

Communicating the threat of severe winter weather goes beyond just amounts of snow or ice accumulation or how cold the temperature will be - an understanding of the impacts of winter weather conditions is also important. The Winter Storm Severity Index (WSSI) is a product from the National Weather Service's Weather Prediction Center (WPC) that presents anticipated impacts from forecasted winter weather for a range of winter conditions in a graphical format. To assess the utility of the WSSI and how an impact-based winter weather forecast product is interpreted and used to inform decision-making, a mixed-methods social science study was conducted by the Nurture Nature Center in coordination with the WPC from 2020-2022. The study included focus groups and surveys across three rounds in six Weather Forecast Office areas: Grand Rapids, MI; San Joaquin/Hanford, CA; Jackson, MS; Boston, MA; Omaha, NE; Boulder, CO. Two-hour focus groups were held with professional stakeholders including emergency managers, municipal officials, water resource professionals and transportation representatives. Also included were virtual focus groups for forecasters throughout the CONUS, industry-specific groups, and with personnel from WPC and NWS Headquarters. The focus group and survey analyses informed several iterations on design and impact category descriptions which were tested in subsequent rounds. In addition, variations of the WSSI product recommendations were tested in the WPC's Hydrometeorology Testbed.

From these analyses, the project team developed recommendations for WSSI design. In addition, several themes emerged about how professional stakeholders understand, interpret, and use the WSSI product for communicating about impending winter weather. Overall, there is perceived utility in the WSSI for situational awareness and value in having the product as part of a package of other information to inform decision-making. While reception of the WSSI was generally strong and positive across most regions and groups tested, additional context was often required to clearly communicate the severity of impacts. Specifically, there was variability in interpretations of impacts, resulting from differences in geography, community readiness and experience, among other factors, which can create complications in communicating the forecast. Further, many users wanted specific quantities of snow and ice, suggesting that education about what impact-based products include and what data is shown is necessary.

Overall, there is perceived utility in the WSSI for situational awareness and value in having the product as part of a package of other information to inform decision-making.

It is recommended that the WSSI be incorporated and described through emergency briefings from WFOs directly to users, especially during its initial years of use as the product is refined and incorporated into decision-making processes. Through briefings, WFOs can address the other stated needs of users, such as quantities for snow and ice amounts, and also can explain the ways in which the WSSI accounts for regional climatological as well as non-climatological factors, such as population density and land use. Inclusion of a Forecasters' Note is highly recommended to help clarify which of the components is driving the impact levels, and to link to other useful information, such as active watches or warnings that may be in effect.

The introduction of an impact-based product presents a new model for winter weather forecast communication. In this study, the process of iterative testing, revision, retesting - and notably, testing in the Hydrometeorology Testbed - produced an evolving understanding of how users can and should best receive impact-based winter storm information. But this project represents just the beginning of the learning in this regard, and continued user testing as the product evolves will be important. Specifically, any forthcoming revisions to legend language should be user-tested to avoid unintended confusion or loss of clarity, and WFOs should continue to identify needs through feedback from stakeholders regarding communication of the WSSI through briefings or other communications. Understanding the factors that influence perspectives on impact levels, and the variable needs for winter weather information across regions, improves forecasters' abilities to effectively communicate and provide critical information that helps end users prepare for severe winter weather.

Introduction

Winter storms present one of the largest weather hazards in the United States, causing tremendous financial damage, disruption to services, and often, loss of life and property. Along with public audiences, professional users of National Weather Service (NWS) products, including emergency managers, transportation departments, utilities, hospitals, schools, and aviation partners, need timely and accurate information about when and where a winter storm may hit. But forecasting winter storms is a complex process involving a range of critical impacts, which can occur at different levels and spatial distributions within a single storm event. As Montz et al. (2015) point out, "Gaps or incomplete information connecting hazards to operations can lead to inadequate understanding of evolving risk and diminished support for decision-making." A shift in NWS forecasting to Impact-Based Decision Support (IDSS) and impact-based warnings (IBWs) undergirds efforts to consider how to better design forecast tools for winter storms to meet the varied needs of these users, and effectively tell the story of the probable threats a winter storm may bring to a location. The Winter Storm Severity Index (WSSI) is an emerging product from this effort and is designed to meet the need for high-level notice of the severity and range of potential impacts from an impending winter weather event.

Much of the research on IDSS centers on IBWs, and although WSSI is not a warning in the technical sense, it is similar in that it presents anticipated impacts from a forecasted storm. Thus, it is important to look at what has been learned from previous work on IBWs to put this work on WSSI in context. While it has been asserted that including specific impacts of an event in a warning may lead to more appropriate responses by those receiving the IBW (Casteel, 2016; 2018; Weyrich et al., 2018; World Meteorological Organization, 2015), others have found either no effect or mixed results (see Potter et al., 2018 and Ripberger et al., 2015 for examples). However, these studies address public responses to IBWs. Studies that focus on perspectives of emergency managers and other professionals have reported on the benefits of IBWs, including among others, "added awareness of antecedent conditions and cascading hazards" (Potter et al., 2021), a focus on the information (impacts, not amounts) that resonates with the decisions emergency managers make (Kox et al., 2018), and providing more insight into what forecasters are thinking (Galluppi et al., 2013). Of course, there are also challenges with IBWs as there are with all forms of risk communication, including how to meet the different needs of target audiences, what impact thresholds are appropriate, and how much information to include (Morss et al., 2016; 2018; Potter et al., 2018; 2021; Ripberger, 2015).

Studies on IBWs provide important background for understanding the use and effectiveness of WSSI, but none of the studies above are focused on winter weather. Further, IBWs are primarily text-based messages while WSSI is a graphical representation. Graphics, in this case maps, have been found to be effective means of presenting hazards because, among other aspects, they indicate who needs to take protective action without requiring familiarity with the language in text products, thus leading to greater personalization of the risk (Bean et al., 2015; Dallo et al., 2020). However, in addition to the challenges noted above with IBWs, all of which also apply to WSSI, a graphical product presents additional challenges relating to design considerations in presenting impacts as well as presenting effective text in legends. For example, two studies found that forecasts that are solely graphical can lead to inaccurate interpretations (Broad et al., 2007; Savelli and Joslyn, 2013). Graphical products may not convey information that is understandable to recipients so that they are motivated to act (Hogan Carr et al., 2016a). Thus, design factors, including the use of color have been shown to help people "…make sense of the information being conveyed" (Hogan Carr et al., 2016b). Further, accompanying text information, particularly in map legends, is critical to provide explanation and detail.

Given that the one of the goals of WSSI is "to enhance communication to external partners, media, and the general public of the expected severity of potential societal impacts due to expected winter hazards and their distribution" (Weather Prediction Center, 2020), it is important to evaluate what is needed to make the WSSI most effective in achieving its goals. To that end, the research objectives of this project are to:

- Ensure that product display, including components (i.e., legends, colors, titles and other design elements), is clear and communicates the appropriate information;
- Determine if there should be additional components;
- Ensure that the product's definition of and categorization of impacts aligns with stakeholder expectations;
- Identify how users want to receive the information;
- Provide recommendations to address needs of professional stakeholder groups.

Conceptual framework: The proposed research is conceptually centered at the intersection of two models, one that recognizes the context in which decisions are made about actions to be taken with impending severe weather (Nichols and Hoekstra, 2011) and the other that addresses end-to-end-to-end research (Morss et al., 2005). There is a paucity of research that addresses users' needs for and use of winter weather forecasts (Sherman-Morris, 2013); much of what exists addresses decisions about school closings (see Call, 2010; Call and Coleman, 2012; and Montz et al., 2015 for examples), use of forecasts to manage transportation routes (see Ye et al., 2009 and Strong et al., 2010), and the impacts of uncertainty in warnings (see Drobot, 2007, Drobot et al., 2008, and LeClerc and Joslyn, 2015). Thus, it is imperative to build on work addressing other severe events to develop our conceptual framework.

Nichols and Hoekstra (2011) illustrate the factors that influence school district decision-making in the face of forecasts for severe weather (Figure 1), and Montz et al. (2015) adopted this model for their work on school closure decisions related to winter storms. Weather information is only part of the decision-making process, but it is the start of that process. Different decisions may well result from similar forecasts, given the other factors at play. However, the more trust users have in the forecasts, the more it will facilitate their decisions. Thus, this project is centered on the nature of the process that the forecast sets in motion for users with various responsibilities and therefore different utility of the products for that process. That is, what steps do decision-makers need to take in the face of winter weather, and how does the WSSI intersect with those steps to facilitate better decision-making?

Further, our research (Hogan Carr et al., 2016a, 2016b, 2018) and that of others (Morss et al., 2005) have shown the application of an iterative process wherein the scientists' (forecasters and modelers) products are tested with user groups (end-to-end) and the results fed back to the scientists for revision and subsequent testing (end-to-end-to-end). Integrating these models sets the framework for the work proposed here (Figure 2).

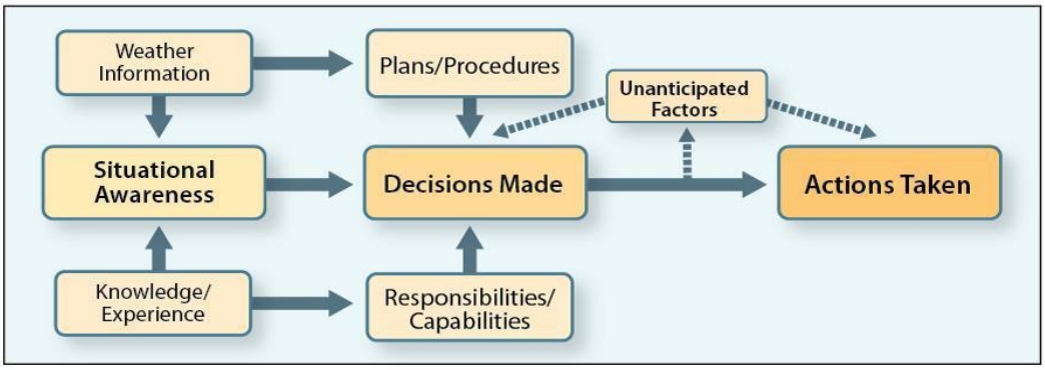

Figure 1. Model of the factors influencing decision making (Nichols and Hoekstra, 2011)

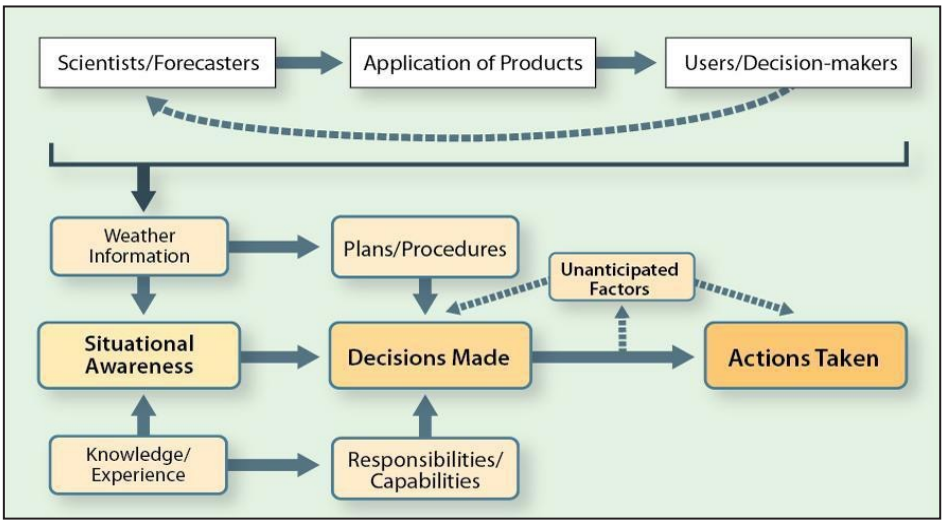

Figure 2. Conceptual Framework for Proposed Project

About WSSI and its needs for improvement: The WSSI has emerged in response to user needs for easily consumable forecast information that identifies the multiple impacts and relative severity of an impending storm. Initially conceived at the Burlington, VT Weather Forecast Office (WFO) as a local response to user needs, the WSSI was taken under development by the Weather Prediction Center (WPC), and the science behind the tool has continued to evolve. At the time of this report, the WSSI has been launched for 116 WFOs across the country, with encouraging feedback from stakeholder users to local offices. The WSSI uses Geographic Information Systems (GIS) and gridded forecasts from the NWS National Digital Forecast Database (NDFD) to identify winter weather elements. It combines those data with non-meteorological or static information datasets (climatology, land-use, and urban areas, for instance) and results in a graphical depiction of impacts from winter weather. WSSI breaks down a storm into six components: Snow Accumulation, Ice Accumulation, Snow Load, Blowing Snow, Ground Blizzard, and Flash Freeze. Each of these components presents a different hazard, and in many cases, creates impacts specific to different users and partners. For instance, transportation related users need to understand where to anticipate ice accumulation and blowing snow to safely prepare for travel conditions. Snow load will be critical for emergency managers, who may need to prepare for extended power outages, necessitating planning for emergency shelters. Ground blizzards combine snow with very strong winds to create hazardous conditions which present significant impacts for the transportation sector. Flash freeze creates urgent transportation considerations that are distinct from that of blowing snow, and which require a different planned response. Similarly, property owners need to be concerned about snow load affecting rooftops. WSSI articulates these distinct impacts for audiences with a 72-hour forecast window, and then scales the resulting forecast severity into five levels: extreme, major, moderate, minor, winter weather area (previously limited and none categories were included instead of winter weather area) (Figure 3). This scaling is designed to help users to quickly and easily look at the product and identify the anticipated or possible level of winter storm impacts.

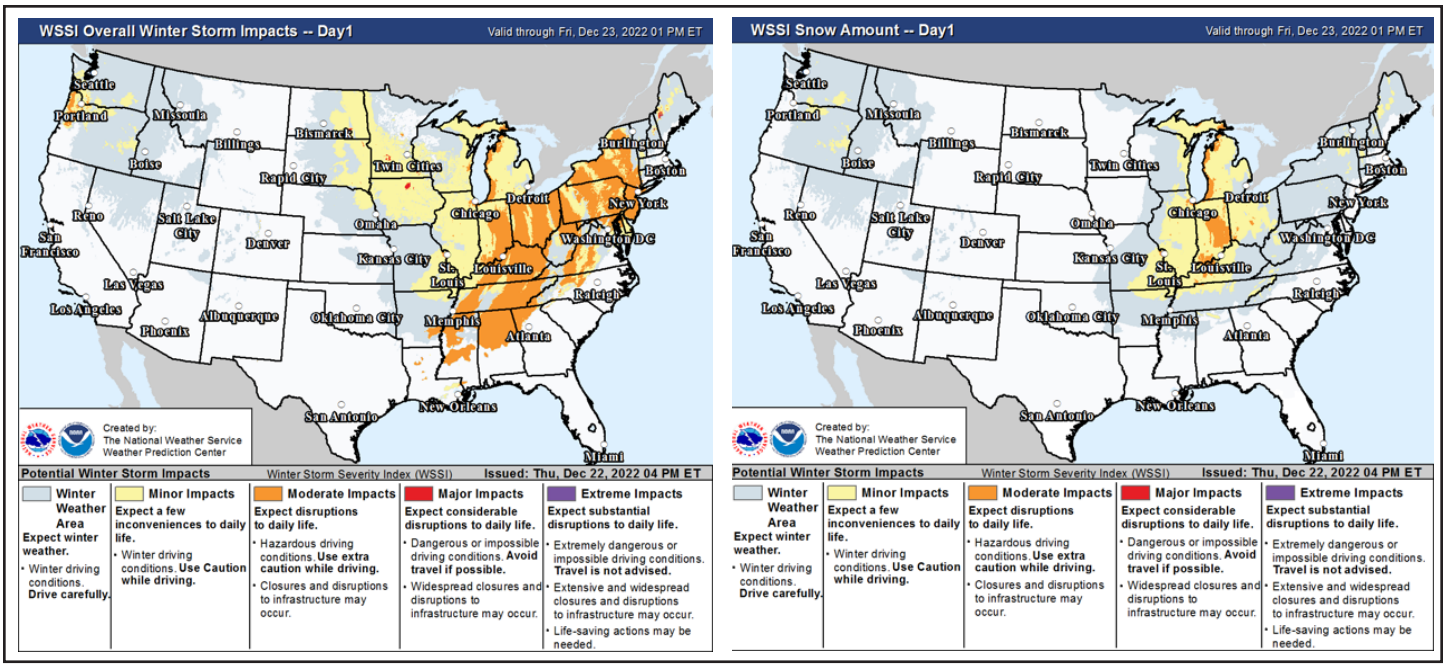

Figure 3. WSSI examples showing overall severity (left) and severity of an individual component, snow amount (right).

WSSI has two key audiences. First, it is intended to assist NWS operational forecasters in maintaining situational awareness of the possible significance of weather-related impacts and facilitate collaboration around such impacts across WFOs and national forecast centers. Second, the WSSI is designed to enhance communication to external professional partners of the expected severity (potential societal impacts) of winter weather and its spatial distribution.

A preliminary initial survey of the WSSI undertaken by the NWS resulted in positive feedback from users about the usefulness and quality of the data, with 95 percent of respondents supporting a national roll-out of the product. Feedback suggested that both the presence of a severity level and differentiation of the components of the storm helped users to make more informed decisions. However, the "shell" of the WSSI had not been studied to ensure that the presentation is appropriate, and no user-testing had been done to ensure that the WSSI is capturing the right mix of storm components or that it is adequately categorizing threats. Further, no testing had been done to determine how various users of the WSSI would interact with the product or to determine how information should be presented.

In this research study, the general hypotheses are formed from the initial survey results, product feedback to the WPC and WFOs, and prior work by the research team, and include:

- Professional stakeholders will have divergent needs for information across sectors – for example, emergency managers will emphasize certain storm components and timing needs, while those in transportation sectors will prioritize others;
- Professional stakeholders will prefer an interactive interface with user-selected parameters; and
- Both focus group and survey feedback from the professional survey respondents will provide clear direction about needed product modifications.

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Methodology

To collect feedback and provide revision recommendations for the WSSI, a mixed-methods research study was conducted to derive both quantitative and qualitative data from a range of professional users. Methods included two rounds of virtual focus groups in six diverse regions of the continental United States, pre and post focus group session surveys, a third round of testing via an online survey to all previous participants, and inclusion in the WPC's Hydrometeorology Testbed Winter Weather Experiment. Two-hour focus groups were held with professional stakeholders including emergency managers, municipal officials, water resource professionals and transportation representatives in six WFO areas: Grand Rapids, MI; San Joaquin/Hanford, CA; Jackson, MS; Boston, MA; Omaha, NE; Boulder, CO (Figure 4). Also included were a virtual focus group for forecasters throughout the CONUS (one in round one and one in Round Two), a virtual focus group with industry-specific groups (round one only), and a virtual focus group with personnel from WPC and NWS Headquarters (Round One only).

Figure 4. Locations of focus group audiences. WFO partners in each of these six areas assisted with developing scenarios used in focus groups.

The focus group discussions and surveys used products provided by each area's WFO as part of a scenario about a severe winter storm event relevant to each geographical area. In round one, the WSSI was the then current WSSI developed by WPC. In Round Two, the same scenarios were used but with revised, mocked-up WSSI graphics designed after incorporating survey and focus group feedback from Round One. In Round Three, the online survey did not use a scenario-based approach, but rather showed a further revised WSSI graphic and included specific questions about components and legend details in order to refine product design recommendations and wording.

For each focus group, participants were recruited through partnering WFOs who provided contacts with whom the research team connected. During each focus group session, participants completed a pre-session survey about winter storm experience, challenges, and demographic information. Specifically, the survey asked questions such as "what are the most significant community or social impacts of winter weather events in your area?," "how do you use and access NWS winter weather information?," and "if you learn a significant winter event is approaching, what do you typically do with that information?" Participants were then led through a winter storm scenario via a presentation including the WSSI as it is commonly used within the local WFO – i.e., as part of briefing packages or weekly partner emails – to test the current format and delivery (examples of these presentations are provided in Appendix A). The facilitator asked questions about the types of decisions the users make and how the users have or might engage with WSSI in their decision-making processes. Following the focus group discussion, participants completed a post-session survey asking for detailed feedback on the design of the products, as well as the ways they would share the information provided in the WSSI. Specific questions included "what is the biggest barrier you face in responding to and/or preparing for winter storm events?" and "what else would be important for us to know about how you gather information about winter weather risks and your intended actions?" Both the pre and post-session survey instruments, focus group transcripts and data are available at https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/H0NGXR.

Following the focus groups, survey responses were aggregated and analyzed, and focus group recordings were transcribed and content coded using NVivo software. For the additional focus groups organized around sector (rather than geography) including industry, forecasters, and WPC/NWS, the scenario included two regions (eastern and western US) and the full CONUS WSSI. Participants were asked to describe how the WSSI products were or could be used in decision-making and to describe the sorts of improvements to the product that would make them most helpful. These sessions were similarly surveyed, recorded and analyzed using NVivo software to identify key themes and trends in use, decision-making and recommendations across sectors.

Examples of the WSSI products used for Round One and Round Two in Boston are shown in Figure 5, along with details of the changes that were made between the two rounds. Scenarios started from two weeks to several days ahead of the target weather date, to incorporate the different regional contexts.

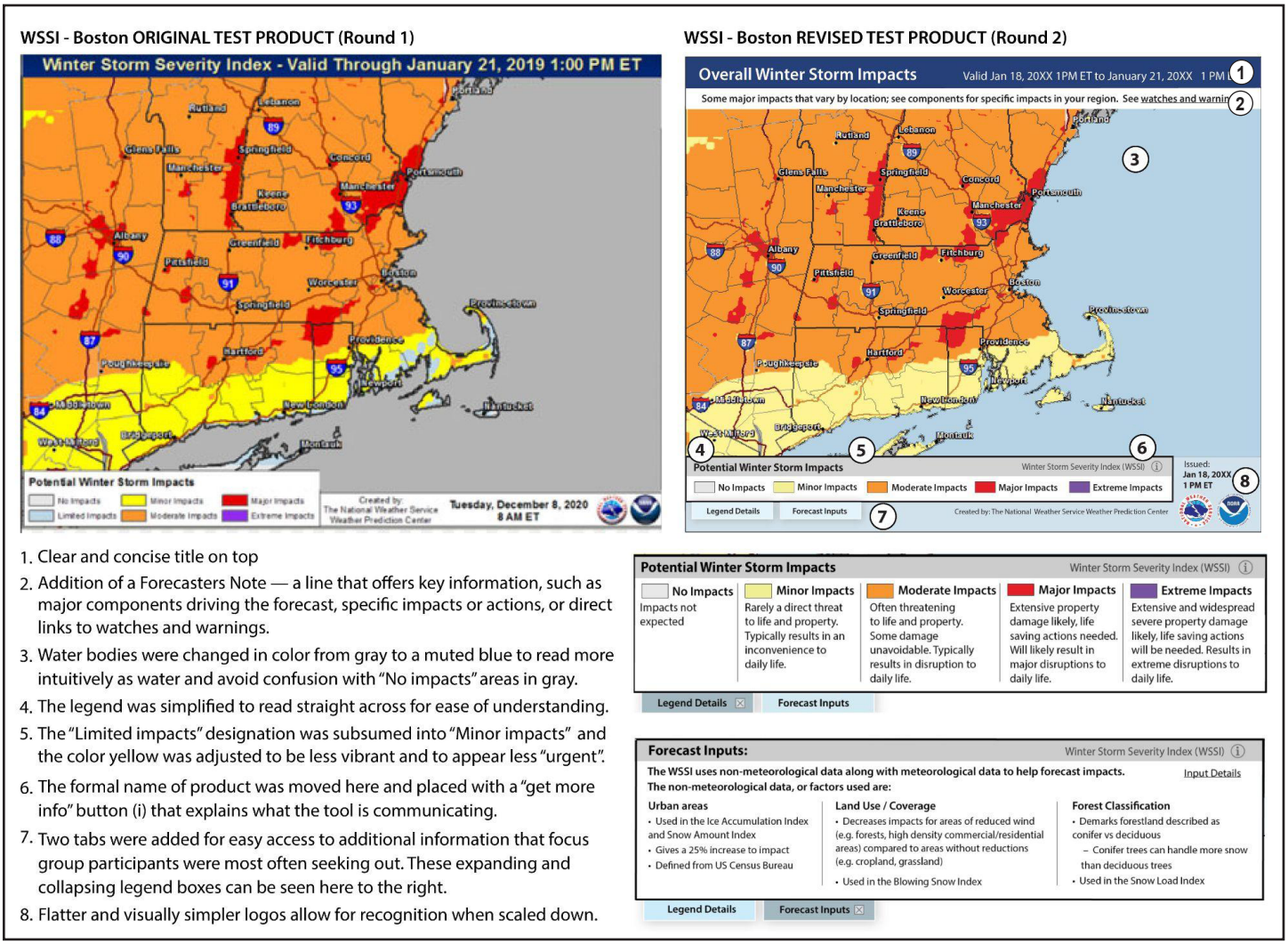


Figure 5. Example of WSSI product used in Boston, MA in Round One (left) and Round Two (right) with details of the changes between the two Rounds highlighted.

Following the analysis of Round Two survey results and focus groups, further refinement of the product design and recommendations were tested with forecasters in the WPC's Hydrometeorology Testbed. A discussion about the utility of the product for forecasters' use and a brief survey were collected. Then a virtual survey was administered (Round Three) to ask previous focus group participants about specific elements and options related to the legend and components (Figure 6). Throughout the process, the research team provided interim findings and recommendations and debriefed with the WPC team which led to the implementation of some recommendations, including changes to the legend descriptions, number of legend categories, title, and other graphic design changes. The transition to operations is ongoing, and the iterative nature of this research highlights the value and effectiveness of collaboration.

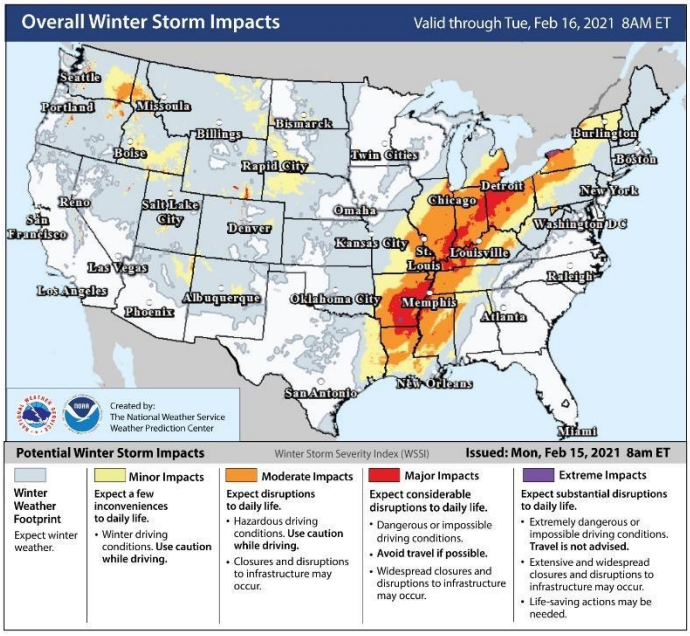


Figure 6. Example of the product tested in the Round Three online survey.

Results

Surveys

Focus group participants were asked to complete a pre- and post-session survey in each round, and all participants were asked to complete an online survey in Round Three. Participation rates are noted in Table 1. Detailed demographics are included in Appendix B. The additional focus groups for industry, forecasters, and WPC, are not included in the analysis here due to their specialized perspectives, but their feedback was considered by the research team in determining redesign options.

Table 1.
Number of participants in the surveys for each Round by location.

	Round One	Round Two	Round Three
Boston, MA	8	6	6
Boulder, CO	8	6	6
Grand Rapids, MI	13	8	13
Hanford, CA	9	5	8
Jackson, MS	9	4	7
Omaha, NE	6	3	4

Across all sites the winter weather impact of most concern related to travel disruptions with 62% mentioning travel in Round One and 39% in Round Two. Power outages was the second most mentioned impact (31% in Round One and 13% in Round Two), followed by school (6% in Round One; 9% in Round Two) and business disruptions (12% in Round One; 7% in Round Two). Barriers to responding to winter storms included unpredictable weather, the timing of storms, lack of confidence in forecasts, accuracy in forecasts/uncertainty, and limited resources.

Focus group participants had a range of familiarity with the WSSI (Figure 7) with Round One having 23% not familiar and 12% using it regularly and Round Two having 22% not familiar and 22% using it regularly.

The perceived usefulness of the WSSI product varied by region (Figure 8) with some such as Jackson seeing less usefulness, and others like Boulder and Omaha finding high utility. Boston, Grand Rapids and Omaha all had higher perceived usefulness in Round Two compared to Round One. These high levels of usefulness across sites, and the increase in usefulness from Round One to Round Two support the effectiveness of design modifications in improving the utility and understandability of the product. Jackson had lower levels of utility for the product in part due to skepticism of forecasting winter weather in the area. Comments relating to needing more time with the product and a desire to

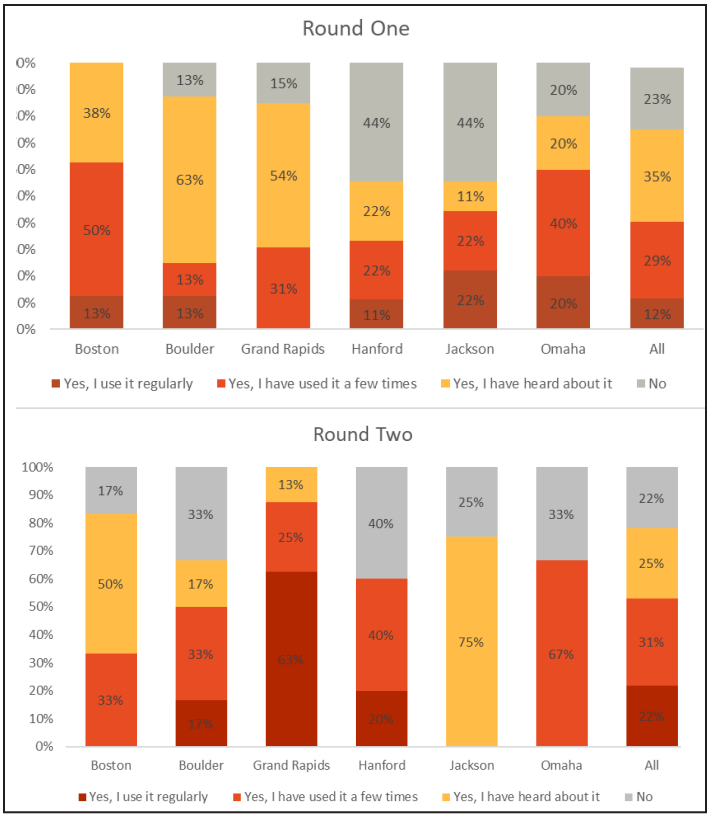


Figure 7. Focus group participants' level of familiarity with the WSSI reported in pre-session surveys for Round One (top) and Round Two (bottom). Each location is reported along with a summary of all locations (far right column in each graph).

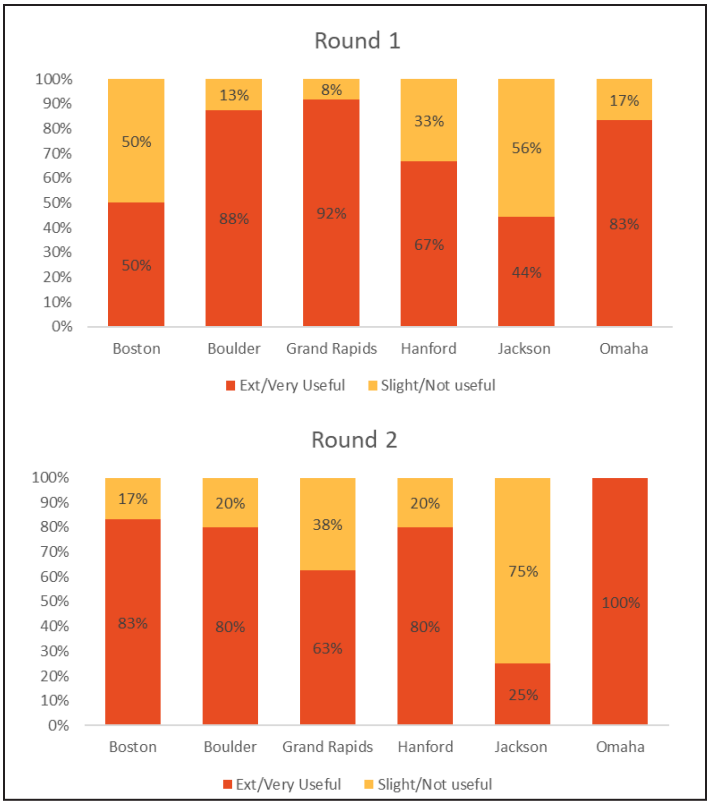


Figure 8. Usefulness of the WSSI reported in post-session surveys across all locations in Round One (top) and Round Two (bottom).

'ground-truth' suggest an openness to using the product even with initial low confidence. See the discussion of focus group findings for more details.

To look at the usefulness perceptions by level of familiarity with the WSSI, we plotted the percentage of respondents in each location who stated the WSSI was useful by the percentage in that location who were not familiar with the WSSI (Figure 9). There was a lower percentage of Round One participants reporting usefulness even when they had familiarity with the product (yellow dots on the left side of the graph) compared to Round Two. Comparing Round One and Round Two participants with less familiarity of WSSI (red and yellow dots on the right side of the graph), Round Two had a higher percentage of respondents who found WSSI useful. This could be due, in part, to the design changes and legend modifications that led to the improvement in the usefulness of the WSSI. The lowest dot (red dot at 25% usefulness) is from Jackson, MS in Round Two.

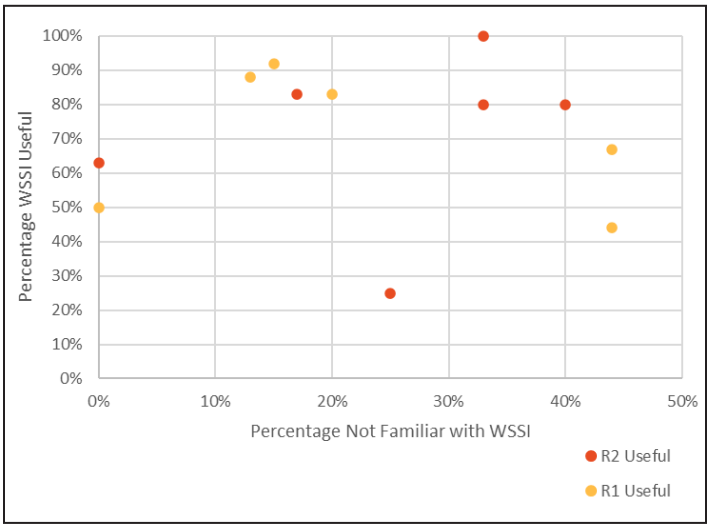


Figure 9. Percentage of respondents who felt the WSSI was useful by level of familiarity and Round.

In the post-session survey, participants in each location were also asked about the usefulness of the other products shown in the focus group scenario alongside the WSSI. Each scenario was customized to the location, so the number and type of products vary, but the following graphs show the relative usefulness of the WSSI compared to the other products presented to the focus group participants. For instance, in Boston, no one rated the WSSI as extremely useful in Round One while all other products had at least some responses of extremely useful. By Round Two, 50% in Boston said the WSSI was extremely useful (Figure 10). In Hanford, CA, the percentage stating WSSI was extremely useful went from 11% in Round One to 40% in Round Two while the WSSI components went from 0% to 80% (Figure 15).

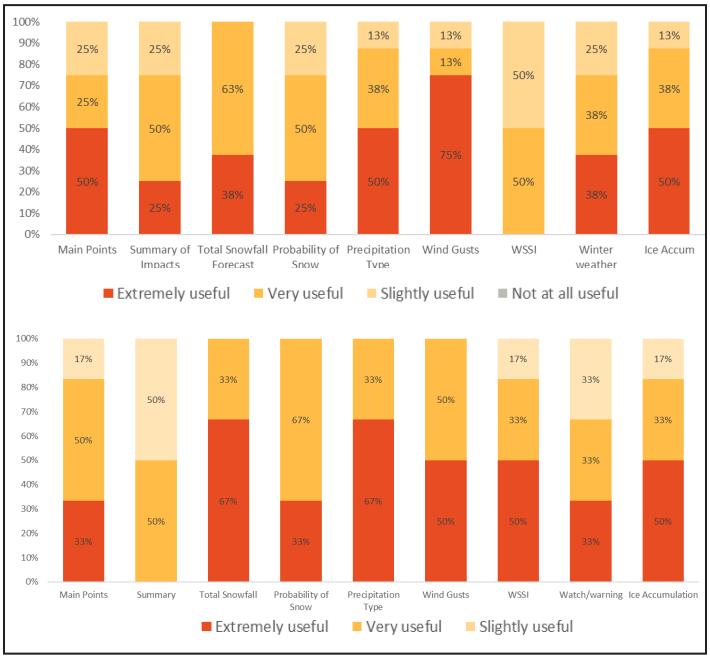


Figure 10. Usefulness of products shown in the Boston, MA focus group scenarios for Round One (top) and Round Two (bottom).

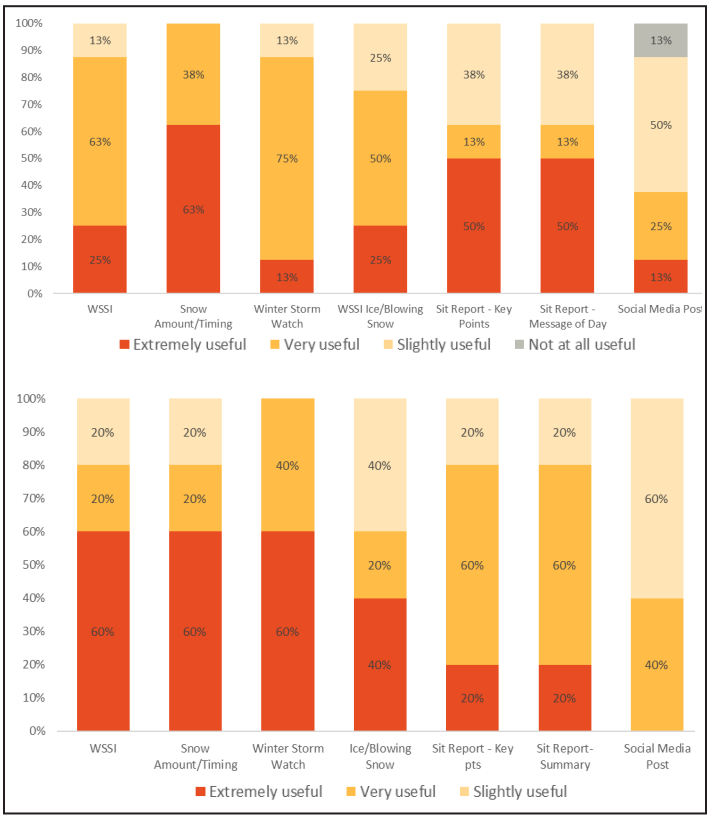


Figure 11. Usefulness of products shown in the Boulder, CO focus group scenarios for Round One (top) and Round Two (bottom).

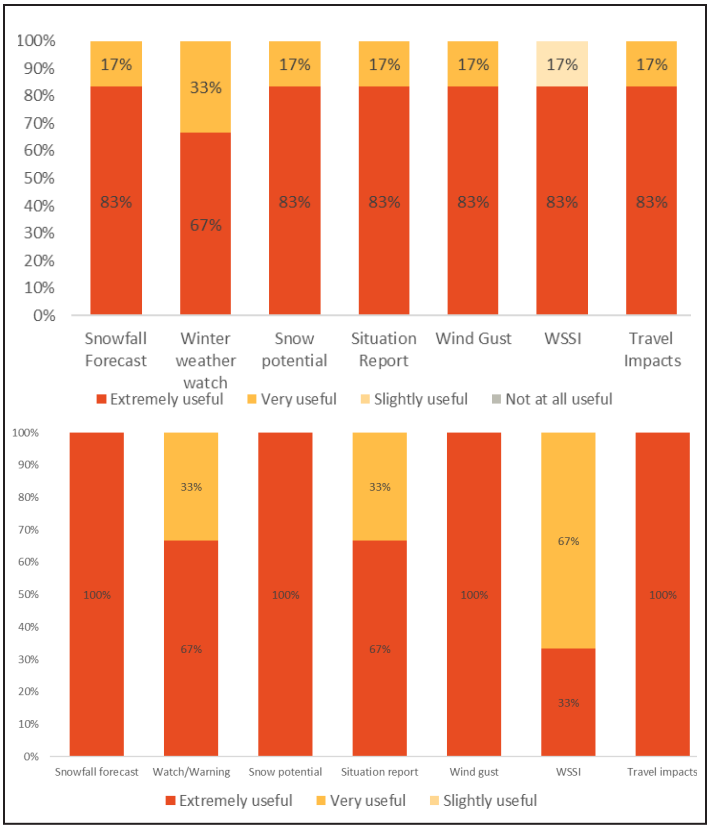


Figure 12. Usefulness of products shown in the Omaha, NE focus group scenarios for Round One (top) and Round Two (bottom).

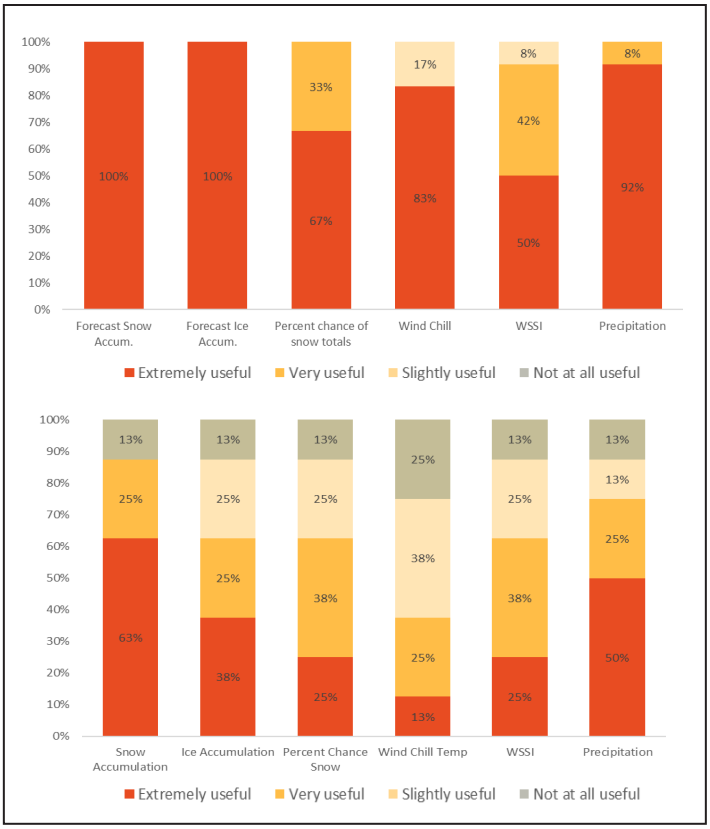


Figure 14. Usefulness of products shown in the Jackson, MS focus group scenarios for Round One (top) and Round Two (bottom).

Figure 13. Usefulness of products shown in the Grand Rapids, MI focus group scenarios for Round One (top) and Round Two (bottom).

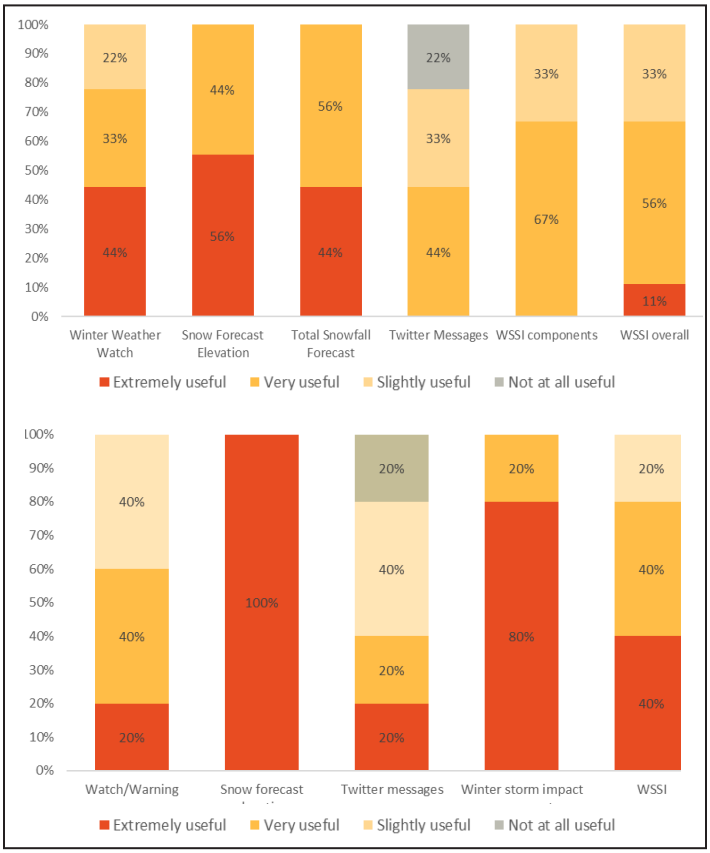


Figure 15. Usefulness of products shown in the Hanford, CA focus group scenarios for Round One (top) and Round Two (bottom).

To help inform redesign considerations, the participants were also asked about the usefulness of WSSI product elements. These elements included each of the six components, the legend, title, map overlays, ability to download, static images, and Forecaster's Note. In both rounds, snow amount (87% Round One; 69% Round Two), ice accumulation (73% Round One; 67% Round Two), and the legend (81% Round One; 64% Round Two) were the three elements ranked the highest, followed by overall impact map (71% Round One; 50% Round Two), map overlays (65% Round One; 61% Round Two) and interactivity (58% Round One; 51% Round Two). Participants were also asked about elements that were not useful. In Round One, ground blizzard (31%), flash freeze (29%), and snow load (29%) were the top elements perceived to be less useful. In Round Two, ground blizzard was removed, and a wind chill product was mocked up instead. As a result, the elements reported as least useful were snow load (28%), flash freeze (22%), and the legend (19%). For rankings of all elements tested, please see Appendix B.

In addition, participants provided written comments related to recommendations for legend changes including, importantly, having more about travel and less about property damage. Survey responses further indicated that a combination of a static product and interactive interface was preferred by a majority of all participants across all sites for both Round One and Round Two. A product that combined text and graphics was preferred (as opposed to just graphics or just text) by almost all participants across all sites and rounds.

A majority of respondents reported that following the focus groups they would recommend the WSSI to other partners, would use the WSSI in decision-making, would seek NWS information about severe winter weather, and would share what they learned with others. One exception was participants in Jackson in Round Two who reported that they were unlikely to recommend WSSI to other partners (75%) or use the WSSI in decision-making (50%). This may reflect the fact that winter weather is not as prominent a concern in this location or skepticism about whether the index can effectively capture impacts for the region.

In both rounds, snow amount (87% Round One; 69% Round Two), ice accumulation (73% Round One; 67% Round Two), and the legend (81% Round One; 64% Round Two) were the three elements ranked the highest.

Focus Groups

As described earlier, focus group participants were led through scenarios where WSSI was included in briefings or other communications WFOs would typically disseminate with an impending event. Because WSSI is a national product, discussion below centers on overall findings about the product's design, components, and information provided for each round, specifically addressing the project objectives presented earlier. Following that, regional differences are presented.

Round One

Product display. Overall, participants thought the WSSI provided good situational awareness. Several mentioned that it provides a heads-up for planning a response. For instance, one participant said "… knowing that this is the weather impacts specifically, and that we can then make it a layer in our own Emergency Operations Center (EOC and add site specific or area specific information on top of that is really helpful for that full picture." WSSI, along with other products, help professionals understand the situation and disseminate that information, as needed. Participants noted that the WSSI is helpful in planning and determining what resources and staffing might be needed where, as well as decisions related to closures.

Despite the utility of the product expressed by many participants, there was some confusion in interpreting the maps. One element of this is the need for more clarity in product titles. The title, WSSI Overall Component, was not readily understood, with one participant asking "What's a WSSI?" and others questioning the use of the word Component. There was a suggestion that the word Component be replaced by Impact, arguing that "Since everything is impact-based everywhere else, I'm not sure what component means." It was also noted that it is not clear that the overall map is a combination of the six components, "… so, if I saw this, without any other context I would go OK, is that the heaviest snow, is that heaviest ice, is this blowing snow, what is this telling me?" In addition to the title of the overall map, titles of some components, such as Ice Accumulation and Snow Amount, caused a number of participants to assume that quantities would be linked to the legend categories "…because you see the word amount and you're immediately searching for totals." This and similar comments made across focus groups illustrate an apparent misunderstanding among some professionals of the impact-based purpose of the product.

Discussion of the legend categories ranged from the colors used to how the levels of impact are differentiated. The colors were seen to be effective as referenced in comments like "I like the colors, they make sense. I think a lot of people understand them" and "I'm a fan of the color scheme. I know there's some color schemes that are used that can imply the wrong you know intensities and stuff, but it is a pretty good color scheme." At the same time, participants did not necessarily understand the differences among the categories in the legend. Without explanations or definitions of the categories beyond the level provided (limited, minor, moderate, etc.), there was often difficulty sorting out the extent of potential impacts: "I think they just generally want to know more about what these different colors mean because the descriptions that you have there in the scale are kind of generalized." It was also noted that "…we're trying to condense all these sort of effects and categorize them into one or, one small things, but there's a lot happening there." Comments like these call for greater detail on the legend on each map.

Existing and Additional Components. Consideration in the focus groups was given to the six components that make up the WSSI as well as additional components that would be helpful to the professionals. When asked if the components are useful to decision-making, and which are particularly important, one participant in the industry focus group said, "We use just about everything that's offered, you know, just to make the best business decisions for our drivers that are out on the road." For others, while the six components as well as the overall are used, the relative utility of the components varies. As an example, flash freeze is very important to professionals concerned with transportation while blowing snow and blizzards are of particular concern to those in agriculture. One professional remarked with respect to blowing snow, "one of our biggest components … would be the use of this in terms of visibility." Yet, some participants wondered what the difference was between blowing snow and ground blizzard and exactly what is considered in snow load, suggesting the need for more information about each component to improve clarity, not just with detailed definitions but also the factors that are taken into consideration in determining the impacts of each. A professional from Jackson summed it up nicely: "One thing I had wondered about with looking at this website is, you

know, some of these terms we're not going to be very familiar with down here like snow load. It makes sense as to what it was after you explained it, but it's not something that's like intuitive. And so there's the very quick and dirty definitions that are there at the top, but even then, it's still pretty baseless. It, there's not a whole lot there and so like I need to know what a flash freeze is. What does that look like? What does that feel like? You know how is that going to impact me? I don't need a paragraph, but I need to know like you know water on surfaces could, could freeze within an hour, that bridges will become suddenly icy, you know something like that. Just I feel a little lost because I'm not used to these snow terms."

In all of the focus groups, there were comments about other impacts of winter weather that are important to their decision-making. Two that were mentioned consistently were temperatures and wind. With respect to the former, one professional pointed out that a couple of degrees of temperature change up or down can have a huge impact on decisions that need to be made regarding such important activities as road treatment and snow removal. It was recognized that wind also plays into this, a requested component that cut across focus groups as illustrated by "… it would be a useful tool and save us a couple of steps if wind speeds, temperatures, and wind chills were also included." Besides the impacts of wind chill, the impact of wind on visibility was also mentioned as being of great importance to their decisions and actions. Further, wind direction makes a difference in some regions.

Although not a component, another need that was expressed was that of timing. It matters when the impacts are going to occur because, as the professionals noted, impacts will vary at different times, so the nature and timing of their decisions will need to reflect that. An obvious example is rush hour versus later in the day or overnight, pointing out the importance of being able to track the impacts in smaller time increments than the three, two, and one day maps available when Round One was undertaken.

Another request relating to the existing components was for historic information. As one asked, "what about archival data somewhere giving the link to the last three, one to three storms with similar forecasts in the actual impacts from previous storms?" Several stated that such information allows them to put the impacts that are forecast into perspective because it would provide something to which they can relate the current event.

Definition and Categorization of Impacts. A topic of particular importance in the focus groups was the categories used in the legend to differentiate impacts within each component as well as the definitions of each category. In all but one focus group, only the categories were shown with no explanation. As a result, participants had a difficult time understanding the difference among the categories, an example being "… that just might be my lack of use of this product, but like I, I don't know, I don't know what minor, moderate, major, extreme what the breakdown of that is." Another participant asked "What's the difference between limited and minor? It seems like it's the same to me." And others questioned why the limited category is even needed. As one professional said, "For me, it's just too general. It's just, it's not specific enough."

There were discussions about the relative nature of the terms used, recognizing that what is minor to one person may be major to another. Again, without definitions of how the categories are determined, one participant asked "what is it that makes it minor impacts or moderate impacts? For me to try to understand it and then effectively communicate it, I want more information, so I can know what I'm looking at and that'll help me better explain it to partners." In general, there was an expressed need for specific information on what leads to an impact being categorized as, for example, major or extreme.

Once the factors that are included in the calculations were explained, discussion centered on the drivers of the categorizations, particularly, the non-meteorological drivers and their relevance to the responsibilities of the professionals in the focus groups. Two issues stood out: the incorporation of population in the categorization and the use of major or extreme at high elevations. There was a difference of opinions about the use of population as an input to the impact levels, reflecting the varying responsibilities of the professionals in the focus groups. On one side were those who thought "If people don't live there or there isn't important infrastructure there … how can you have an extreme impact?" On the other hand, "You know for the people in those smaller areas I mean the impacts are going to be the same for them, so I don't think we need to classify things differently just because it won't affect as many people." The issue of population density at high elevations led to some discussion. One professional noted that at high elevations that are mostly unpopulated, it might be useful for some components to "cap it at a certain impact level

or a certain threshold, like it wouldn't be above a minor or moderate threshold … because it's just snow." On the other hand, infrastructure is still affected, so there are concerns that this needs to be reflected in the impact level so that professionals can determine resource needs. The discussions around these factors illustrate the different needs and concerns both of the varying roles of the professionals who participated in the focus groups and of the varying geographies represented.

Preferences for Receiving the WSSI. Across focus groups, professionals liked the interactivity available on the website, particularly the ability to zoom in to an area and to download the maps as well as the data. Having the static maps for briefings and other presentations is important, but so too is the interactivity to be able to understand more clearly what is forecast when. The importance of the three-day notice was mentioned, giving the professionals lead time to help with staffing and other resource considerations. However, there was also a need expressed for smaller time increments, because as noted by one participant, it makes a difference if icing is going to occur overnight or during rush hour. Thus, while three days out provides an important heads up, rolling time periods (6 or 12 hours) as the event progresses provide the professionals with the ability to track the forecasted impacts spatially.

Round Two

Based on the survey results and the focus group discussions, revisions were made to the WSSI for use in the second round of focus groups. The changes can be seen in Figure 5, including a title change, deletion of the limited category, muting of the color for the minor category, a Forecaster's Note, and clickable tabs to provide legend details and forecast inputs. Definitions of the categories were also changed. Finally, an information icon was added allowing users to hover and see descriptions of the components (see Figure 16 for snow amount used in the Hanford focus group).

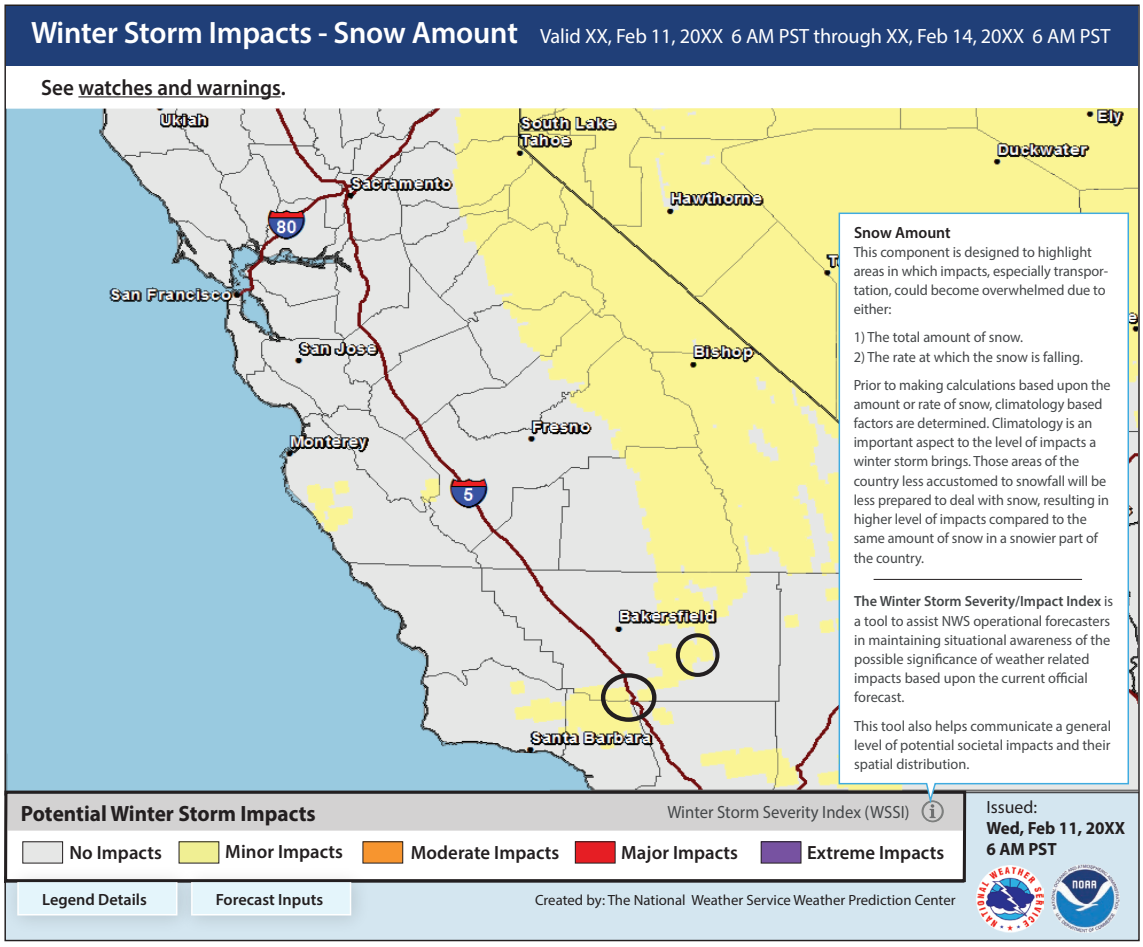


Figure 16. Information icon with pop-up window that gives the component description.

Product display. Overall, the revised WSSI was seen as quite useful, at least as a starting point, for the professionals in the focus groups. "It's a really just quick way to aggregate a lot of information and a lot of atmospheric properties into one map and kind of convey risk." And it was noted that the information provided helps the professionals make decisions about the scale and locations of the resources that may be needed.

While the title changes led to less discussion, suggesting that the new titles are less problematic, it still was not understood in some focus groups that the overall map is a composite of the six components, and that one component might well be an important part of the overall Winter Storm Severity Index and others less so. The Forecaster's Note was seen as very useful to address this because of the additional information provided, whether it presented the major contributor to the overall severity or, on the individual component maps, the anticipated level and type of impacts forecasted. At the same time, many noted that they did not even notice the Forecaster's Note until directed to it. As one professional said, echoed by many, "It's kind of hidden. Yes, the information is there, but that's a pretty important piece of information that I think should be highlighted." Further, as part of the Forecaster's Note, clickable links to watches and warnings were added, an option that was seen to present challenges when shared in a static document if the source product is not provided.

Participants were quite positive about the clickable tabs that provide more information. As one stated, "It doesn't complicate the map for those who just want to see visually the impact, but if you do have folks who may be preparing a more detailed report or those who are really interested in wanting to know more, that option is there. So it's nice to have available for those who need to access it, but it doesn't take away from the overall objective of the document or the map." It was acknowledged that most of the information provided would be very helpful to professionals, but there was some concern about its utility to executive decision makers in an organization, or the general public, suggesting that they are not likely to click on the tabs. As before, however, there remained an expressed need for quantities: "…why not tell me the amount of snow that we're going to get, rather than say minor or, or, or moderate? Tell me we're gonna get two to four inches or we're gonna get one to three inches, not just a color coded graph." This and similar statements continue to reflect the need for greater clarity and/or education about this impact-based product.

Existing and Additional Components. As in Round One, the utility of the components as well as that of the overall map was mentioned. As one professional said, "I think having the individual components is helpful just because when I'm explaining to my management team that's trying to make a decision on whether to delay school or shut down for a day or two, the more info they have the better …. So the more data I can present, the better." Further, providing the clickable tabs that provide pop-ups describing what comprises each component was found to be very helpful as there were few questions in the focus groups about those details, supporting the importance of that information.

Because in Round One wind and temperatures were mentioned a number of times as needed components, a wind chill impact map was introduced in Round Two. Some participants saw this as an important addition, as evidenced by statements like "Yeah, we definitely need any wind chill data, timing, severity…. I think it also helps us interpret sort of, you know icing and snow, and you know if the wind chill, if it might affect you know the heavy wet snow or accumulation that's already there. So yeah, it's an integral part of how we try and interpret or forecast storms and our response." The importance of wind chill information to decision-making was emphasized by one school official who noted that it is critical to their discussions about delaying or closing, and another professional who said he would use the information to keep their people who are in the field safe. Yet, not all agreed on the helpfulness of the wind chill impact map with one professional questioning what sort of damage wind chill has on property and others saying that they need to see numbers rather than categories of impact. Some thought it would be helpful, "…but in combination with at least an approximation of what the temperatures would be."

Timing of impacts remained a concern, whether time of day or on a weekend or weekday, because of how that affects various responders' operations. There was an appreciation for the 24-hour rolling display in 6 hour increments. "Certain decision-making points happen at certain times, so for us I mean 24 hours and at least 12 hours prior. I mean by the time we're six hours before, we're already moving into what we need to do with stuff as far as staffing and planning…. So I think it would be a useful tool." Professionals in other positions requested more temporal detail: "I think there's still issues that we've talked about in terms of explaining some of the timing or onset, or closeout that would either have to be conveyed in some way because

I know that would be a question I would still want to ask or know would come up and want to sort of proactively answer when sharing this kind of information out to folks." In these situations, it matters to decision-making what impacts are forecast to happen within the 6 hour intervals and not just between them.

Definition and Categorization of Impacts. The clickable tab for legend descriptions was seen by most as very helpful, resulting in less discussion about the difference between categories than occurred in Round One, with comments that it is a "good, general tool" providing a way to start understanding the situation. Having said that, there was concern again that what is minor, moderate, and major, for instance, is relative such that a "…moderate impact may be more severe depending on where it is" and "…it can't be complete unless it's layered upon local impact."

The minor category generated a great deal of discussion, with suggestions that it could generate a false sense of security. Specifically, it was noted that, while the impacts might not be a direct threat to life and property, it is not clear what the impacts are besides inconvenience. Further, those that might occur could be more than minor, because, for instance, "…we know that poorly timed minor conditions can cause a real pile up." And location makes a difference: "…if Southern Mississippi receives a fourth inch of snow, I guarantee it's gonna be a direct threat to life and property." One participant worried that if she communicated minor to her "higher ups", they would only consider basic preparedness and not worry about the potential for moderate or major impacts.

The extreme category also generated discussion. One participant said "I think this would be a terrifying map to look at. … I got an extreme impact right next door to us, so I would definitely start, well, probably already making calls," while a professional in the Grand Rapids focus group said "The extreme should only be multi-day, multi, you know, up to a week impact. It should never be used except for the most extreme events." The extreme category definitely draws attention, but the comments also indicate that the professionals want more specific definitions of what the impacts for each category are, similar to what came out of the Round One focus groups. As one put it, "I would expect OK, it's going to be really really bad in certain areas or circumstances, but why? It doesn't say why, what's causing it." A number of participants asked for examples of the kinds of impacts one might expect in each category with some requesting specific transportation impacts or impacts to power, while others suggested providing examples of potential property damage.

The clickable tab for forecast inputs was appreciated by the focus group participants, but there was some discussion as to how helpful it is beyond the needs of the professionals and if it might be confusing in some cases. With respect to land use coverage, one noted that it is "neat info," but he is not clear "…applicability wise how it would work." Another said "I understand that urban areas kick things up a little bit, but people aren't going to understand why one mile difference makes it go from red to yellow, to orange." This statement reflects a continued challenge in user understanding of what spurs a transition between categories, as also expressed in Round One's discussion of the need to understand thresholds for categories.

Preferences for Receiving the WSSI. Similar to the findings from Round One, there were positive reactions to both the static products and the interactive option. As one professional said, "the ability to grab different static images and then pull those… so we can sort of customize additional items beyond what's in the typical report… is a nice function." But the needs of the different participants vary. One emergency manager noted that she would want to be able to layer the maps in their own GIS system because what is shown as "…moderate impacts might be different locally if it's building on something that has occurred previously." And while the ability to see 6-hour intervals was seen as particularly helpful to their needs, a broadcast meteorologist pointed out that if the "…rolling six hour was available in a GIF or an MP4, downloadable even, [that] would be awesome."

Summary. Findings from both rounds of the focus groups provide insights into the utility of WSSI as well as needed revisions to meet the needs of the various professionals. Table 2 provides an overview of concepts derived from the focus groups that illustrate both similarities and differences between rounds.

Table 2. General takeaway concepts from the focus group discussions with example quotes from Round One and Round Two.

CONCEPT	ROUND ONE	ROUND TWO
WSSI useful for situational awareness, heads-up	"It gives you that snapshot of what is anticipated and that's where, in just this one slide, it gives you all of that. You know, do we, are we concerned with icing that maybe, may bring down tree limbs, power lines whatever the case may be, or is it going to be primarily a snow or a wind event? So again, at just a glance, it really gives you that situational awareness you need."	"I mean, it would make us start to pay attention. I mean it kind of be on that like standby kind of thing, like OK there are some impacts at this point…I think it's helpful to know that something to pay attention to…I think it is beneficial and it helps me to determine who needs this information pushed and when."
Impact versus quantities	"I think when you have a map depicting snow amount but you don't have estimated inches, that's going to confuse people as well." "From my perspective, having snow amount is very important because it does dictate a lot of our impacts to communities."	"I do think that by trying to add or display things like ice accumulation or snow amount in here without those actual numbers, I think it waters down the effectiveness of the product." "I still think that for me, being a quantitative person, you know the more detail we can get the better, versus the sort of qualitative threshold breaks."
Category Definitions	"Something in the product [is needed] that provides an explanation about what the definitions are so you can make a judgment about whether it applies to your particular issues or not." "You know that, I think just they [partners] just generally want to know more about what these different colors mean because the descriptions that you have there in the scale are kind of generalized."	"It's just a starting point. It doesn't sell the characteristics of a storm, even if it said extreme impacts, what about it is extreme? So it's limited in what it's trying to tell you, I guess." "Is there any way to tie in the transportation disruption to this? Or is it just assumed that people will know that if there's a threat to life and property that transportation is going to be difficult?"
Utility of components	"I think we try to use WSSI to kind of be the summary and to try to narrow down where the biggest impact might be within a particular area and then go into each component because it has different meanings."	"Especially when there's like the ice accumulation, I like to see that separately. And the wind speeds, like the blowing snow type situations."
Temporal details/ information	"For us there's so much planning that goes ahead of time, so certainly day three to day one works very well within, you know, for state transportation and we have planning meetings, usually 24 hours prior." "Because decision makers need to see if it's going to be over the weekend or if it's going to be at night. Those kind of things are important to us." "It's all about time of year and perception and what's going on, but there there's been a lot of times that when less snow or almost like some freezing drizzle, not an ice storm but some freezing drizzle, will cause much bigger events crash wise than the bigger events themselves."	"I would like to know if there's going to be an ice accumulation prior to the snow, because that can really change things." "I think you know a specified more time frame of when you could see it [flash freeze] is probably more something that I would like to see kind of elaborated more, you know on that." "So again 6 hours helps, but having sort of a larger narrative of like what happens even within that six hours, right? Are we waiting for, are the major impacts at the end of that six hours, throughout the six hours, right smack in the middle? Do they happen twice? Do they go up and down and up?"

CONCEPT	ROUND ONE	ROUND TWO
Interactivity	"Knowing that this is the weather impacts specifically, and that we can then make it a layer in our own EOC and add site specific or area specific information on top of that is really helpful for that full picture."	"And I like the ability if I'm understanding the new product correctly, the ability to grab different static images and then pull those. I do like that option so we can sort of customize additional items beyond what's in the typical report, so that is a nice function."
Impact categorization depends on location	"So, it would be very useful if it was standardized for, you know, less common, in other words, less frequent impacts we don't have as good a determination as far as what that local impact is going to be. With snow, because it's so frequent, we have a pretty good determination of what that impact will be ahead of time. This product would only confirm it, but with ice or wind impacts it would be more useful, frankly."	"I know that you know the topography obviously has an impact here and I'm sure that's why those things are there, but it doesn't present, none of that is, you know, this is there's nothing about elevation, there's nothing about terrain." "For us we're more rural and so blowing, drifting, snow, and visibilities are less of a concern for us because we don't have those visibility factors like on the freeways. so for us, it's that heavier snow that can cause more impacts." "I think it also depends on how the population and individuals themselves regard their vulnerability to these impacts. In my neighborhood, extreme impacts would be a week long power outage, nothing else, but in other areas, you know, a moderate impact might be a purple. And so I think it depends on your population, your, you know, the vulnerability index, if that makes any sense."
Wind and temperature information sought	"When we look at those subject matter experts and snow removal and treating the pavement, the matter of a couple of degrees one way or another can have a significant impact on their plans to prepare and then to respond. And obviously wind plays into that as well. So, if we're talking about wind chill, things along those lines, that, those are very important variables for that equation."	"Wind chill: I think it would be helpful, but in combination with at least an approximation of what the temperatures would be."
More information needed by some, too much for others (forecast inputs)	"Forgive me for not knowing all of the details of what goes into each component of the index, but just anecdotally it tends to be pretty overdone with snowstorms in a lot of, in a number of cases, especially in the urban areas."	"Without [the] additional information, it's not explaining enough." "I think that's very helpful as a pop up so you can see exactly, you know, what is being factored into the impact analysis."

Regional Differences

WSSI is a national product, providing the same components and category definitions everywhere. To address differences across the country, as mentioned above, impact levels are adjusted based on climatology, population density, and land use. Yet, in both rounds of focus groups, regional differences became clear that might affect the potential utility of WSSI because of the possibility of misclassification of impacts. For instance, as was pointed out in Jackson, MS: "you're in Mississippi, your impacts are going to be impactful, your winter weather stuff is going to be impactful." And the types of winter weather experienced in the South are different than elsewhere in the country: "some of these terms we're not going to be very familiar with down here like snow load. It makes sense as to what it was after you explained it, but it's not something that's like intuitive."

To address differences across the country, … impact levels are adjusted based on climatology, population density, and land use. Yet, in both rounds of focus groups, regional differences became clear that might affect the potential utility of WSSI because of the possibility of misclassification of impacts.

Some of the discussion in the focus groups in the Grand Rapids region centered on lake effect and the difficulty in addressing it in the WSSI. As an example, in 2016, a 53-car pile up on an interstate caused three deaths, and one professional pointed out that "…it happened in a minor impact forecast." There is concern about how unpredictable lake effect events can be with respect to what area they will affect, particularly given problems when motorists "…drive from sunshine to a band of lake effect that is two miles wide." Thus, participants noted that wind speed and direction as well as the scale of lake effect events pose issues for determining impact severity.

Another regional difference came up in the Boulder and Hanford focus groups, relating to the role of elevation. There was some confusion as to the categories used in mountainous areas. On one hand, a participant asked with respect to the snow amount map, "it is appearing that the moderate impacts are kind of on the western faces of those mountains, tapering off as it gets higher into elevation, …but is that meaning that the impacts and that level is adjusted based on elevation?" The lower population at that location led to the lowering of the impact category, a factor that was not readily understood. Yet, in another scenario, the WSSI showed major and extreme impacts at high elevations, which was contested by the participants because there are few people and communities to be affected. Similarly, professionals wanted to have a better idea of the elevation at which the snow and ice are occurring: "This [the ice accumulation WSSI map] plus the elevation data would be helpful because it would give us a better understanding of, you know, the roads and communities where people are used to ice being impacted, or is it getting down further to the areas where it is less common for people to deal with it."

These three examples illustrate the needs as they vary geographically across the country. While the WSSI provides an important product to bring attention to potential impacts of an impending storm, it is one part of an overall package.

Round Three Survey

All previous focus group participants were invited to take an online survey about the redesigned WSSI in Round Three. A 54% response rate (44 responses) provided feedback on two legend options and several elements of the WSSI product. Overall participants found the redesign extremely or very helpful with 75% reporting high usefulness (Figure 17).

The redesign focused on changes to the legend. When given two options for an updated legend with travel and power outage details, a bulleted, more detailed legend (Option A) was preferred by most (61% of all participants) compared to a simple, less detailed legend (Option B), though preferences differed by region. The percentage choosing each option is shown in Figure 18. Option A was mainly preferred because it made specific impacts clear.

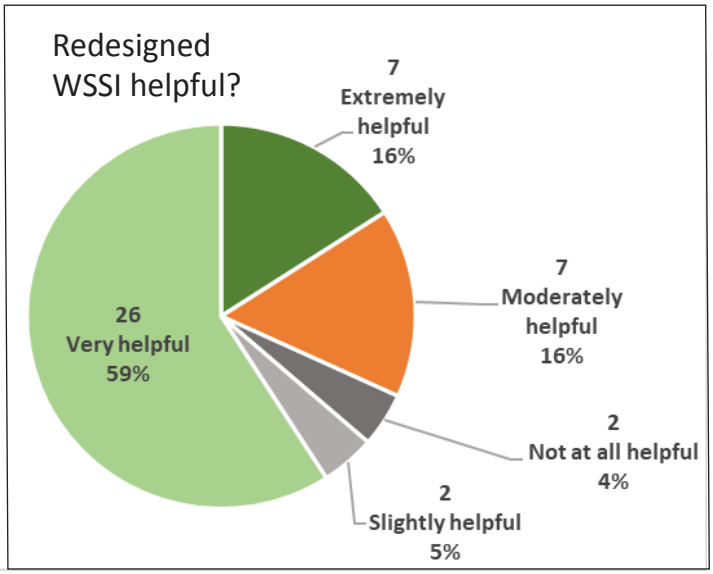
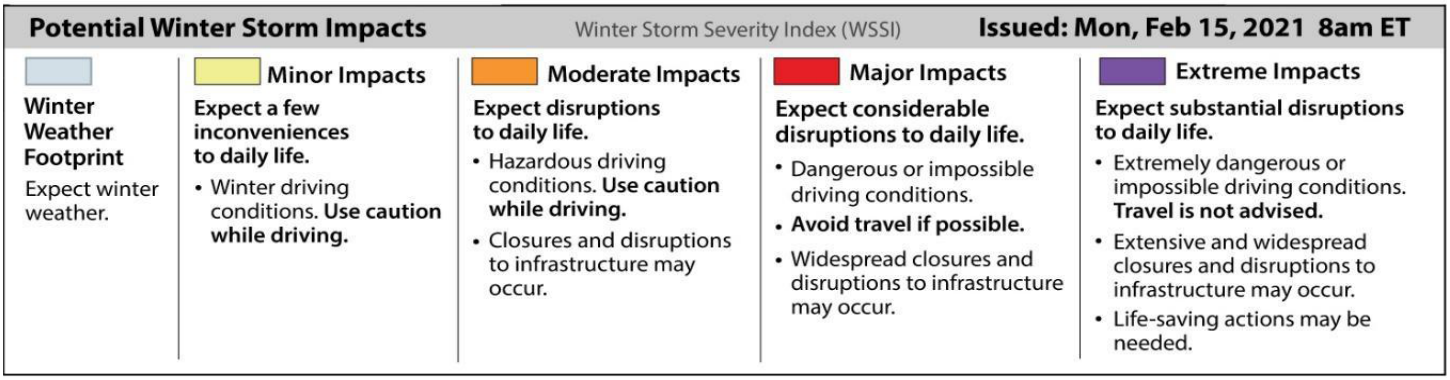
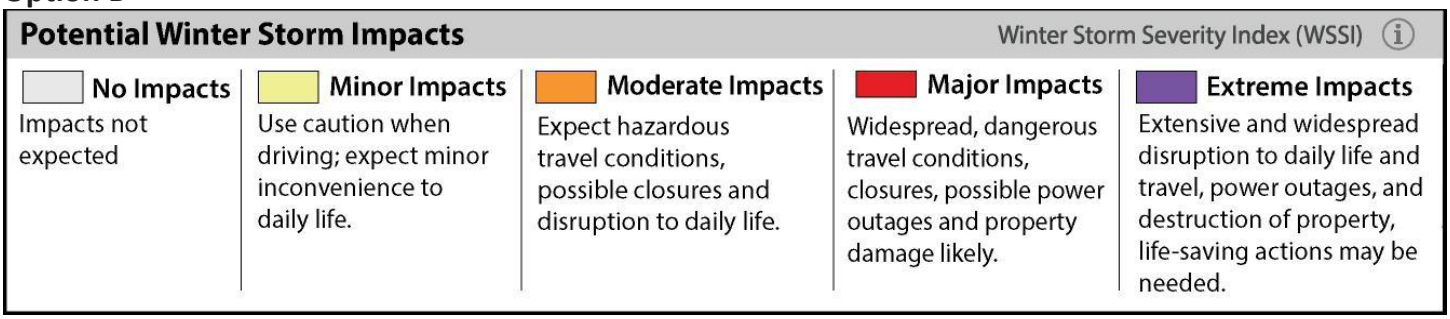


Figure 17. Participants' rating of the helpfulness of the redesigned WSSI with participants from all locations reporting.

Option A



Option B



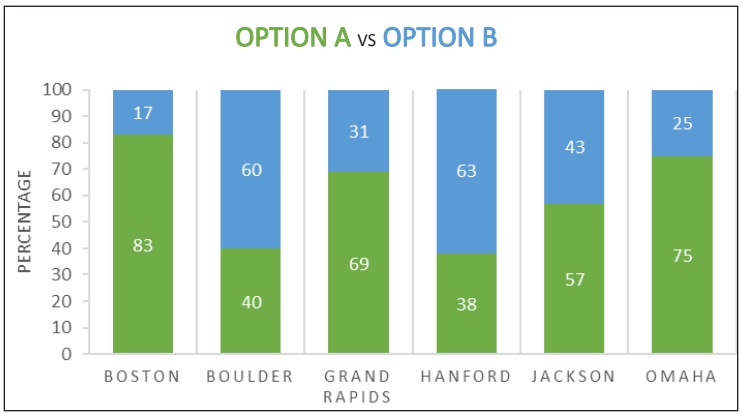


Figure 18. Legend options and percentage of respondents who preferred Option A or Option B.

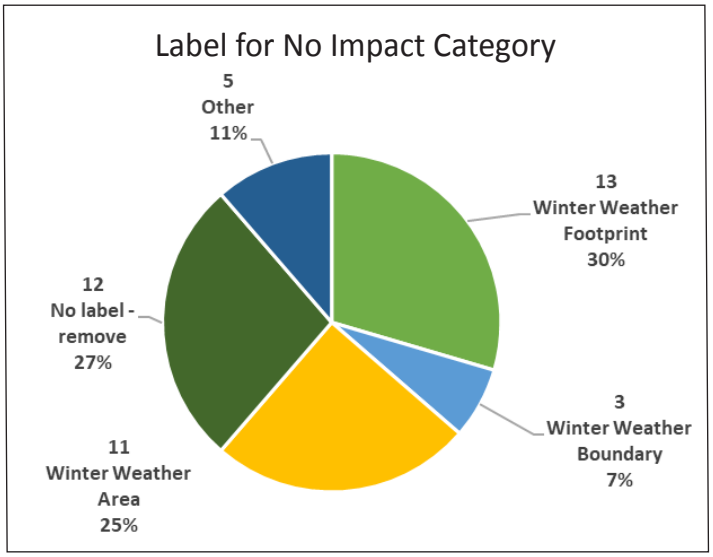


Figure 19. Respondents' preference for labeling the no impact category.

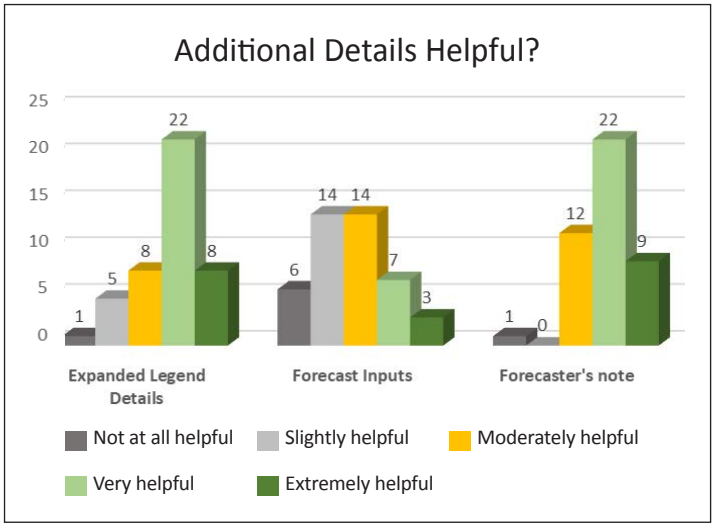


Figure 20. Survey responses related to helpfulness of the expanded legend details, forecast inputs, and Forecaster's Note elements in the redesigned WSSI.

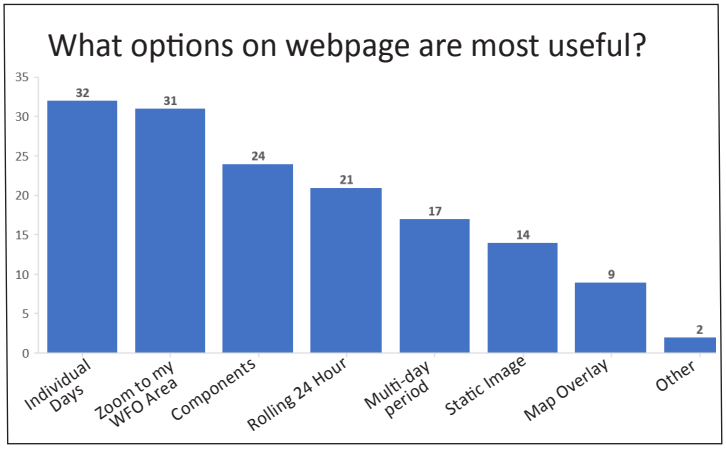


Figure 21. Ranking by value of the various elements of the WSSI interactive web page.

Further, respondents were asked what they recommended calling the no/limited impact category which was labeled "Winter Weather Footprint." This area could experience up to 1/10 inch of snow, active snow or may have a limited threat for ground blizzard or potential for flash freeze, but impacts are minimal to none. The responses were fairly diffuse with no clear preference for the label (Figure 19).

The redesigned WSSI also had the option to have an expandable legend and forecast inputs. The expanded legend provided more details on what each category included, and the forecast inputs provided details on what parameters were included in the WSSI. Having the ability to expand legend details was seen as very helpful by a majority of respondents, while the forecast inputs (expanded details on what goes into the WSSI calculation) was less helpful (Figure 20). This may be due to different levels of user ability and interest. The Forecaster's Note, a white bar at the top of the graphic that provides a short text summary of the forecast highlights, was ranked as very or extremely helpful by most respondents.

The survey also asked about the current WSSI webpage and what features were most useful. The ability to see individual days (Days 1, 2, 3, and Days 1-3) was valued as was the ability to zoom and to break out the components (Figure 21). Of the six components, snow amount and ice accumulation (Figure 22) were rated highest, while snow load, flash freeze and ground blizzard had lower rankings of usefulness.

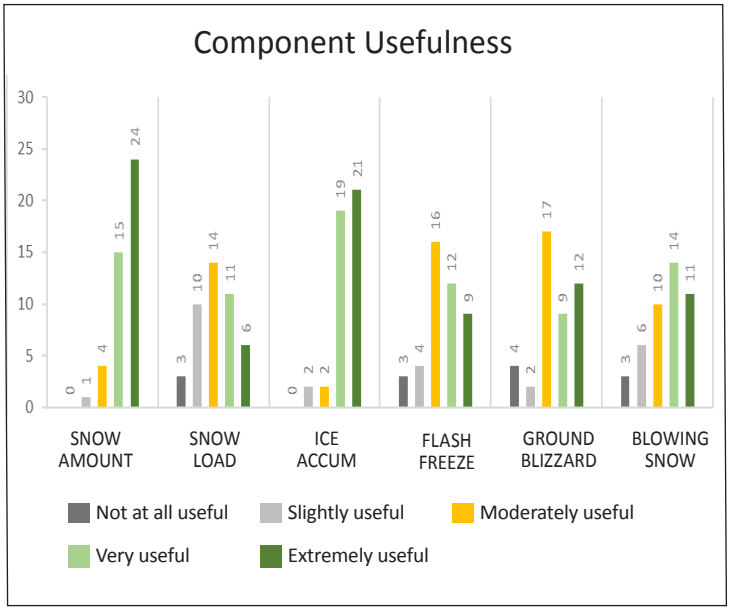


Figure 22. Usefulness of each component of the WSSI as reported in the Round Three Online Survey

Winter Weather Hydrometeorology Testbed

The 12th Winter Weather Experiment in the WPC's Hydrometeorology Testbed had six objectives, one of which was to evaluate the redesigned WSSI in parallel with the operational WSSI. Analyses of the surveys and focus group discussions, presented in the previous sections, led to recommendations for a redesigned WSSI product. The WPC WSSI team has already implemented several of these recommendations and there have been several iterations of legend descriptions, some of which were tested in the Winter Weather Hydrometeorology Testbed. Participants in the testbed, including NWS forecasters from both WFO and National Centers, FEMA personnel, university researchers, and model developers, were asked to discuss the use of the WSSI product and then respond to a short survey about what they liked or disliked about it and what impact legend they preferred. Of 33 respondents, 85% preferred the proposed iteration tested. Specifically, the combination of limited and no impacts was a prominent part of the discussion, with the majority (73%) of the participants preferring the combination of those categories, though some noted the language still needed work.

The legend has been further refined and modified since the testbed and now includes bullets under each category and a focus on travel conditions. Additionally, the Limited impacts category was removed and the no impacts/limited impacts was replaced with Winter Weather Area. These changes were implemented after the Round Three online survey that was conducted in order to gather more information about the proposed changes, including what to call the combined no/limited impact category.

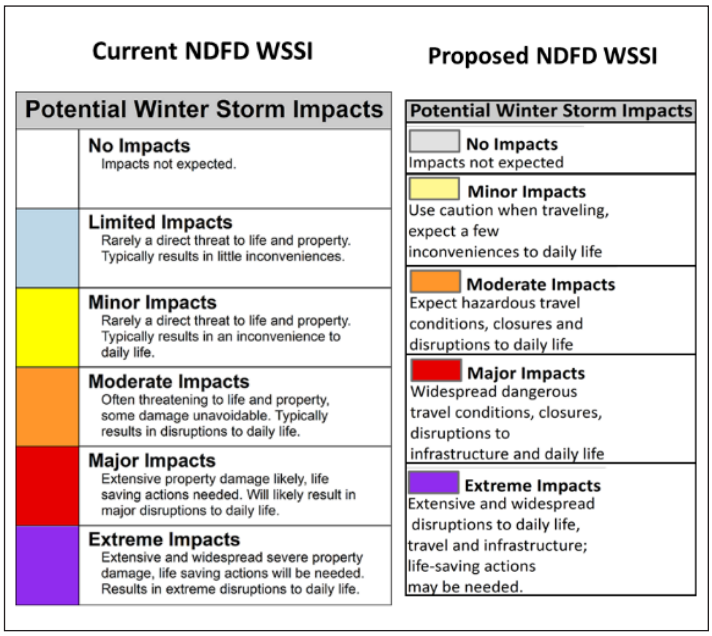


Figure 23. The current and proposed WSSI legend descriptions tested as part of the 2022 Winter Weather Hydrometeorological Testbed.

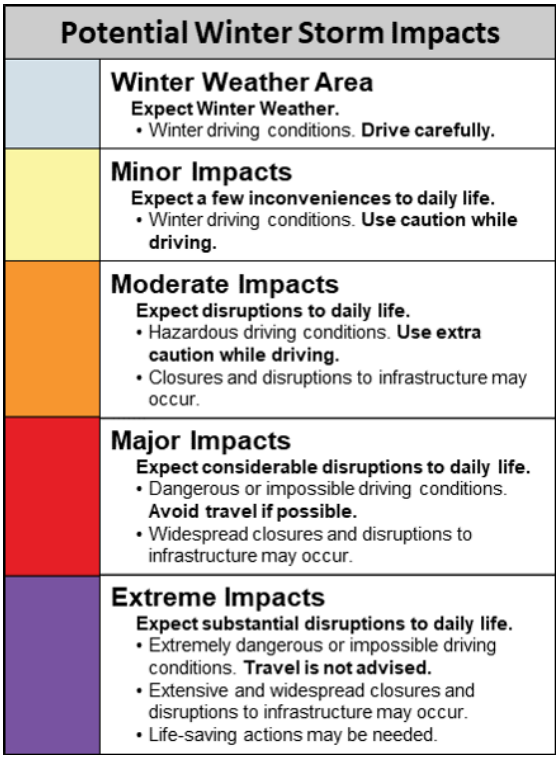


Figure 24. Current WSSI legend impact definitions as of January 2023.

Discussion and Conclusion

Findings from the focus groups and surveys reflect the complexity of interpreting impacts across regions through a national product with a uniform template. Overall, users saw WSSI as likely to be helpful for a "heads-up" or high-level guidance when considering impacts and resource needs. Users see WSSI as a simple way to communicate risk to different stakeholders, and will incorporate it as a part of the overall weather data package used for decision-making. However, different geographies, winter weather experiences, and cultural expectations for winter weather forecasts mean that the WSSI is likely to be more helpful in some regions than others, and that some regions with less winter weather experience may require a longer user ramp-up period to establish the usefulness of the product in operations. Users inherently understand that their regions have specific considerations (among them experience, elevation, and population) that affect how serious the impacts may be from any given winter storm, and are accustomed to using forecast data to determine that severity. Multiple users suggested that their own sense of moderate or major is likely to differ from another region's, and sought assurance that the product had incorporated those factors in the categorization. Additionally, the impact-based nature of the product is still relatively new to many of the professional users though they indicated they will incorporate the product into their decision-making. As discussed above, although the WSSI does consider climate in its calculation of categories, users nonetheless requested quantities for components including snow amount and ice accumulation, in some cases intending to correlate those amounts into their internal processes for determining threshold decisions - in essence, to determine their own categorization of the severity of impacts. An impact-based product, by design, works differently, and users appear to require more experience and clarification about the goals of the product in order to use it appropriately. Training over time, as well as careful explanation of categories, will help users as they incorporate severity levels into their operational systems.

Other factors, like timing and community readiness, can also affect how severity levels are interpreted. For instance, users reported that the same winter storm event might have different degrees of impact if it is the first snow or ice event of the season than if it came later in the season. And the community's overall experience and preparedness are also factors: areas that are used to snow and have equipment to handle transportation and power impacts have higher thresholds for impact than those typically not as frequently affected by winter weather.

Beyond the severity levels, understanding the details of the impacts is also important to users. First, specific impacts are of higher importance than others - travel impacts; the potential for interruptions to operations for schools, businesses and institutions; and health impacts from extreme cold and wind - emerge as most critical, while impacts to property overall rank of lesser importance and frequency. As such, some components, including snow amount, ice amount and wind chill were useful to many groups, while others, like snow load or flash freeze, are useful in some areas but not all. Further, visibility was important but many users did not distinguish between the components Blowing Snow and Ground Blizzard, and for this purpose, we recommend combining these into one component called Blowing Snow, which could encompass both types of events and capture the impact - reduced visibility - that is of importance to the user. At the same time, addition of a Wind Chill Impact Severity map was seen as essential by most participants across regions. For all groups, however, clear and specific legend language about those impacts is central. Vague phrases like "disruption to daily life" are less helpful than direct language about travel impacts and risks to human safety and health.

As noted, reception of the WSSI was generally strong and positive across most regions and groups tested. But it was also clear that additional context was often required to clearly communicate the severity of impacts. It is recommended that the WSSI be incorporated and described through emergency briefings from WFOs directly to users, especially during its initial years of use as the product is refined and incorporated into decision-making processes. Through briefings, WFOs can address the other stated needs of users, such as quantities for snow and ice amounts, and also can explain the ways in which the WSSI accounts for regional climatological as well as non-climatological factors, such as population density and land use. Inclusion of a Forecasters' Note is highly recommended to help clarify which of the components is driving the impact levels, and to link to other useful information, such as active watches or warnings that may be in effect. Indeed, continuing to advance the interactive components of the product is important for

the integration of the information into decision-making; but in some areas, a static product will still be required.

The introduction of an impact-based product presents a new model for winter weather forecast communication. The process of iterative testing, revision, retesting - and notably, testing in the Hydrometeorology Testbed - produced an evolving understanding of how users can and should best receive impact-based winter storm information. But this project represents just the beginning of the learning in this regard, and continued user testing as the product evolves will be important. Specifically, any forthcoming revisions to legend language should be user-tested to avoid unintended confusion or loss of clarity, and WFOs should continue to identify needs through feedback from stakeholders regarding communication of the WSSI through briefings or other communications. Impact-based winter weather information from the WSSI holds great promise for use, and is still evolving. In the interim, education, training, and careful attention to descriptions of categories and legends will be central to ensuring that WSSI is a helpful tool for decision-making.

References

Bean, H., J. Sutton, B.F. Liu, S. Madden, M.M. Wood, D.S. Mileti. 2015. The study of mobile public warning messages: a research review and agenda, *Review of Communication* 15: 60–80, https://doi.org/10.1080/15358593.2015.1014402

Broad, K., A. Leiserowitz, J. Weinkle, and M. Steketee. 2007. Misinterpretations of the "cone of uncertainty" in Florida during the 2004 hurricane season, *Bulletin of the American Meteorological Society* 88: 651–668, https://doi.org/10.1175/BAMS-88-5-651.

Call, D.A. 2010. A survey of county emergency managers' response to ice storms. *Journal of Homeland Security and Emergency Management* 7: Article 32.

Call, D.A. and J.S. Coleman. 2012. The decision process behind inclement-weather school closings: a case-study in Maryland, USA. *Meteorological Applications*. DOI: 10.1002/met.1359.

Casteel, M. 2016. Communicating increased risk: An empirical investigation of the National Weather Service's impact-based warnings. *Weather, Climate, and Society* 8: 219–232, https://doi.org/10.1175/WCAS-D-15-0044.1.

Casteel, M. 2018.An empirical assessment of impact based tornado warnings on shelter in place decisions. *International Journal of Disaster Risk Reduction* 30: 25–33, https://doi.org/10.1016/j.ijdrr.2018.01.036.

Dallo, I., Stauffacher, M., and Marti, M. 2020. What defines the success of maps and additional information on a multi-hazard platform? *International Journal of Disaster Risk Reduction* 49, 101761, https://doi.org/10.1016/j.ijdrr.2020.101761

Drobot, S. D. 2007. Evaluation of winter storm warnings: A case study of the Colorado Front Range December 20-21,2006, winter storm. *Quick Response Research Report* 192. University of Colorado Natural Hazards Center.

Drobot, S., C. Schmidt, and J. Demuth. 2008. The January 5-6, 2008, California winter storm: assessing information sources, actions, and damages. *Quick Response Research Report* 207. University of Colorado Natural Hazards Center.

Galluppi, K., J. Losego, and B. Montz. 2013. Evaluation of the effectiveness of the Central Region Impact Based Warning Demonstration. Report to the NWS Central Region Headquarters. https://repository.library.noaa.gov/view/noaa/28893

Hogan Carr, R., B.E. Montz, K. Semmens, K. Maxfield, S. Hoekstra, and E. Goldman. 2016a. Motivating action under uncertain conditions: enhancing emergency briefings during coastal storms. *Weather, Climate and Society* 8: 421-434, https://doi.org/10.1175/WCAS-D-16-0028.1.

Hogan Carr, R., B.E. Montz, K. Maxfield, S. Hoekstra, K. Semmens, and E. Goldman. 2016b. Effectively communicating risk and uncertainty to the public: assessing the National Weather Service's flood forecast and warning tools. *Bulletin of the American Meteorological Society* 97(9): 1649-1665, https://doi.org/10.1175/BAMS-D-14-00248.1

Hogan Carr, R., Montz, B., Semmens, K., Maxfield, K., Connolly, S., Ahnert, P., Shedd, R., and Elliott, J. 2018. Major Risks, Uncertain Outcomes: Making Ensemble Forecasts Work for Multiple Audiences. *Weather and Forecasting* 33(5): 1359-1373. https://doi.org/10.1175/WAF-D-18-0018.1.

Kox, T., C. Lüder, and L. Gerhold. 2018. Anticipation and response: Emergency services in severe weather situations in Germany. *International Journal of Disaster Risk Science*, 9: 116–128, https://doi.org/10.1007/s13753-018-0163-z.

LeClerc, J. and S. Joslyn. 2015. The cry wolf effect and weather-related decision making. *Risk Analysis* 35(3): 385-395.

Montz, B.E., K.J. Galluppi, J.L. Losego, and C.F. Smith. 2015. Winter weather decision-making: North Carolina school closings, 2010-11. *Meteorological Applications* 22: 323-333, https://doi.org/10.1002/met.1457.

Morss, R.E., Wilhemi, O.V., Downton, M.W., and Gruntfest, E. 2005. Flood risk, uncertainty, and scientific information for decision making: lessons from an interdisciplinary project. *Bulletin of the American Meteorological Society* 86(11): 1593-1601.

Morss, R. E., J. L. Demuth, J. K. Lazo, K. Dickinson, H. Lazrus, and B. H. Morrow. 2016. Understanding public hurricane evacuation decisions and responses to forecast and warning messages. *Weather and Forecasting* 31: 395–417, https://doi.org/10.1175/WAF-D-15-0066.1.

Morss, R. E., C. L. Cuite, J. L. Demuth, W. K. Hallman, and R. L. Shwom. 2018. Is storm surge scary? The influence of hazard, impact, and fear-based messages and individual differences on responses to hurricane risks in the *U.S. International Journal of Disaster Risk Reduction* 30: 44–58, https://doi.org/10.1016/j.ijdrr.2018.01.023.

Nichols, A.C. and S. Hoekstra. 2011. Buses, bars, and breakdowns: non-weather factors affecting decision-making at K-12 schools and universities during Tornado warnings. Presentation at the American Meteorological Society Annual Meeting, Seattle, WA. http://ams.confex.com/ams/39BROADCAST/flvgateway.cgi/id/18157?recordingid=181.

Potter, S., P. Kreft, P. Milojev, C. Noble, B. Montz, A. Dhellemmes, R.J. Woods, and S. Gauden-Ing. 2018. The influence of impact-based severe weather warnings on risk perceptions and intended protective actions. *International Journal of Disaster Risk Reduction* 30 (Part A): 34-43, https://doi.org/10.1016/j.ijdrr.2018.03.031

Potter, S., S. Harrison, and P. Kreft. 2021. The benefits and challenges of implementing impact-based severe weather warning systems: Perspectives of weather, flood, and emergency management personnel. *Weather, Climate, and Society* 13: 303-314, https://doi.org/10.1175/WCAS-D-20-0110.1

Ripberger, J. T., C. L. Silva, H. C. Jenkins-Smith, and M. James. 2015. The influence of consequence-based messages on public responses to tornado warnings. *Bulletin of the American Meteorological Society* 96: 577–590, https://doi.org/10.1175/BAMS-D-13-00213.1.

Savelli, S. and S. Joslyn. 2013. The advantages of predictive interval forecasts for non-expert users and the impact of visualizations: advantages of predictive interval forecasts. *Applied Cognitive Psychology* 27: 527–541, https://doi.org/10.1002/acp.2932

Sherman-Morris, K. 2013. The public response to hazardous weather events: 25 years of research. *Geography Compass* 7(10): 669-744.

Strong, C.K., Z. Ye, and X. Shi. 2010. Safety effects of winter weather: the state of knowledge and remaining challenges. *Transport Reviews* 30(6): 677-699.

Weather Prediction Center. 2020. Winter Storm Severity Index (WSSI) Product Description Document. https://nws.weather.gov/products/PDD/PDD_OplWSSI_2020-2021.pdf. Accessed June 2023.

Weyrich, P., A. Scolobig, D.N. Bresch, and A. Patt. 2018. Effects of impact-based warnings and behavioral recommendations for extreme weather events. *Weather, Climate, and Society* 10: 781–796, https://doi.org/10.1175/WCAS-D-18-0038.1.

World Meteorological Organization, 2015. WMO guidelines on multi-hazard impact-based forecast and warning services. WMO Doc. 1150, 34 pp., https://library.wmo.int/doc_num.php?explnum_id=7901.

Ye, Z., X. Shi, C. Strong, and T. Greenfield. 2009. Evaluation of the effects of weather information on winter maintenance costs. *Transportation Research Record* 2017: 104–110.

APPENDICES

APPENDIX A. EXAMPLES OF FOCUS GROUP PRESENTATIONS FOR ROUND ONE (GRAND RAPIDS) AND ROUND TWO (BOSTON)

APPENDIX B. DETAILED SURVEY RESULTS FROM ROUND ONE AND ROUND TWO INCLUDING DEMOGRAPHICS AND RANKINGS OF ALL ELEMENTS IN THE WSSI

APPENDIX A:
EXAMPLES OF FOCUS GROUP PRESENTATIONS FOR ROUND ONE (GRAND RAPIDS) AND ROUND TWO (BOSTON)

Project Team and Partners

Nurture Nature Center

Rachel Hogan Carr, Executive Director (PI); Dr. Kathryn Semmens, Science Director (CO-I); Keri Maxfield, Art Director (CO-I)

East Carolina University

Dr. Burrell Montz, Professor of Geography, Planning and Environment (CO-PI)

NOAA

LEAD NOAA COLLABORATOR, Dr. Joshua Kastman, CIRES/WPC (Cooperative Institute for Research in Environmental Sciences/Weather Prediction Center) (CO-I)

NOAA COLLABORATORS: Dr. Kirstin Harnos, CIRES/WPC (CO-I) and James Nelson, WPC

Focus Group Agenda

Introduction to the Project and Introduction of all Participants

Pre-session survey

Scenario 1

Scenario 2

Post-session survey

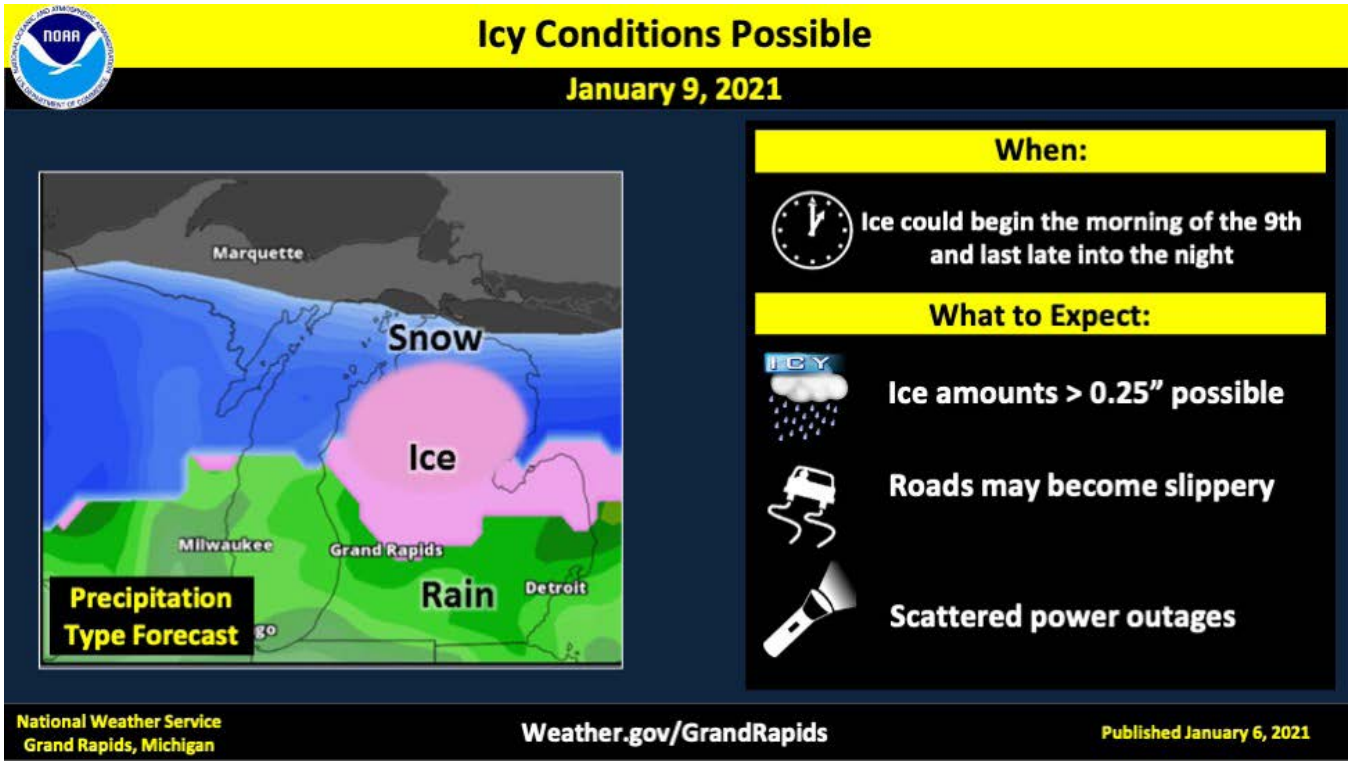
Scenario 1

Winter Storm Severity Index

Improving Storm Readiness through Severity and Social Impact Forecasting

ROUND ONE - GRAND RAPIDS

This presentation from the Nurture Nature Center, Inc. was prepared under grant award number NA20OAR4590355 from the Joint Technology Transfer Initiative Program of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions and recommendations are those of the author(s) and do not necessarily reflect those of NOAA or of the U.S. Department of Commerce.



Significant Ice to Impact Michigan

January 9, 2021

Key Points

- Power outage potential is increasing and could last beyond a day or two
- Ice amounts of 0.25”-0.50” likely
- Temperatures will be close to freezing; icy roads, bridges, and overpasses possible
- Commute delays and event delays/cancellations likely
- 24 hour break before snow + cold + wind moves in late January 10

National Weather Service
Grand Rapids, Michigan

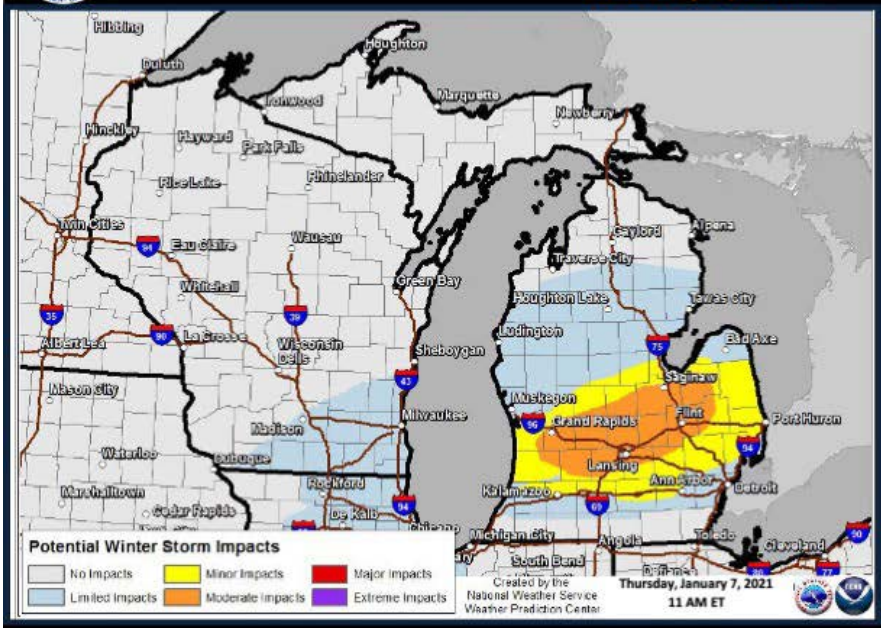
Weather.gov/GrandRapids

Issued: 2/18/2019 3:52

Published January 7, 2021

Potential Winter Storm Impacts

January 9, 2021



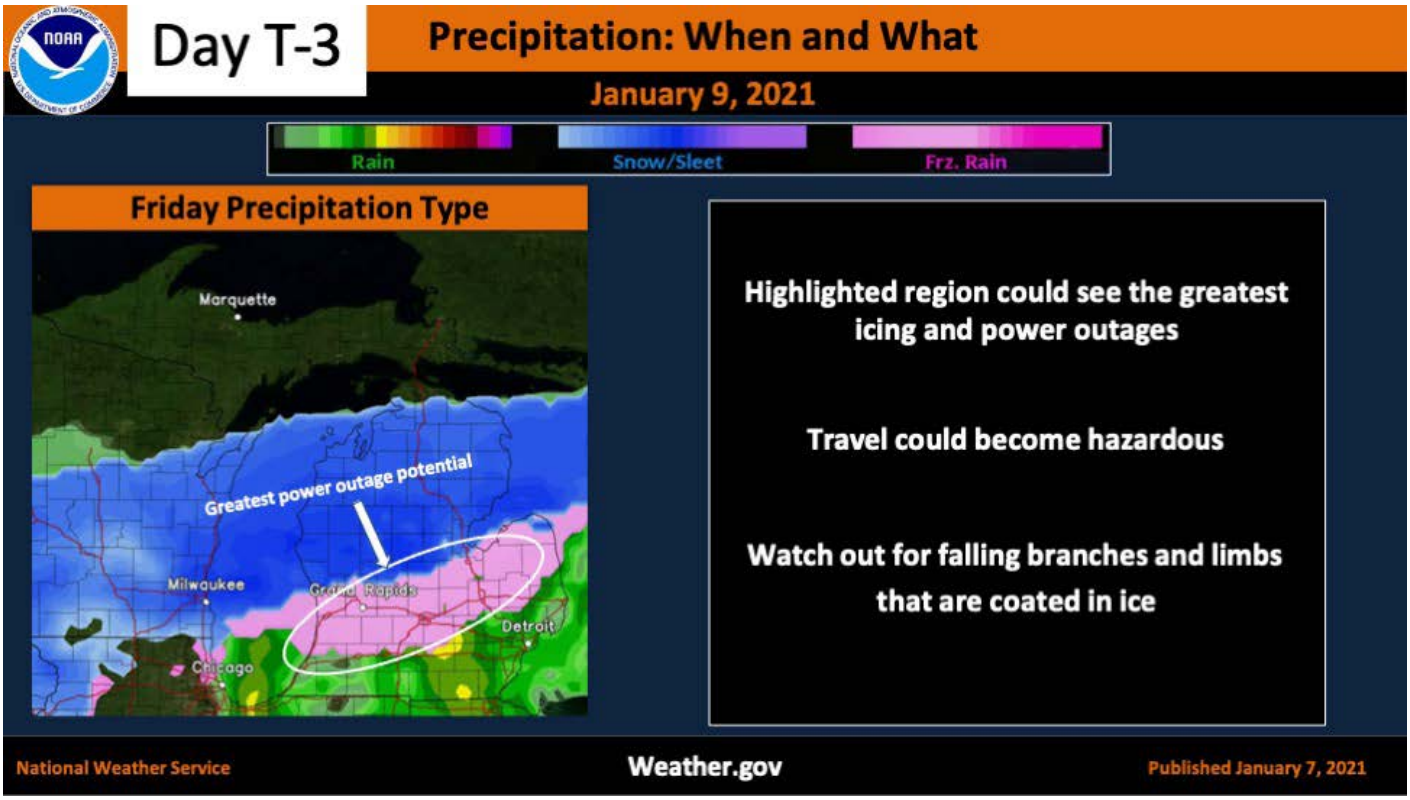
IMPACTS	DESCRIPTION
None	No Significant Weather Expected
Limited	Little to No Impact on Daily Life Low risk for some travel inconveniences
Minor	Caution – Especially When Travelling Plan for typical winter travel inconveniences
Moderate	Significant Inconveniences Disruption of normal activities is likely Travel is hazardous Some utility outages and property damage possible
Major	Wide Disruption of All Normal Activities Major delays and cancellations Travel not recommended Utility outages and property damage may be unavoidable
Extreme	Extremely Life Threatening Historic storm with extended cancellation of daily activities Travel may not be possible Expansive outages and property damage

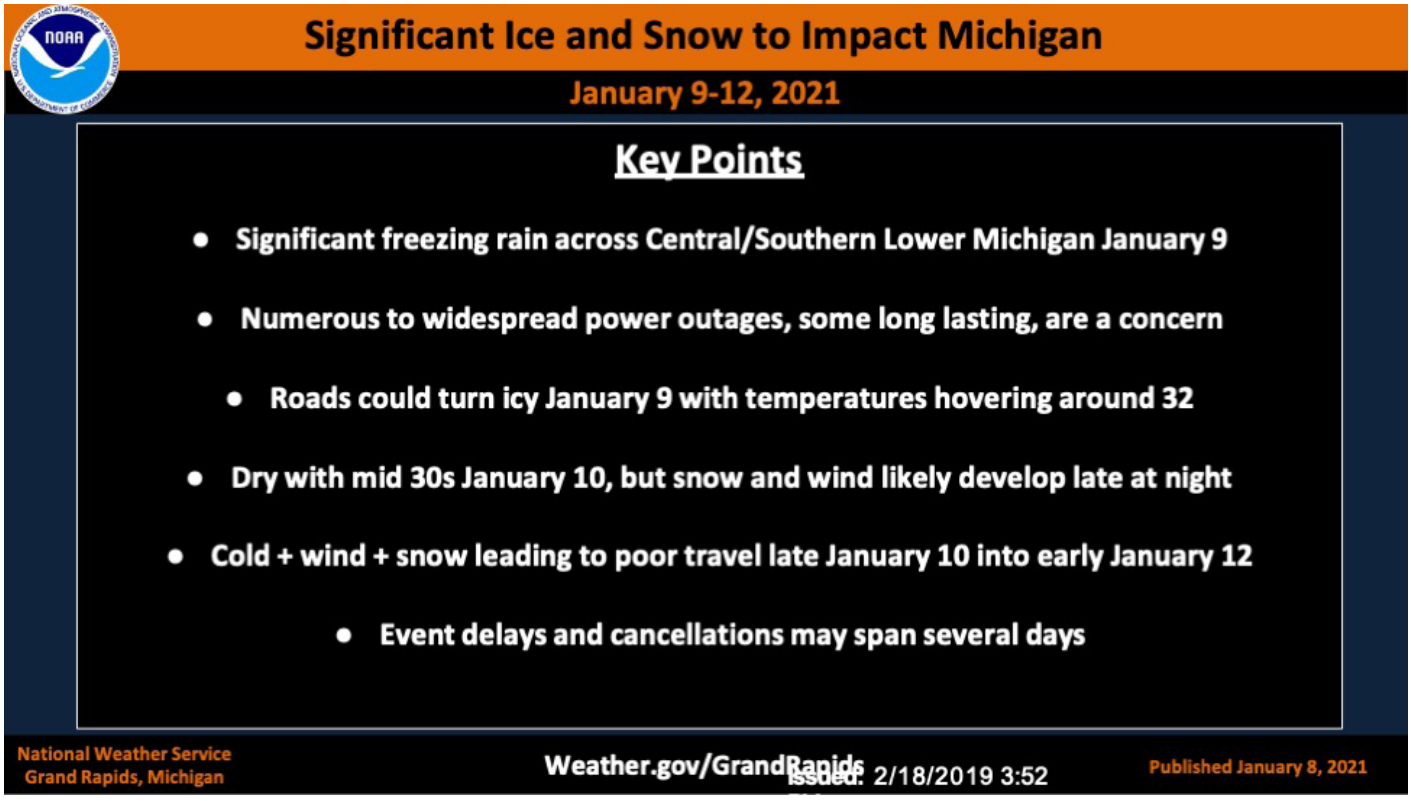
National Weather Service
Grand Rapids, Michigan

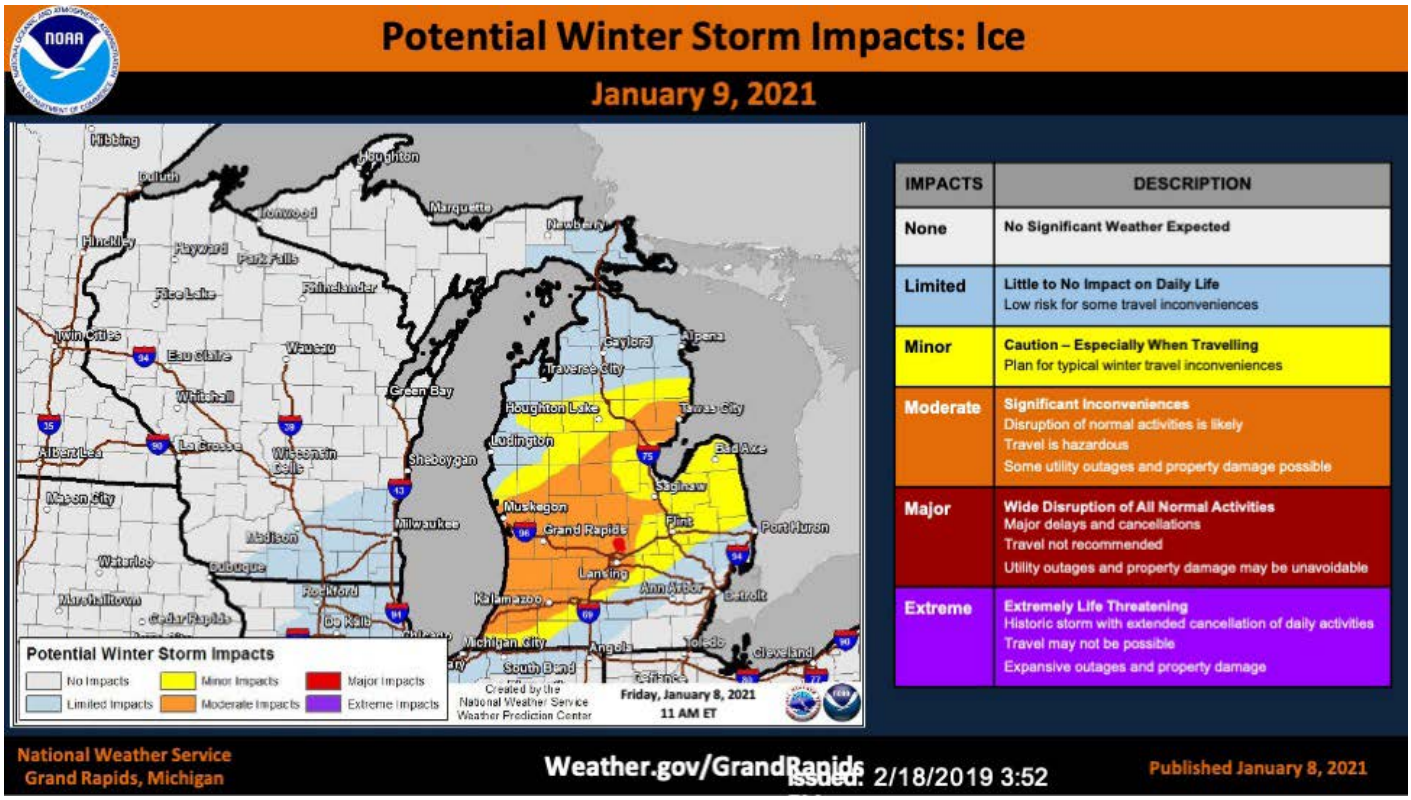
Weather.gov/GrandRapids

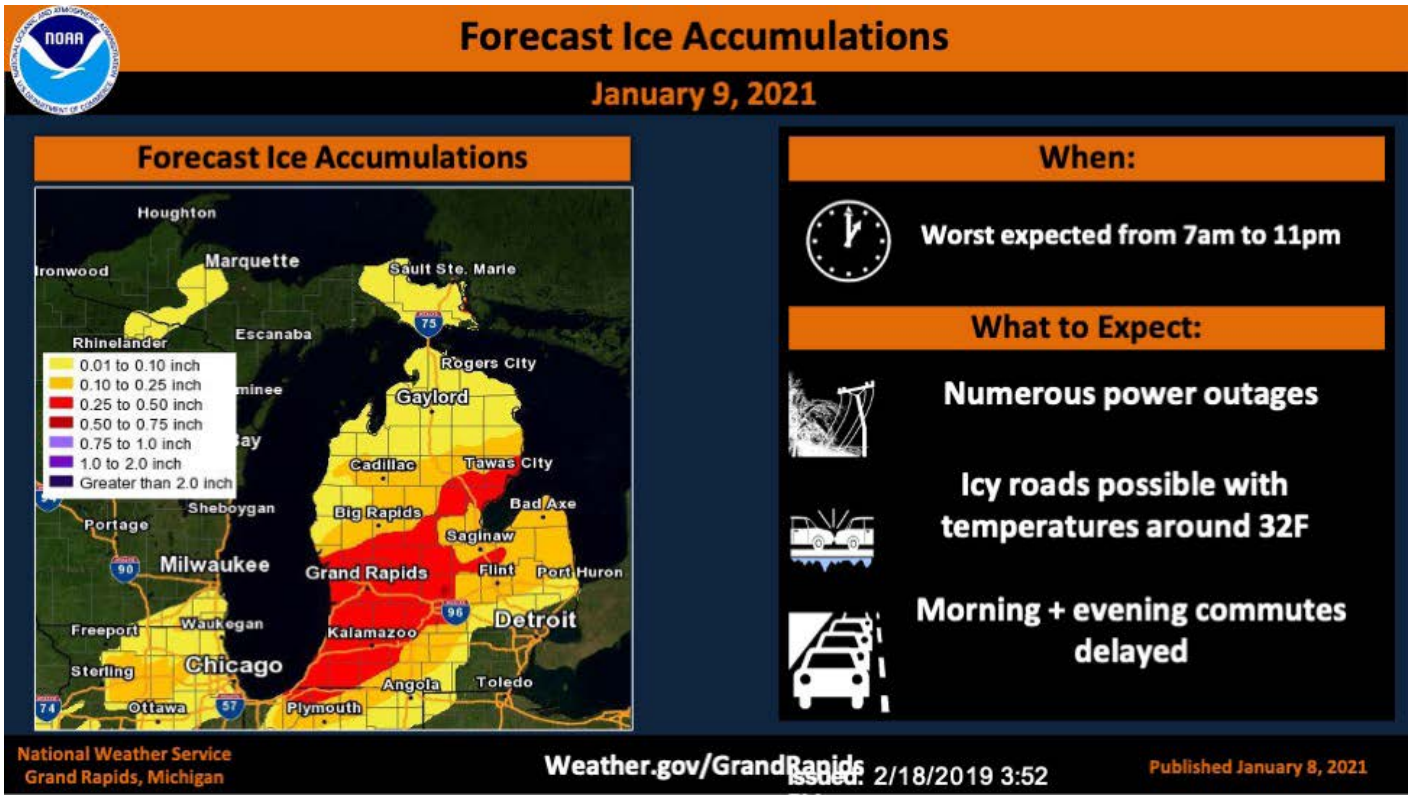
Issued: 2/18/2019 3:52

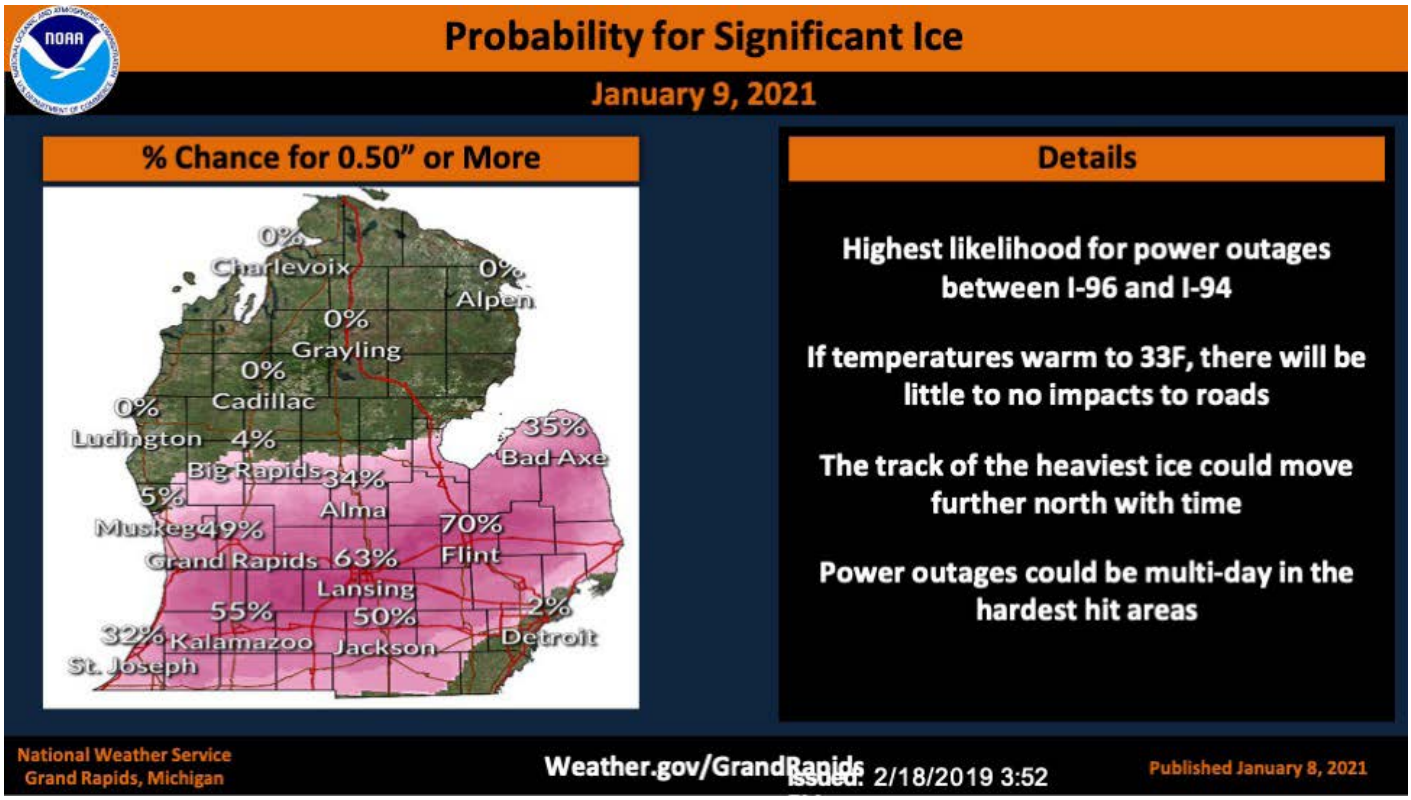
Published January 7, 2021

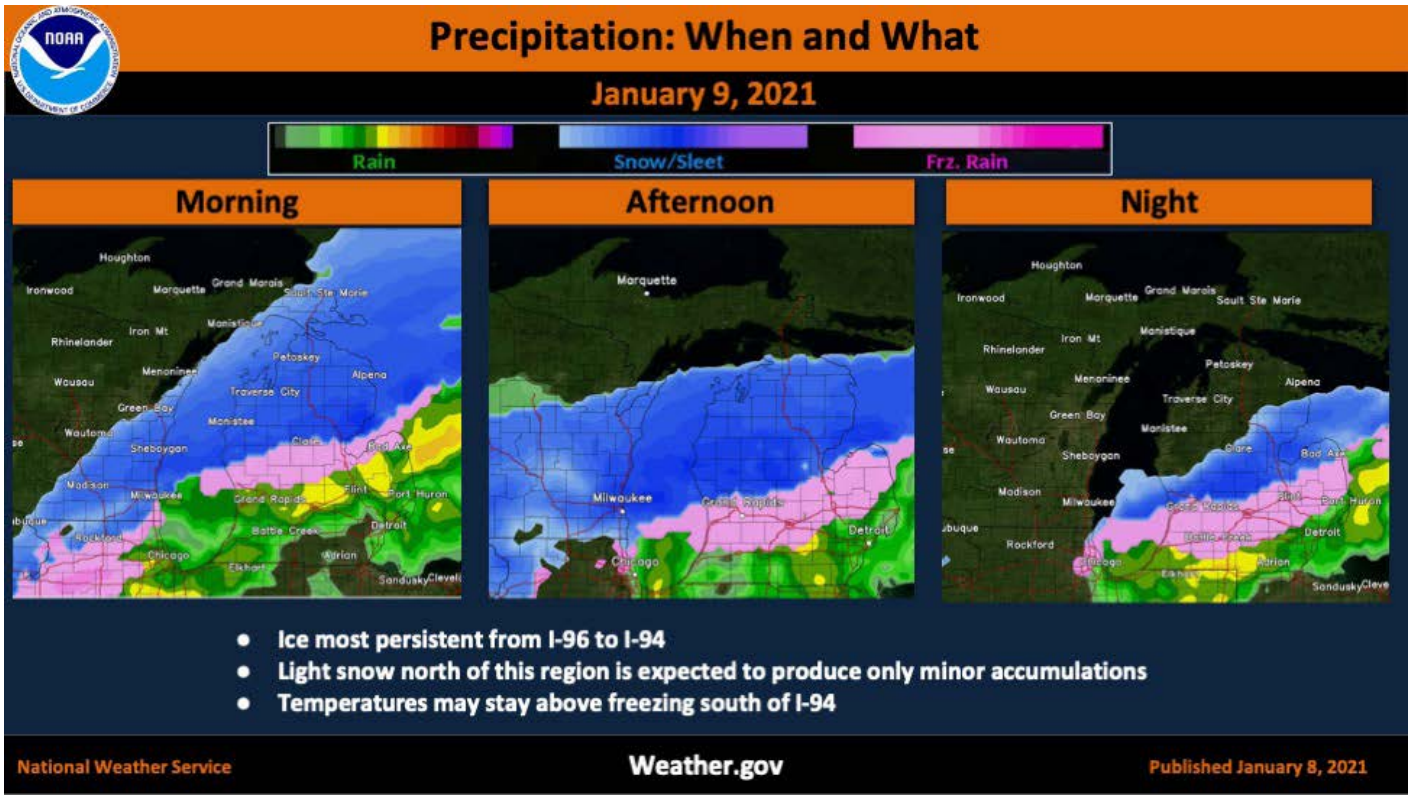

Day T-3
Precipitation: When and What
January 9, 2021
Rain
Snow/Sleet
Frz. Rain
Friday Precipitation Type
Marquette
Greatest power outage potential
Milwaukee
Grand Rapids
Detroit
Chicago
Highlighted region could see the greatest icing and power outages
Travel could become hazardous
Watch out for falling branches and limbs that are coated in ice
National Weather Service
Weather.gov
Published January 7, 2021

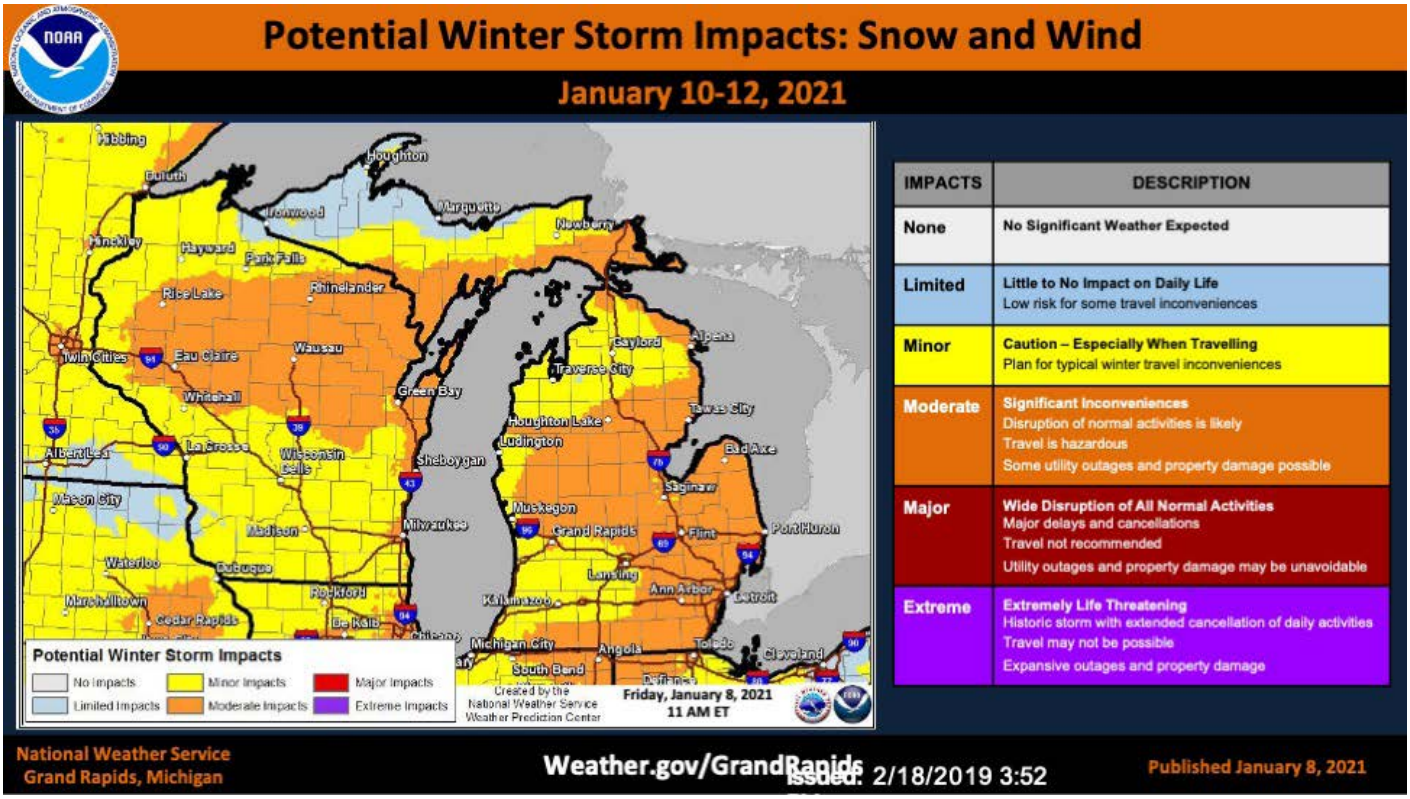

Significant Ice and Snow to Impact Michigan
January 9-12, 2021
Key Points
Significant freezing rain across Central/Southern Lower Michigan January 9
Numerous to widespread power outages, some long lasting, are a concern
Roads could turn icy January 9 with temperatures hovering around 32
Dry with mid 30s January 10, but snow and wind likely develop late at night
Cold + wind + snow leading to poor travel late January 10 into early January 12
Event delays and cancellations may span several days
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 8, 2021

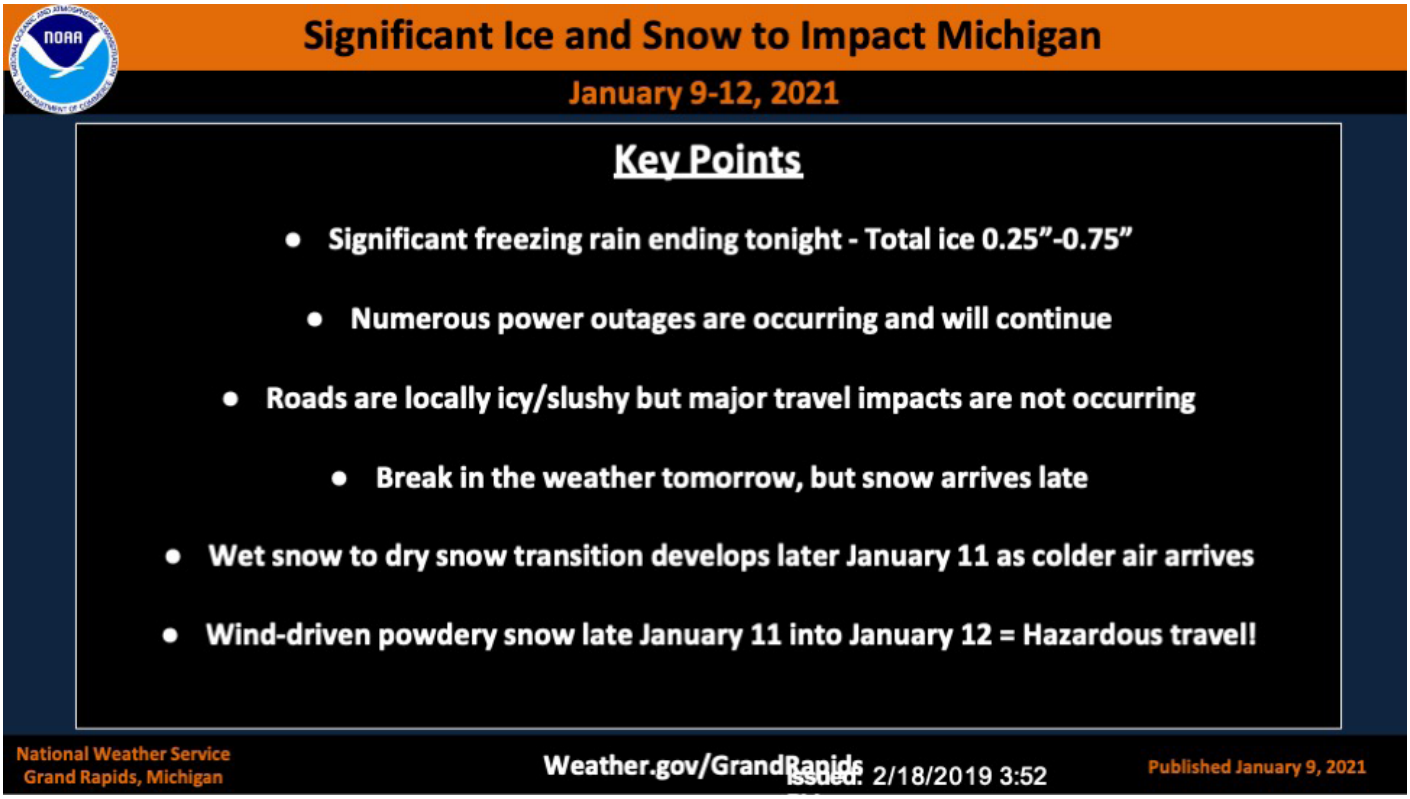

Potential Winter Storm Impacts: Ice
January 9, 2021
Potential Winter Storm Impacts
No Impacts
Minor Impacts
Major Impacts
Limited Impacts
Moderate Impacts
Extreme Impacts
Created by the National Weather Service Weather Prediction Center
Friday, January 8, 2021 11 AM ET
IMPACTS
DESCRIPTION
None
No Significant Weather Expected
Limited
Little to No Impact on Daily Life
Low risk for some travel inconveniences
Minor
Caution – Especially When Travelling
Plan for typical winter travel inconveniences
Moderate
Significant Inconveniences
Disruption of normal activities is likely
Travel is hazardous
Some utility outages and property damage possible
Major
Wide Disruption of All Normal Activities
Major delays and cancellations
Travel not recommended
Utility outages and property damage may be unavoidable
Extreme
Extremely Life Threatening
Historic storm with extended cancellation of daily activities
Travel may not be possible
Expansive outages and property damage
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 8, 2021

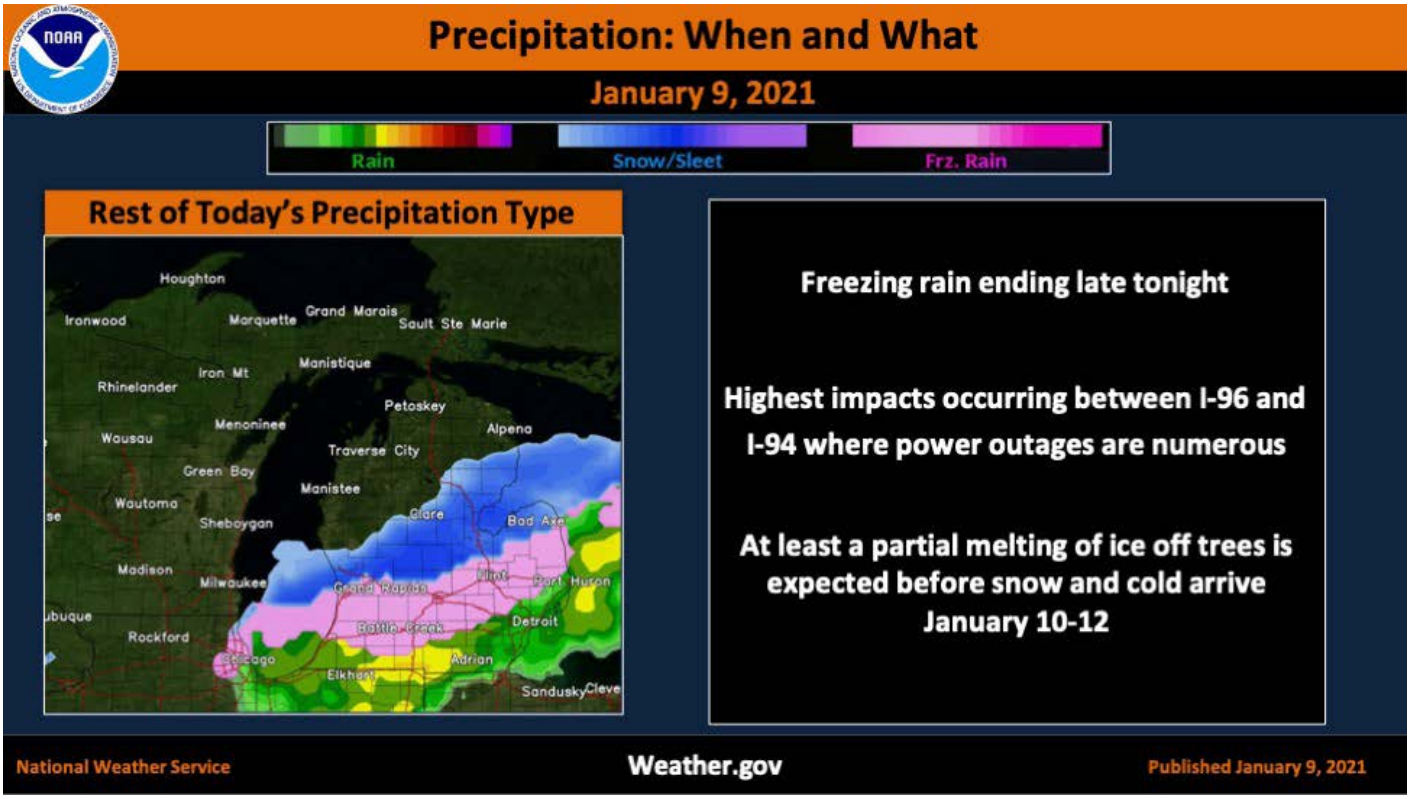

Forecast Ice Accumulations
January 9, 2021
Forecast Ice Accumulations
0.01 to 0.10 inch
0.10 to 0.25 inch
0.25 to 0.50 inch
0.50 to 0.75 inch
0.75 to 1.0 inch
1.0 to 2.0 inch
Greater than 2.0 inch
When:
Worst expected from 7am to 11pm
What to Expect:
Numerous power outages
Icy roads possible with temperatures around 32F
Morning + evening commutes delayed
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 8, 2021

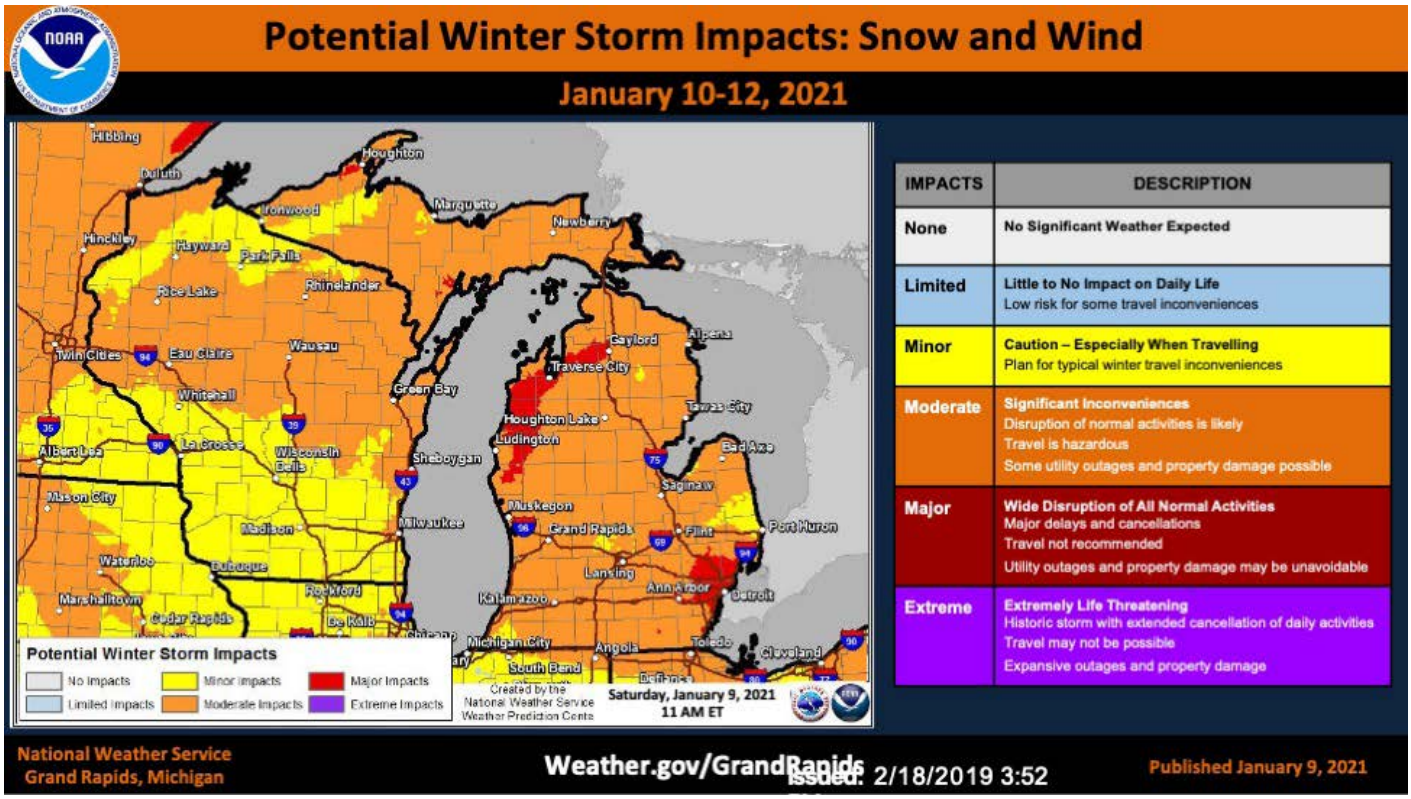

Probability for Significant Ice
January 9, 2021
% Chance for 0.50" or More
0%
Charlevoix
0%
Alpen
0%
Grayling
0%
Cadillac
0%
Ludington
4%
35%
Bad Axe
Big Rapids
34%
5%
Alma
Muskegon
49%
70%
Flint
Grand Rapids
63%
Lansing
55%
50%
2%
32%
Kalamazoo
Jackson
Detroit
St. Joseph
Details
Highest likelihood for power outages between I-96 and I-94
If temperatures warm to 33F, there will be little to no impacts to roads
The track of the heaviest ice could move further north with time
Power outages could be multi-day in the hardest hit areas
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 8, 2021


Precipitation: When and What
January 9, 2021
Rain
Snow/Sleet
Frz. Rain
Morning
Afternoon
Night
Houghton
Ironwood
Marquette
Grand Marais
Sault Ste Marie
Rhinelander
Iron Mt
Manistique
Petoskey
Wausau
Menominee
Alpena
Traverse City
Green Bay
Manistee
Wautoma
Sheboygan
Clare
Bad Axe
Madison
Milwaukee
Grand Rapids
Flint
Port Huron
Battle Creek
Detroit
Rockford
Chicago
Elkhart
Ayrion
Sandusky
Cleve
Dubuque
Ice most persistent from I-96 to I-94
Light snow north of this region is expected to produce only minor accumulations
Temperatures may stay above freezing south of I-94
National Weather Service
Weather.gov
Published January 8, 2021


Potential Winter Storm Impacts: Snow and Wind
January 10-12, 2021
Hibbing
Duluth
Houghton
Ironwood
Marquette
Newberry
Hayward
Park Falls
Rice Lake
Rhinelander
Twin Cities
Eau Claire
Wausau
Gaylord
Alpena
Traverse City
Whitehall
Green Bay
Houghton Lake
Ludington
Tawas City
Albert Lea
La Crosse
Wisconsin Dells
Sheboygan
Bad Axe
Saginaw
Mason City
Muskegon
Madison
Milwaukee
Grand Rapids
Flint
Port Huron
Waterloo
Dubuque
Lansing
Marshalltown
Rockford
Kalamazoo
Ann Arbor
Detroit
Cedar Rapids
DeKalb
Michigan City
Angola
Toledo
Cleveland
South Bend
Potential Winter Storm Impacts
No Impacts
Minor Impacts
Major Impacts
Limited Impacts
Moderate Impacts
Extreme Impacts
Created by the National Weather Service Weather Prediction Center
Friday, January 8, 2021 11 AM ET
IMPACTS
DESCRIPTION
None
No Significant Weather Expected
Limited
Little to No Impact on Daily Life
Low risk for some travel inconveniences
Minor
Caution – Especially When Travelling
Plan for typical winter travel inconveniences
Moderate
Significant Inconveniences
Disruption of normal activities is likely
Travel is hazardous
Some utility outages and property damage possible
Major
Wide Disruption of All Normal Activities
Major delays and cancellations
Travel not recommended
Utility outages and property damage may be unavoidable
Extreme
Extremely Life Threatening
Historic storm with extended cancellation of daily activities
Travel may not be possible
Expansive outages and property damage
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 8, 2021


Significant Ice and Snow to Impact Michigan
January 9-12, 2021
Key Points
Significant freezing rain ending tonight - Total ice 0.25”-0.75”
Numerous power outages are occurring and will continue
Roads are locally icy/slushy but major travel impacts are not occurring
Break in the weather tomorrow, but snow arrives late
Wet snow to dry snow transition develops later January 11 as colder air arrives
Wind-driven powdery snow late January 11 into January 12 = Hazardous travel!
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 9, 2021


Precipitation: When and What
January 9, 2021
Rain
Snow/Sleet
Frz. Rain
Rest of Today's Precipitation Type
Houghton
Ironwood
Marquette
Grand Marais
Sault Ste Marie
Manistique
Iron Mt
Rhinelander
Petoskey
Menominee
Alpena
Wausau
Traverse City
Green Bay
Manistee
Wautoma
Clare
Bad Axe
Sheboygan
Madison
Milwaukee
Flint
Port Huron
Dubuque
Rockford
Battle Creek
Detroit
Chicago
Adrian
Elkhart
Sandusky
Cleve
Freezing rain ending late tonight
Highest impacts occurring between I-96 and I-94 where power outages are numerous
At least a partial melting of ice off trees is expected before snow and cold arrive January 10-12
National Weather Service
Weather.gov
Published January 9, 2021


Potential Winter Storm Impacts: Snow and Wind
January 10-12, 2021
Hibbing
Duluth
Houghton
Ironwood
Marquette
Newberry
Hinckley
Hayward
Park Falls
Rice Lake
Rhinelander
Twin Cities
Eau Claire
Wausau
Gaylord
Alpena
Traverse City
Whitehall
Green Bay
Houghton Lake
Tawas City
Albert Lea
La Crosse
Wisconsin Dells
Ludington
Sheboygan
Bad Axe
Saginaw
Mason City
Muskegon
Madison
Milwaukee
Grand Rapids
Flint
Port Huron
Waterloo
Dubuque
Lansing
Ann Arbor
Detroit
Marshalltown
Cedar Rapids
Kalamazoo
De Kalb
Michigan City
Angola
Toledo
Cleveland
South Bend
Potential Winter Storm Impacts
No Impacts
Minor Impacts
Major Impacts
Limited Impacts
Moderate Impacts
Extreme Impacts
Created by the National Weather Service Weather Prediction Cente
Saturday, January 9, 2021 11 AM ET
IMPACTS
DESCRIPTION
None
No Significant Weather Expected
Limited
Little to No Impact on Daily Life
Low risk for some travel inconveniences
Minor
Caution – Especially When Travelling
Plan for typical winter travel inconveniences
Moderate
Significant Inconveniences
Disruption of normal activities is likely
Travel is hazardous
Some utility outages and property damage possible
Major
Wide Disruption of All Normal Activities
Major delays and cancellations
Travel not recommended
Utility outages and property damage may be unavoidable
Extreme
Extremely Life Threatening
Historic storm with extended cancellation of daily activities
Travel may not be possible
Expansive outages and property damage
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
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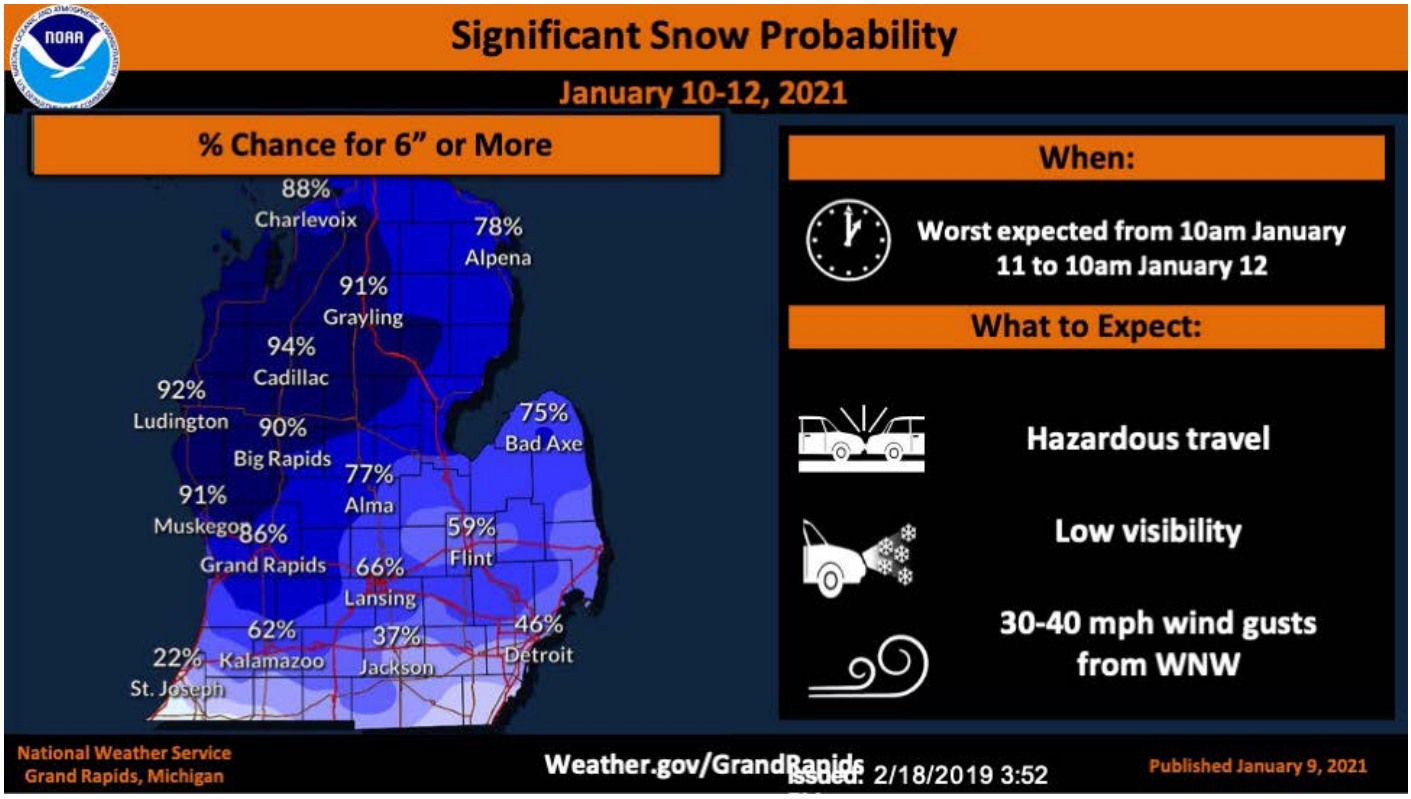
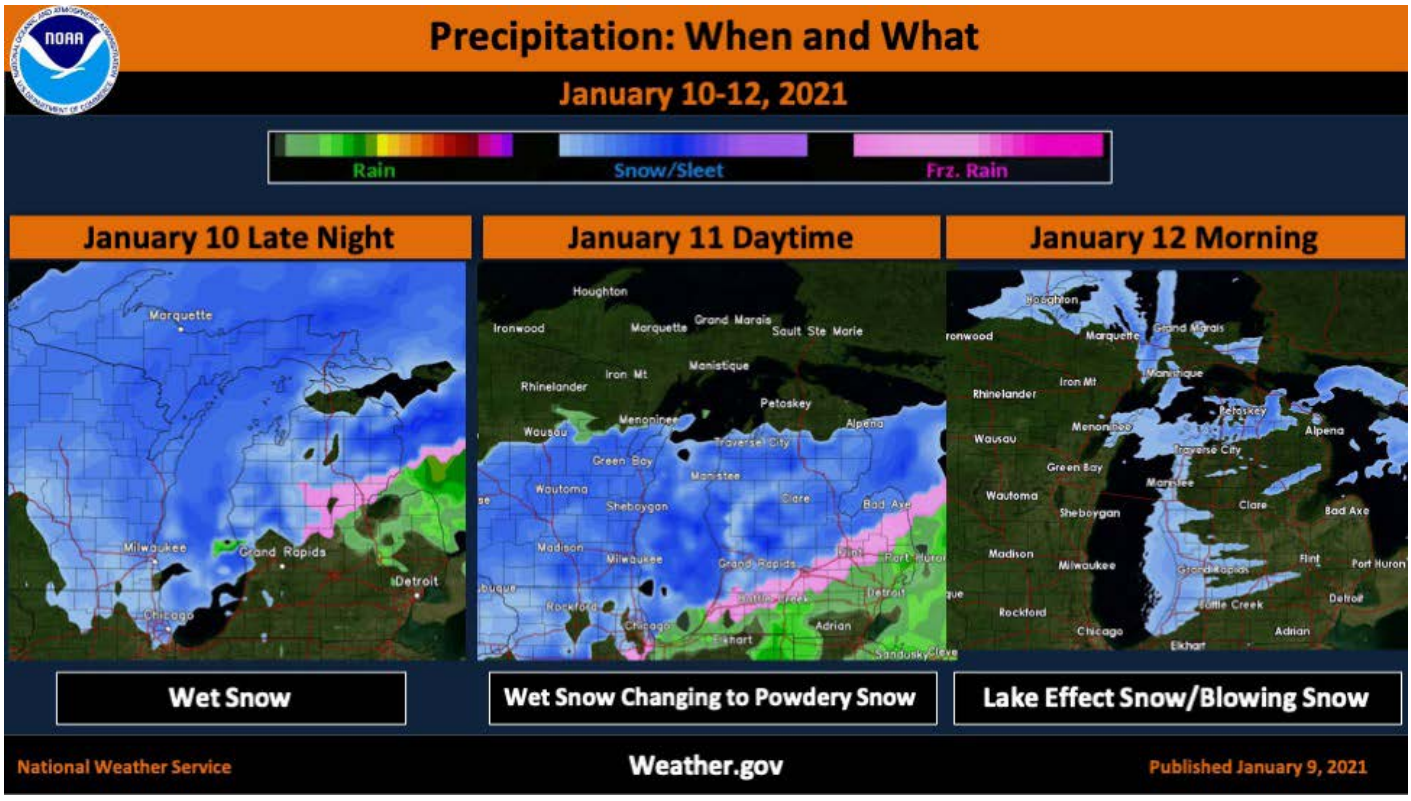

Significant Snow Probability
January 10-12, 2021
% Chance for 6" or More
88%
Charlevoix
78%
Alpena
91%
Grayling
94%
Cadillac
92%
Ludington
90%
Big Rapids
75%
Bad Axe
77%
Alma
91%
Muskegon
86%
Grand Rapids
59%
Flint
66%
Lansing
62%
37%
46%
Detroit
22%
Kalamazoo
Jackson
St. Joseph
When:
Worst expected from 10am January 11 to 10am January 12
What to Expect:
Hazardous travel
Low visibility
30-40 mph wind gusts from WNW
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 9, 2021


Precipitation: When and What
January 10-12, 2021
Rain
Snow/Sleet
Frz. Rain
January 10 Late Night
January 11 Daytime
January 12 Morning
Houghton
Ironwood
Marquette
Grand Marais
Sault Ste Marie
Manistique
Rhinelander
Iron Mt
Petoskey
Menominee
Wausau
Alpena
Traverse City
Green Bay
Manistee
Wautoma
Sheboygan
Clare
Bad Axe
Madison
Milwaukee
Grand Rapids
Flint
Port Huron
Detroit
Rockford
Chicago
Adrian
Elkhart
Sandusky
Battle Creek
Wet Snow
Wet Snow Changing to Powdery Snow
Lake Effect Snow/Blowing Snow
National Weather Service
Weather.gov
Published January 9, 2021

Significant Snow and Wind to Impact Michigan

January 10-12, 2021

Key Points

- Very hazardous travel likely with near blizzard conditions at times
- Several hours of wet snow starts late tonight creating greasy / slippery roads
- Temperatures fall into the teens and 20s with powdery snow late January 11
- January 12 morning commute looks very poor especially for N-S roads
- Gusty winds from WNW over 40 mph at times creating blowing/drifting snow

National Weather Service
Grand Rapids, Michigan

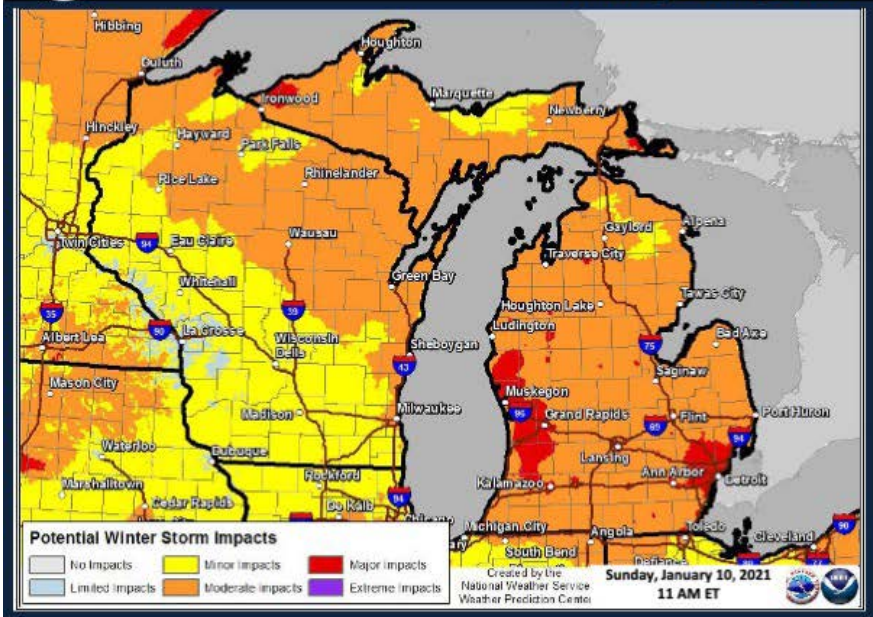
Weather.gov/GrandRapids

Issued: 2/18/2019 3:52

Published January 10, 2021

Potential Winter Storm Impacts: Snow and Wind

January 10-12, 2021



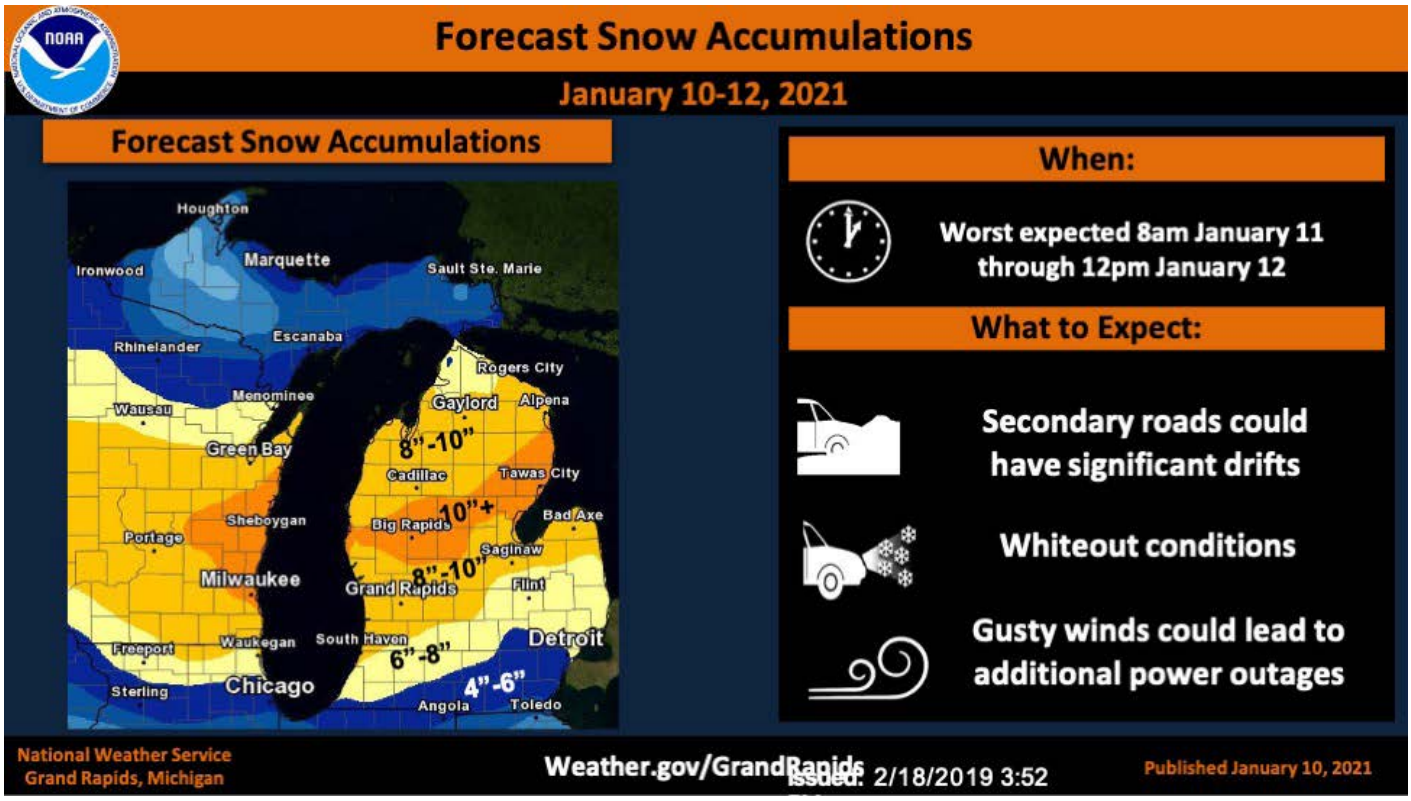
IMPACTS	DESCRIPTION
None	No Significant Weather Expected
Limited	Little to No Impact on Daily Life Low risk for some travel inconveniences
Minor	Caution – Especially When Travelling Plan for typical winter travel inconveniences
Moderate	Significant Inconveniences Disruption of normal activities is likely Travel is hazardous Some utility outages and property damage possible
Major	Wide Disruption of All Normal Activities Major delays and cancellations Travel not recommended Utility outages and property damage may be unavoidable
Extreme	Extremely Life Threatening Historic storm with extended cancellation of daily activities Travel may not be possible Expansive outages and property damage

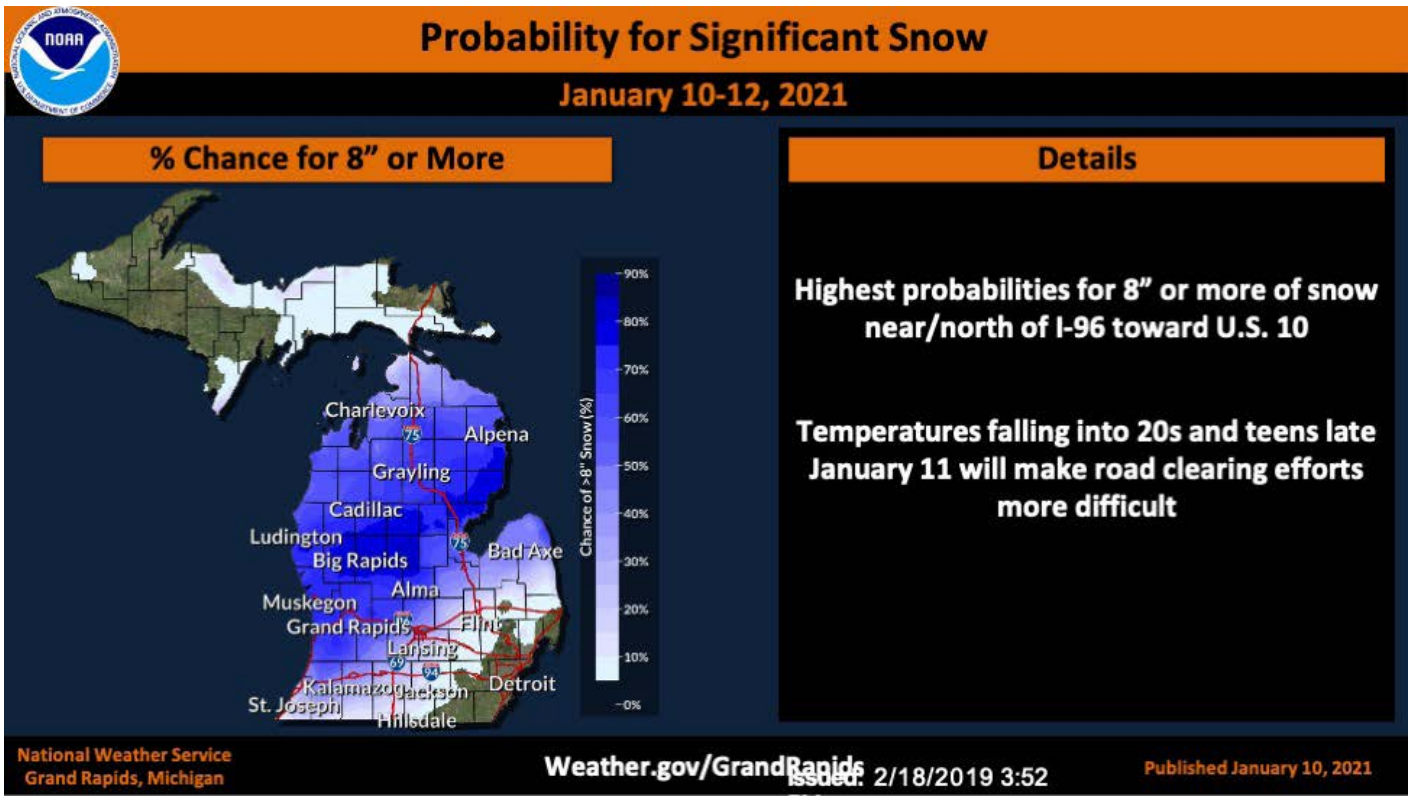
National Weather Service
Grand Rapids, Michigan

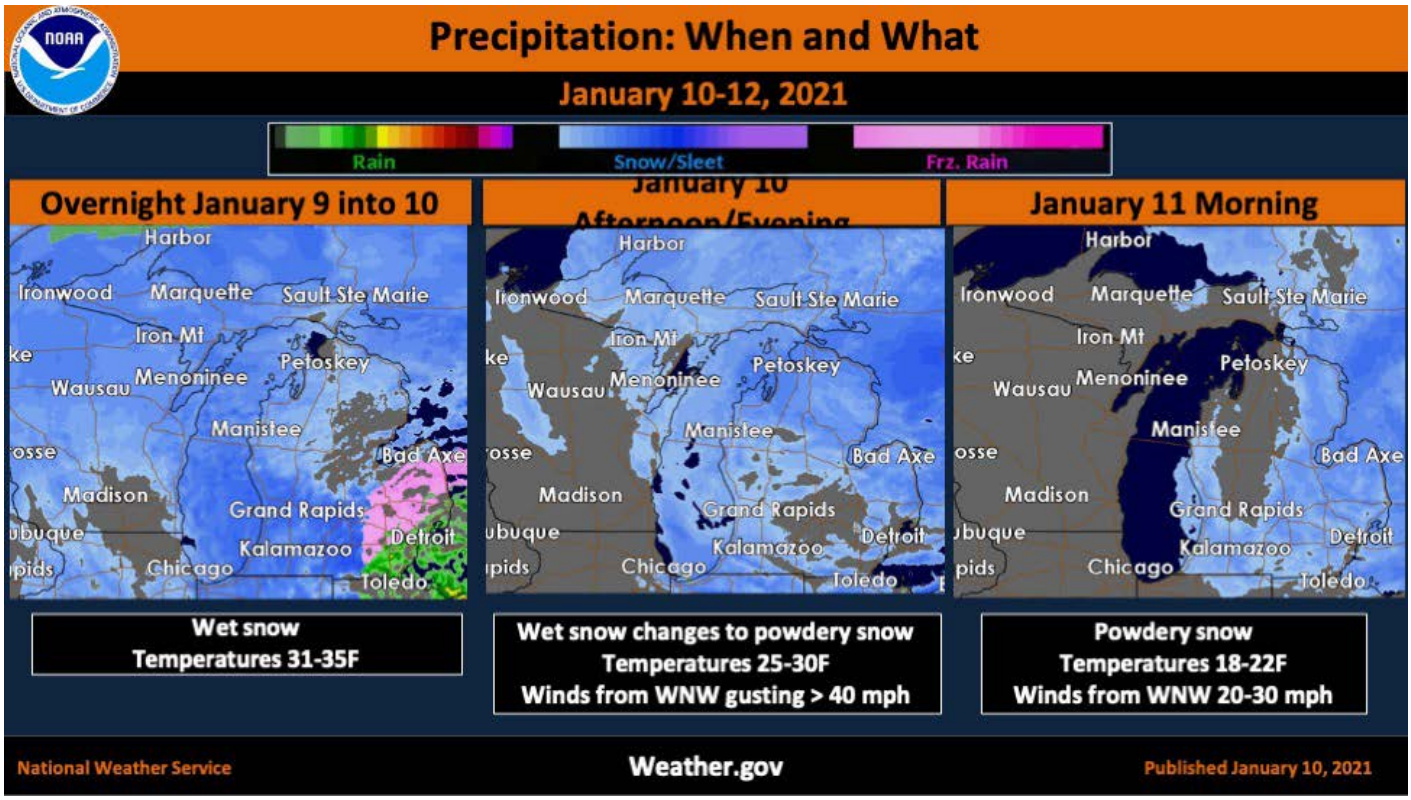
Weather.gov/GrandRapids

Issued: 2/18/2019 3:52

Published January 10, 2021


Forecast Snow Accumulations
January 10-12, 2021
Forecast Snow Accumulations
Houghton
Marquette
Ironwood
Sault Ste. Marie
Rhinelander
Escanaba
Rogers City
Menominee
Wausau
Gaylord
Alpena
Green Bay
8"-10"
Cadillac
Tawas City
Sheboygan
Big Rapids
10"+
Bad Axe
Portage
Saginaw
Milwaukee
8"-10"
Grand Rapids
Flint
Freeport
Waukegan
South Haven
Detroit
6"-8"
Sterling
Chicago
4"-6"
Angola
Toledo
When:
Worst expected 8am January 11 through 12pm January 12
What to Expect:
Secondary roads could have significant drifts
Whiteout conditions
Gusty winds could lead to additional power outages
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 10, 2021


Probability for Significant Snow
January 10-12, 2021
% Chance for 8" or More
Charlevoix
Alpena
Grayling
Cadillac
Ludington
Big Rapids
Bad Axe
Alma
Muskegon
Grand Rapids
Flint
Lansing
Kalamazoo
Jackson
Detroit
St. Joseph
Hillsdale
Chance of >8" Snow (%)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Details
Highest probabilities for 8" or more of snow near/north of I-96 toward U.S. 10
Temperatures falling into 20s and teens late January 11 will make road clearing efforts more difficult
National Weather Service
Grand Rapids, Michigan
Weather.gov/GrandRapids
Issued: 2/18/2019 3:52
Published January 10, 2021



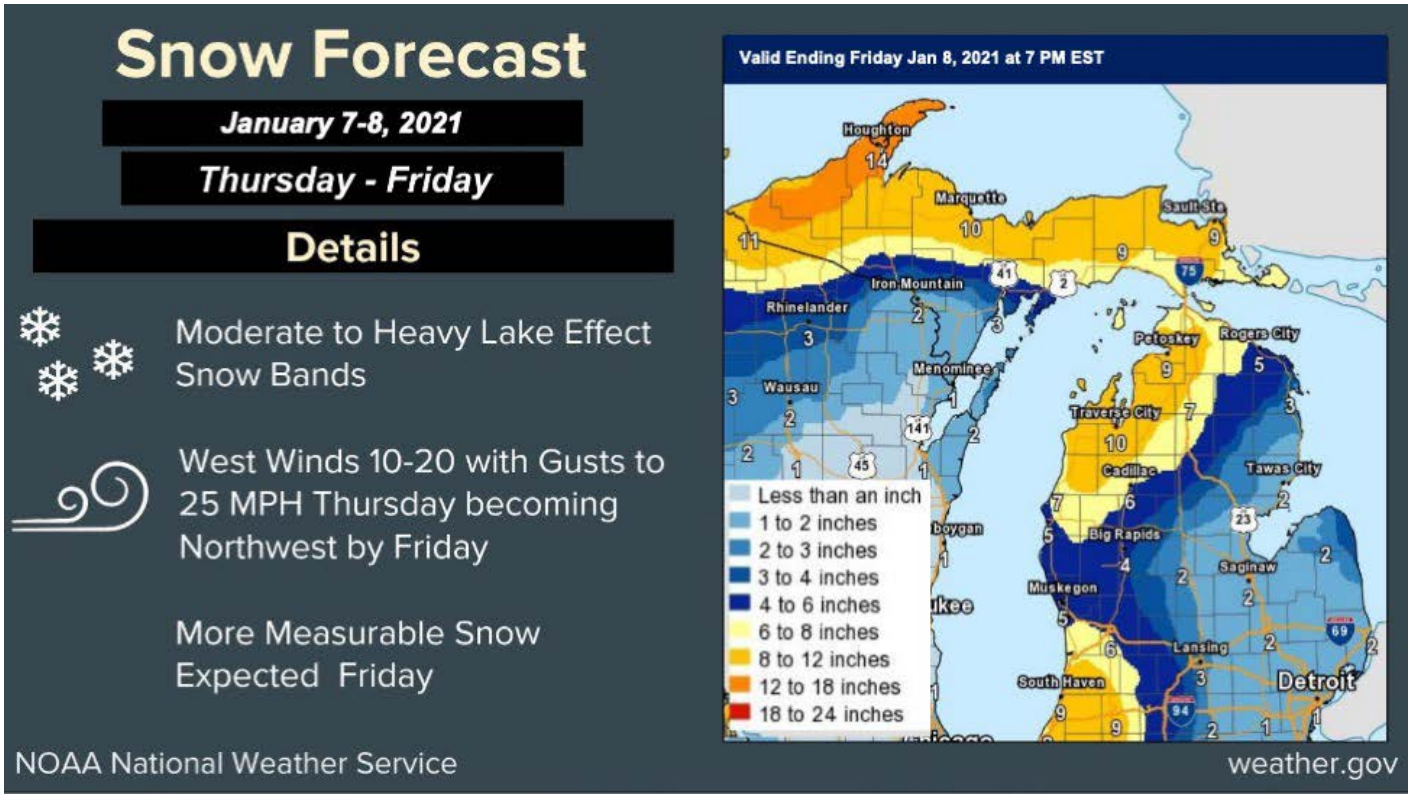
Scenario 2

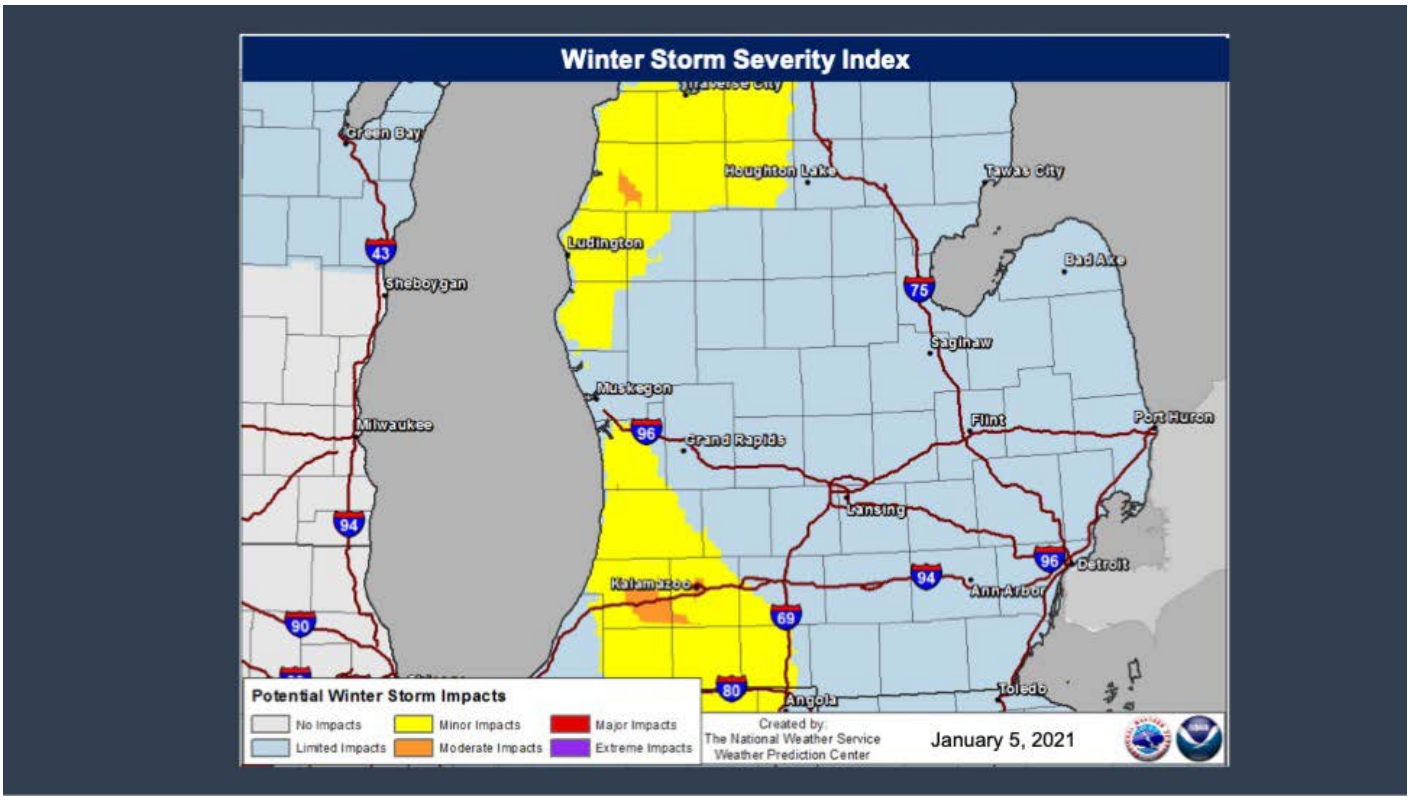
Winter Weather Scenario

T-2 Jan 5, 2021

General Overview

Lake effect snow looks likely toward the end of the week. The best chance of seeing accumulating snow will be toward the lakeshore, mainly from Kalamazoo west to Holland. Accumulating snow is likely west of US-127 and scattered snow showers elsewhere.


Snow Forecast
January 7-8, 2021
Thursday - Friday
Details
Moderate to Heavy Lake Effect Snow Bands
West Winds 10-20 with Gusts to 25 MPH Thursday becoming Northwest by Friday
More Measurable Snow Expected Friday
NOAA National Weather Service
Valid Ending Friday Jan 8, 2021 at 7 PM EST
Less than an inch
1 to 2 inches
2 to 3 inches
3 to 4 inches
4 to 6 inches
6 to 8 inches
8 to 12 inches
12 to 18 inches
18 to 24 inches
Houghton
Marquette
Sault Ste
Iron Mountain
Rhinelander
Menominee
Wausau
Petoskey
Rogers City
Traverse City
Cadillac
Tawas City
Big Rapids
Saginaw
Muskegon
Lansing
South Haven
Detroit
weather.gov


Winter Storm Severity Index
Green Bay
Houghton Lake
Tawas City
Ludington
Sheboygan
Bad Axe
Saginaw
Muskegon
Milwaukee
Grand Rapids
Flint
Port Huron
Lansing
Detroit
Kalamazoo
Ann Arbor
Toledo
Angola
Potential Winter Storm Impacts
No Impacts
Minor Impacts
Major Impacts
Limited Impacts
Moderate Impacts
Extreme Impacts
Created by:
The National Weather Service
Weather Prediction Center
January 5, 2021

Winter Weather Scenario

T-1 Jan 6, 2021

General Overview

Winter is definitely making a return to West Michigan. Winter Storm Warnings and Winter Weather Advisories have been issued for Jan 7th and Jan 8th along the lake shore and as far inland as Battle Creek. A cold front will sweep across Lower Michigan today and usher in colder air. Across Mid Michigan, mostly cloudy skies are expected with a 30 percent chance of snow showers tonight and a 50 percent chance of snow showers tomorrow, Jan 7th. Winds from the west will gust to around 30 mph across much of Lower Michigan which may result in lower visibilities where the snow is falling.

Snow Forecast

January 7-8, 2021

Thursday - Friday

Details

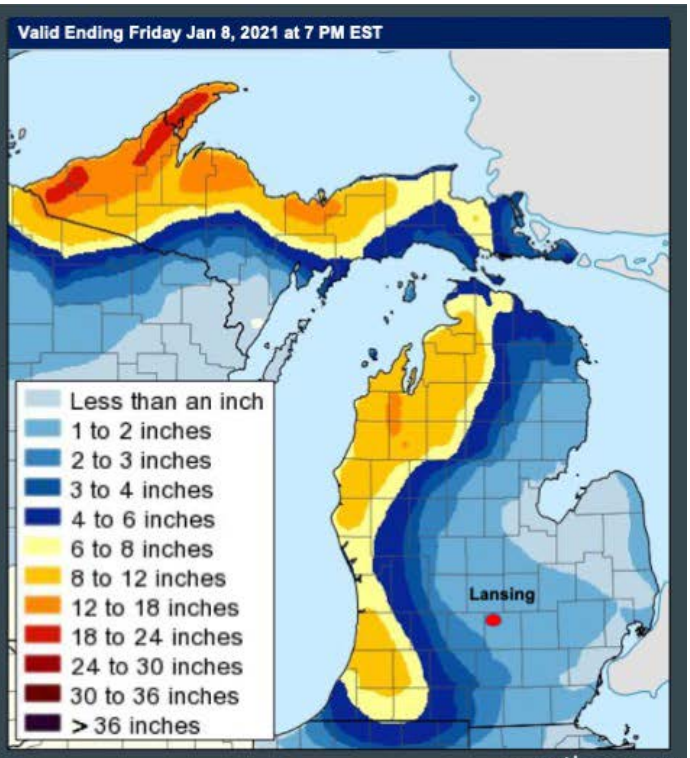
SNOW

Fluffy Snow
Greater Than 1 Inch/Hour
Rapid local changes expected

BLOWING SNOW

Will Blow/Drift Over Roads
Occasional Whiteouts

Most Intense Snowfall
Thursday evening



NOAA National Weather Service

weather.gov

Peak Wind Gusts

January 7-8, 2021

Thursday - Friday

Details

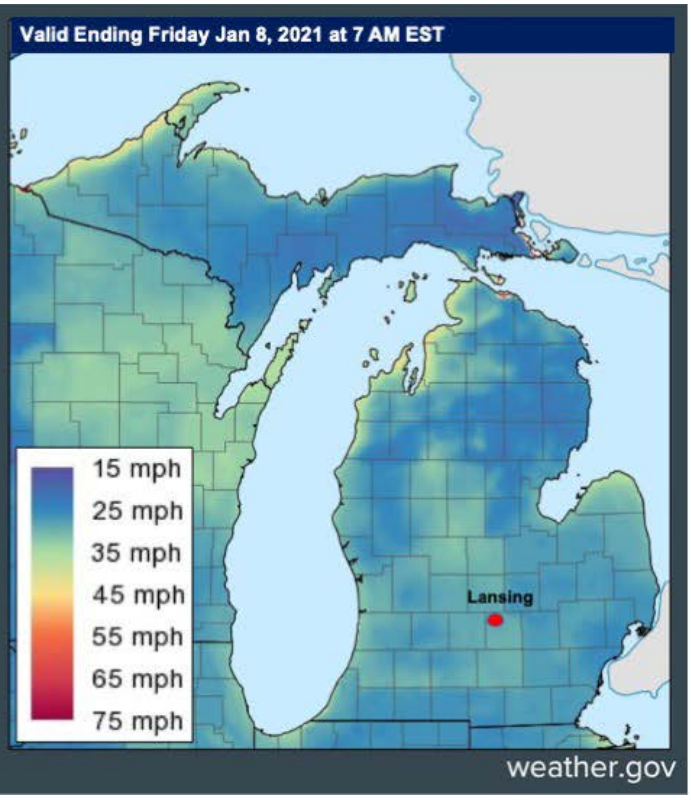
Winds from the West 15-25 mph with Gusts over 30 mph

BLOWING SNOW

Will Blow/Drift Over Roads Especially North/South Roads Whiteouts at Times

Strongest Winds Occur Thursday and Thursday Night

NOAA National Weather Service



Lowest Wind Chill

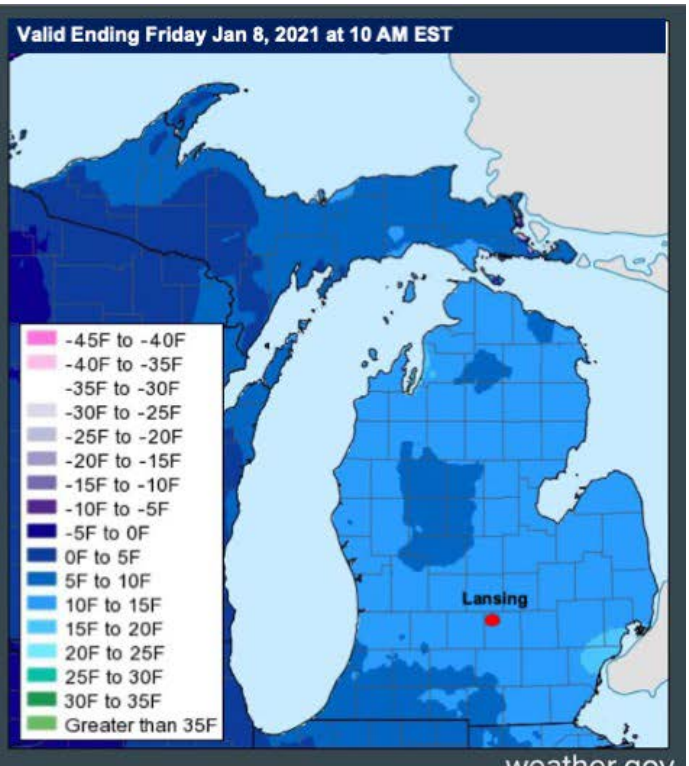
January 7-8, 2021

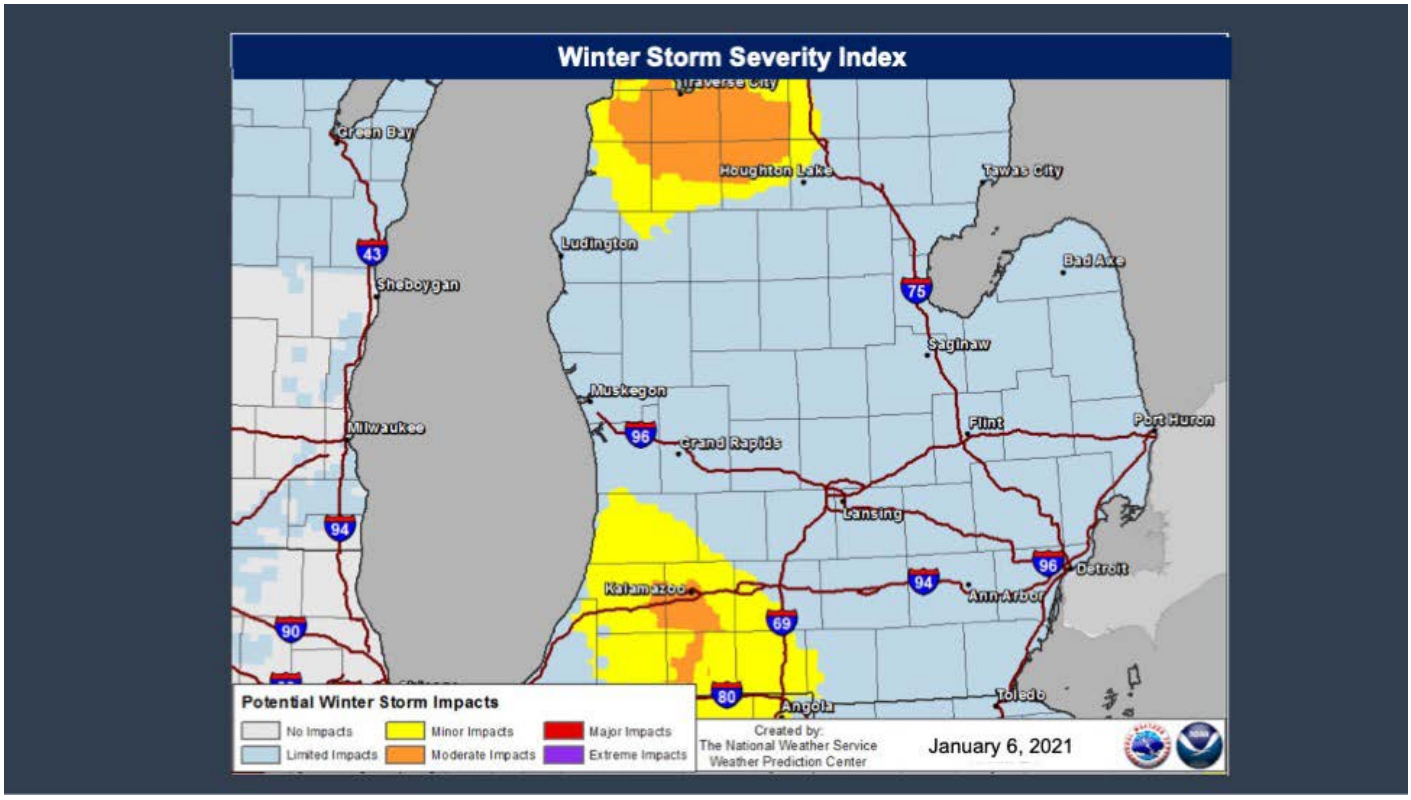
Wind Chill Range: +15 to 0 degrees

Wind Chill	Time to Frostbite
0 to -15	30-60 minutes
-15 to -30	15 to 30 minutes
-30 to -50	Less than 15 minutes
Less than -50	Less than 5 minutes

Lowest Wind Chills Occur Thursday Morning

NOAA National Weather Service

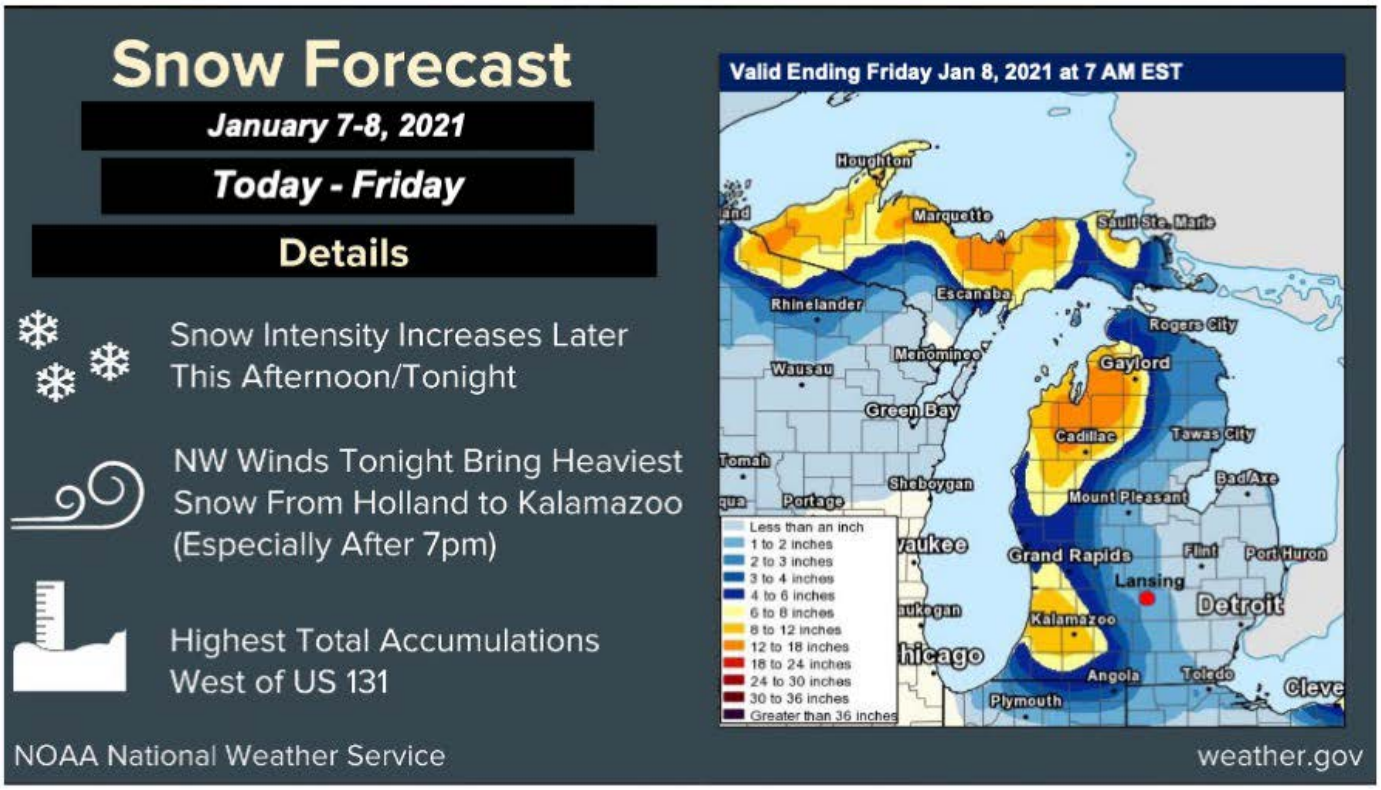


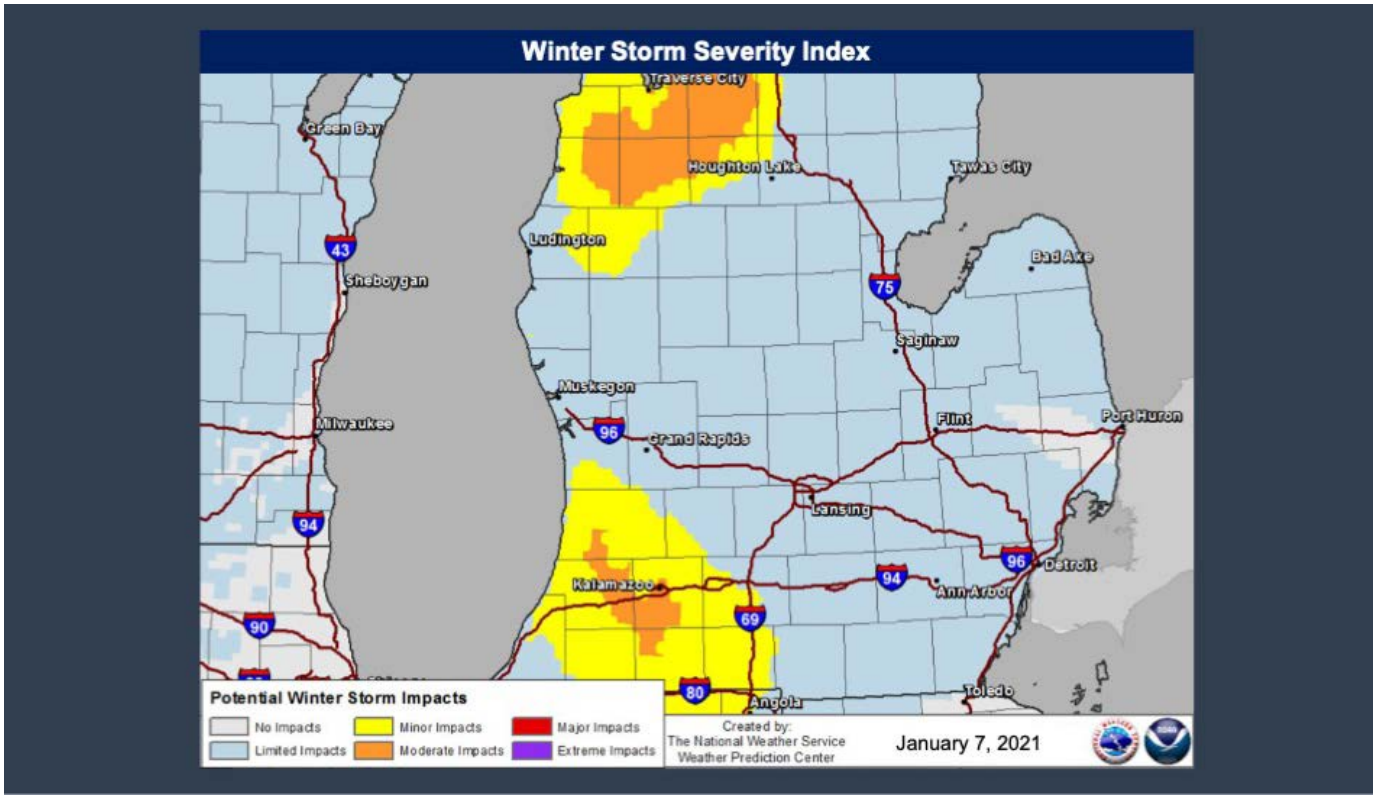


Winter Weather Scenario
T-0 Jan 7, 2021

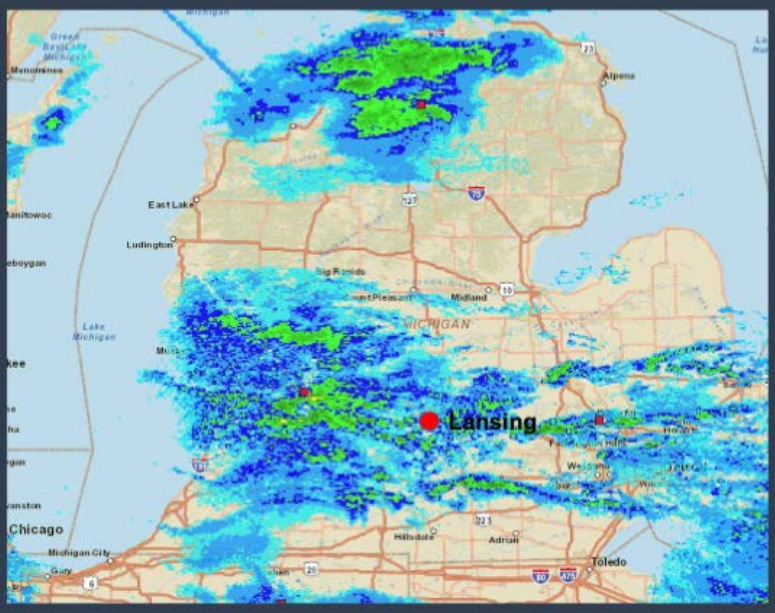
General Overview

A cold front has just passed through the area with a reinforcing shot of cold air poised to move through tonight. Winds from the northwest behind the front will likely create lake effect snow showers. The snow showers will be heaviest along the lake shore. Farther inland, snow showers will be scattered in nature and any accumulations will be an inch or less. Across Mid-Michigan, a 30 to 50 percent chance of snow is expected today and high temperatures will remain nearly steady in the upper 20s. Northwest winds 15 to 25 mph will gust to 30 mph at times. Freezing rain is not expected. Any snow that falls, will likely reduce visibility to less than a mile due to the gusty winds.


Snow Forecast
January 7-8, 2021
Today - Friday
Details
Snow Intensity Increases Later This Afternoon/Tonight
NW Winds Tonight Bring Heaviest Snow From Holland to Kalamazoo (Especially After 7pm)
Highest Total Accumulations West of US 131
NOAA National Weather Service
Valid Ending Friday Jan 8, 2021 at 7 AM EST
Houghton
Marquette
Sault Ste. Marie
Escanaba
Rhinelander
Rogers City
Menominee
Wausau
Gaylord
Green Bay
Cadillac
Tawas City
Tomah
Sheboygan
Portage
Bad Axe
Mount Pleasant
Grand Rapids
Flint
Port Huron
Lansing
Detroit
Kalamazoo
Angola
Toledo
Plymouth
Less than an inch
1 to 2 inches
2 to 3 inches
3 to 4 inches
4 to 6 inches
6 to 8 inches
8 to 12 inches
12 to 18 inches
18 to 24 inches
24 to 30 inches
30 to 36 inches
Greater than 36 inches
weather.gov


Winter Storm Severity Index
Traverse City
Green Bay
Houghton Lake
Tawas City
Ludington
Bad Axe
Sheboygan
Saginaw
Muskegon
Milwaukee
Grand Rapids
Flint
Port Huron
Lansing
Detroit
Kalamazoo
Ann Arbor
Angola
Toledo
43
75
96
94
90
69
80
Potential Winter Storm Impacts
No Impacts
Limited Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Created by:
The National Weather Service
Weather Prediction Center
January 7, 2021

Radar at 7AM January 7, 2021



Summary of Event

- This was an actual event that occurred December 8, 2016. Lake effect snow showers developed as expected. While the heaviest snow fell along the lake shore, a few snow bands migrated inland toward the Lansing area. Temperatures in the upper 20s combined with the snow created black ice on I-96 near the Ingham/Livingston county line, east of Lansing. This resulted in a 53 car pileup in which 3 people died. EB I-96 was closed 6 hours and WB I-96 was closed 13 hours.

Photos – Courtesy: Lansing State Journal

Winter Storm Severity Index

Improving Storm Readiness through Severity
and Social Impact Forecasting

ROUND TWO - BOSTON

This presentation from the Nurture Nature Center, Inc. was prepared under grant award number NA20OAR4590355 from the Joint Technology Transfer Initiative Program of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions and recommendations are those of the author(s) and do not necessarily reflect those of NOAA or of the U.S. Department of Commerce.

Focus Group Agenda

Introduction to the Project and Introduction of all Participants

Pre-session survey

Scenario 1 (5 Day)

Scenario 2 (3 Day)

Post-session survey

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Tuesday Afternoon Short "One-Pager" Email, T-5

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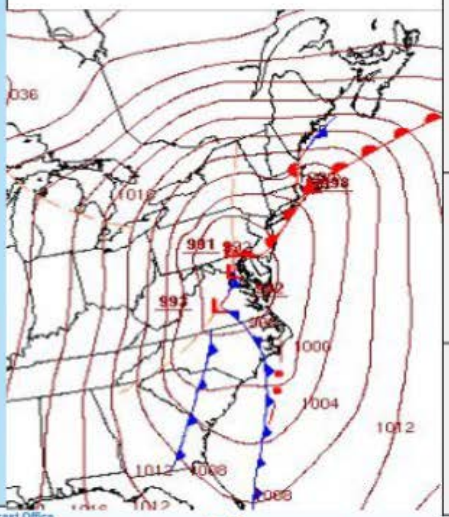
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Potential Weekend Winter Storm

- potentially starting as period of heavy, wet snow, changing to ice then to heavy rain into the day on Sunday



TIMING	▪ Late Saturday and Sunday
HAZARDS & IMPACTS	▪ Could be an area with significant ice accumulations, resulting in power outages ▪ Could be areas with heavy/wet snow, leading to travel issues and potential power outages
NWS ALERTS	▪ None at this time
FORECAST CHALLENGES	▪ Storm track is the key to location and amounts of rain vs freezing rain vs snow locations ▪ Forecasts are expected to change considerably over the next few days

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WRN WEATHER-READY NATION

Wednesday Afternoon Briefing
T-4

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WRN WEATHER-READY NATION

Multi-Faceted Winter Storm
Saturday Night – Sunday Night

National Weather Service
Decision Support Briefing
Wednesday Afternoon

What Has Changed?

- ✓ First briefing
- ✓ No alerts yet
- ✓ Mix of heavy & wet snow, ice, heavy rain followed by very cold air.

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Main Points

Hazard	Impacts	Location	Timing
Heavy Wet Snow	Precipitation begins as heavy, wet snow. 2+ inch/hour rates.	All of Southern New England, except the extreme south coast.	10 PM Saturday – Mid Morning Sunday for some. Some locations remain all snow through Sunday.
Freezing Rain/ Sleet	A period of freezing rain and sleet with more than 0.5 inch ice accumulations possible.	Greatest ice accumulations across the central to northeast interior.	Sunday morning – afternoon.
Flash Freeze	Temperatures drop rapidly below freezing. Rain changes back to sleet or freezing rain. Wet surfaces freeze. Bitter cold by Sunday night.	All of Southern New England	Late Sunday afternoon – Sunday Night

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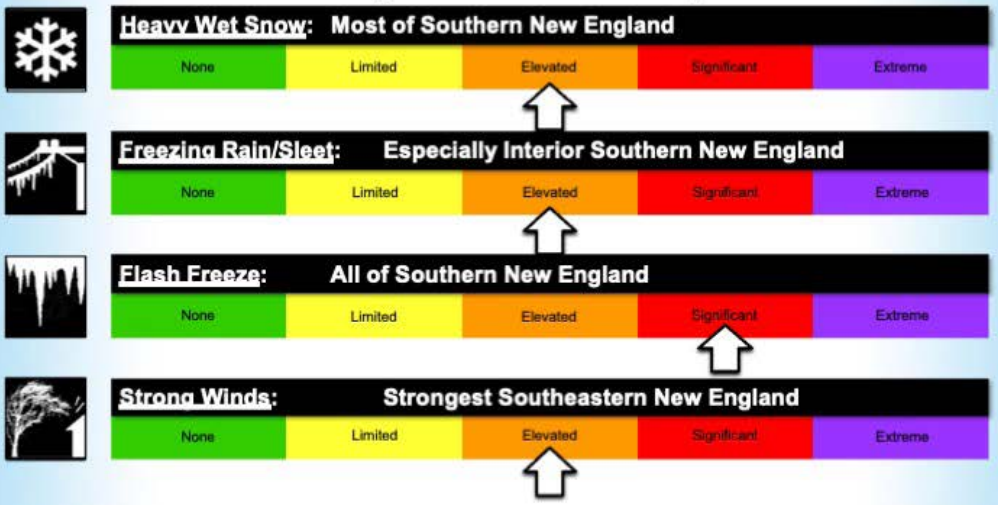
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Summary of Greatest Impacts



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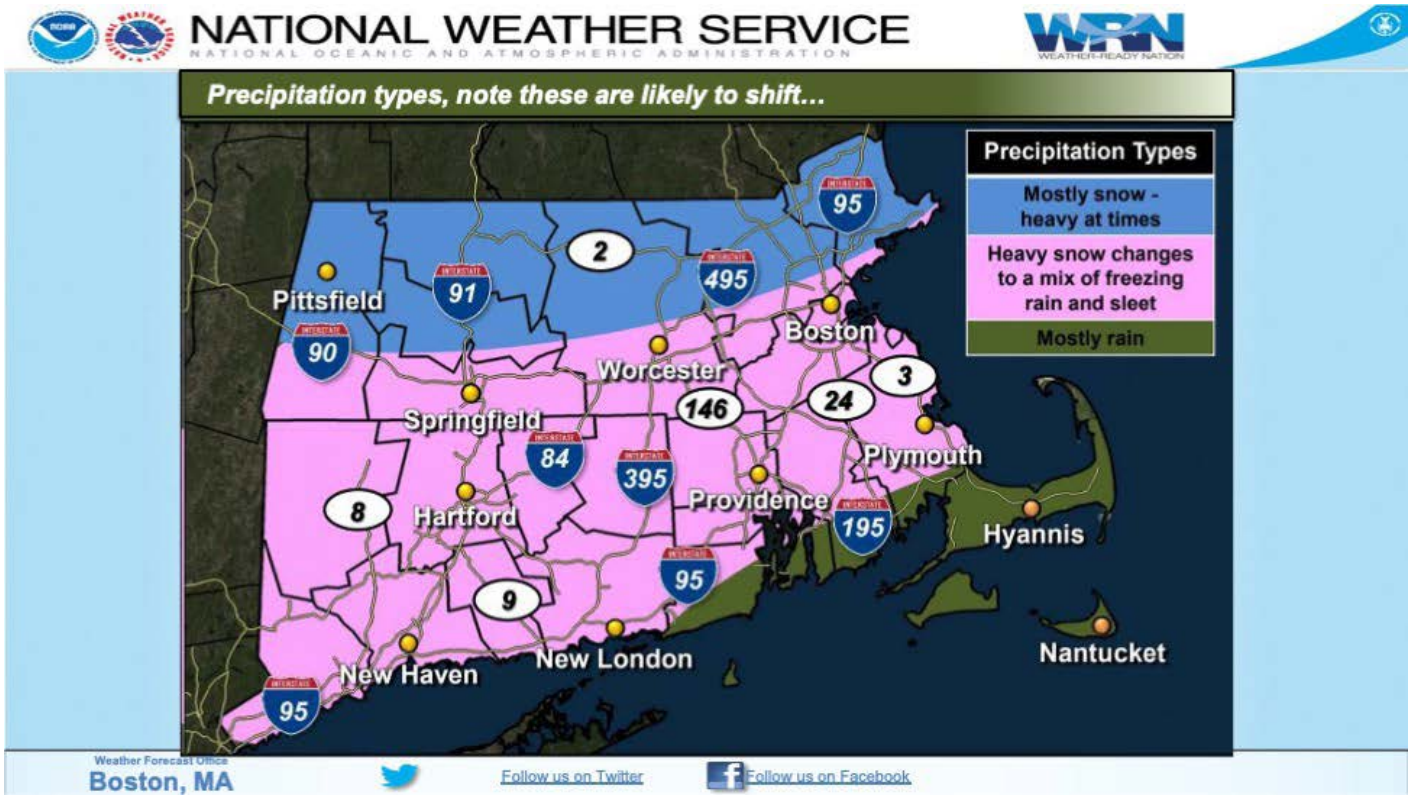
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Precipitation types, note these are likely to shift...
Precipitation Types
Mostly snow - heavy at times
Heavy snow changes to a mix of freezing rain and sleet
Mostly rain
Pittsfield
Springfield
Worcester
Boston
Hartford
Providence
Plymouth
Hyannis
Nantucket
New Haven
New London
2
91
90
495
95
146
24
3
84
395
8
195
9
95
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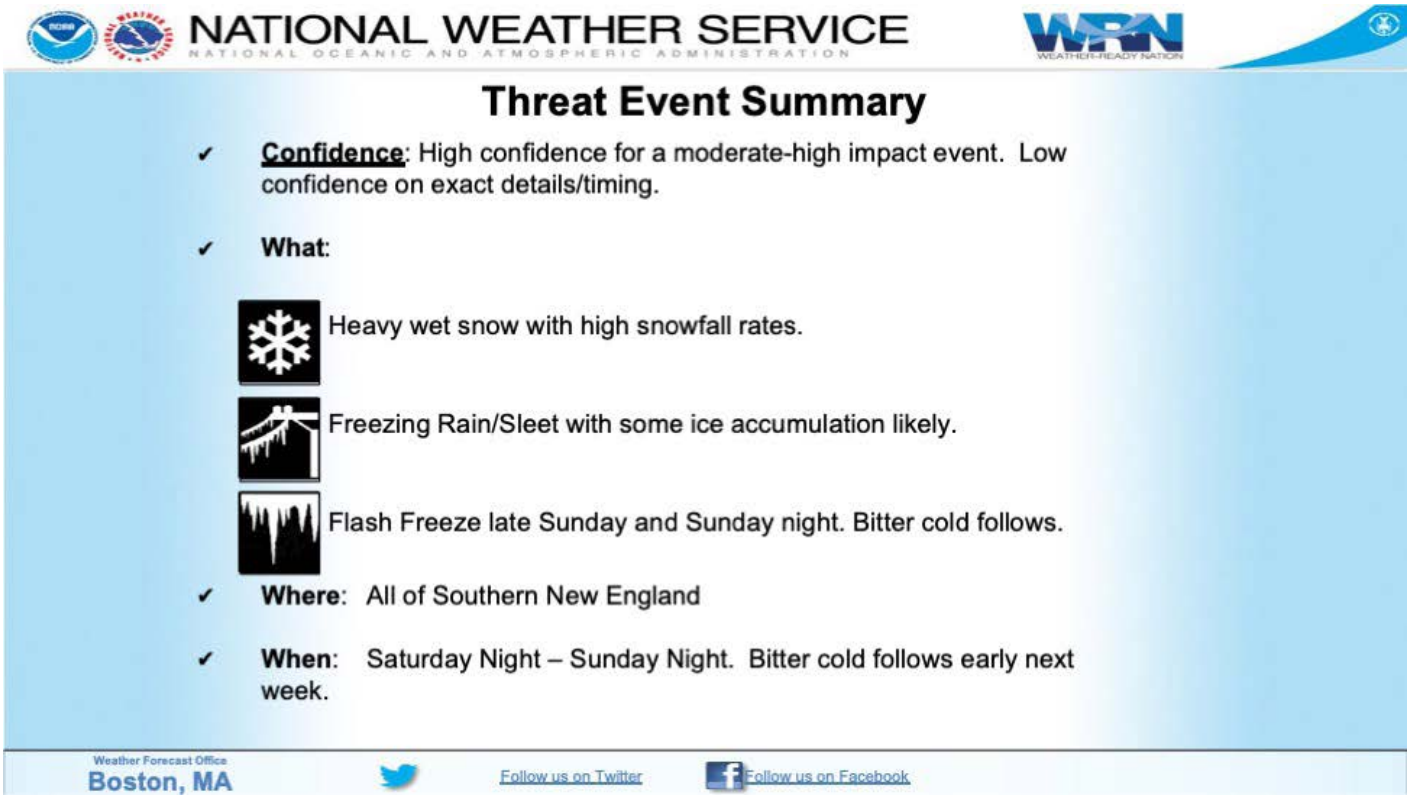
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Threat Event Summary
✔ Confidence: High confidence for a moderate-high impact event. Low confidence on exact details/timing.
✔ What:
Heavy wet snow with high snowfall rates.
Freezing Rain/Sleet with some ice accumulation likely.
Flash Freeze late Sunday and Sunday night. Bitter cold follows.
✔ Where: All of Southern New England
✔ When: Saturday Night – Sunday Night. Bitter cold follows early next week.
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Thursday Afternoon Briefing
T-3

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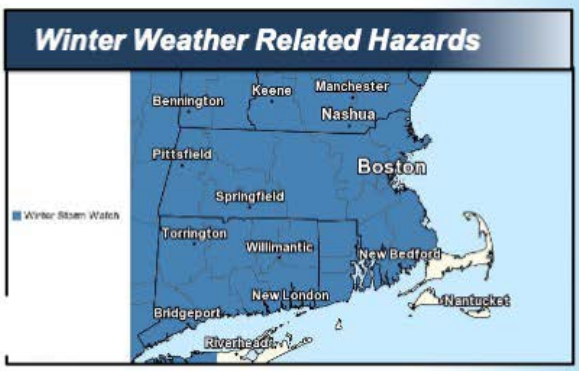
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Multi-Faceted Winter Storm
Saturday Night – Sunday Night

National Weather Service
Decision Support Briefing
Thursday Afternoon

What Has Changed?

- ✓ Slightly lower snow totals due to more sleet/freezing rain.
- ✓ Winter Storm Watch for all of southern New England, except Cape Cod and Islands



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Friday Afternoon Briefing
T-2

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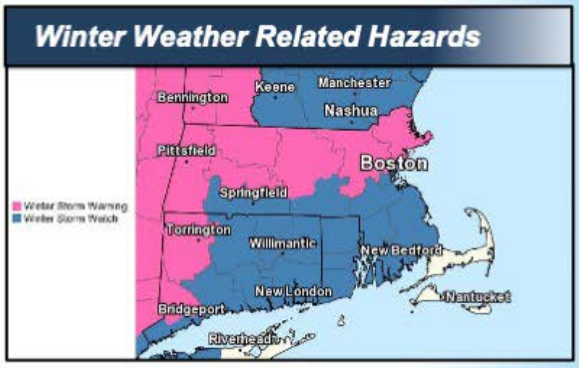
Multi-Faceted Winter Storm
Saturday Night – Sunday Night

National Weather Service
Decision Support Briefing # 5
Friday, 3 PM

What Has Changed?

- ✓ Minor adjustments to snow and ice accumulations
- ✓ Winter Storm Warnings issued for MA to the north of the Mass Pike.



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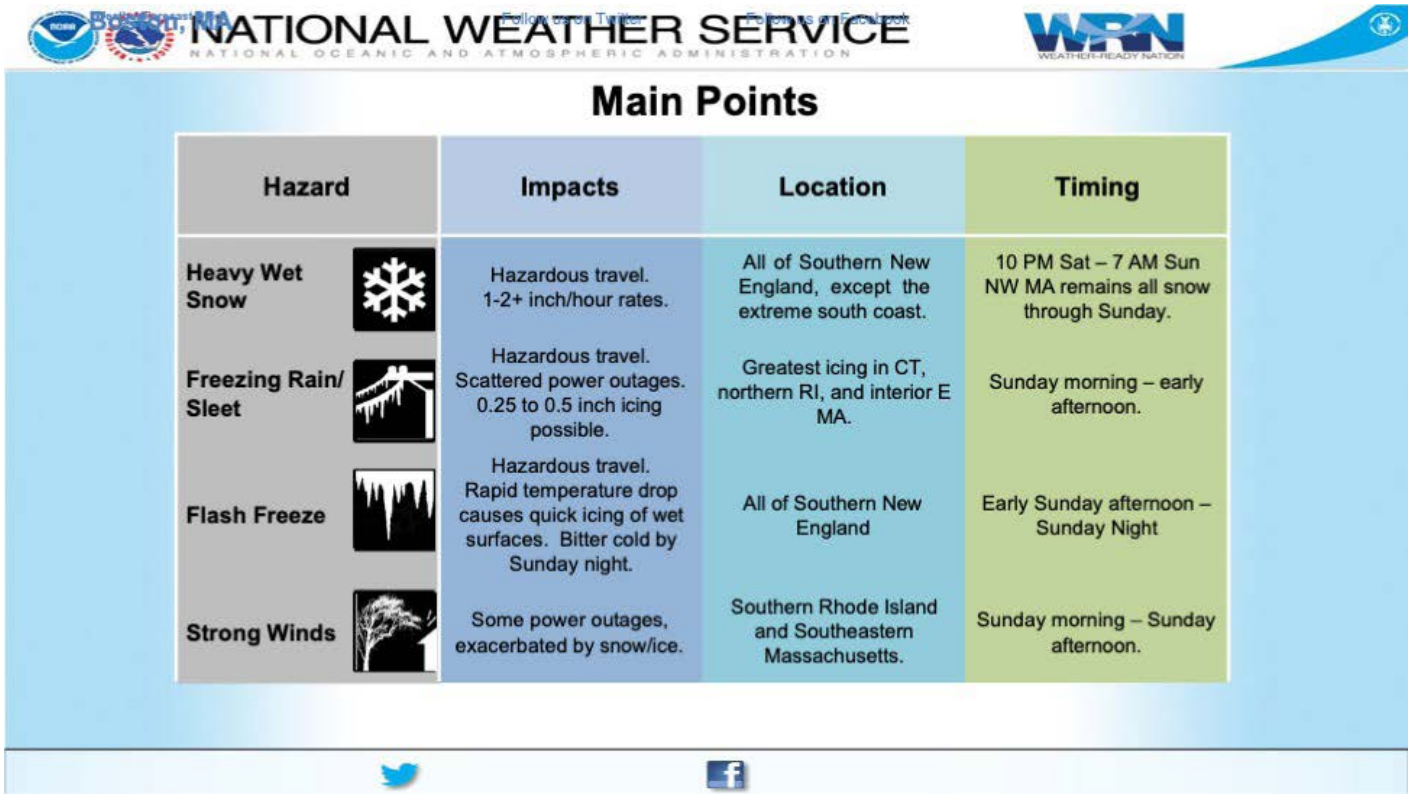
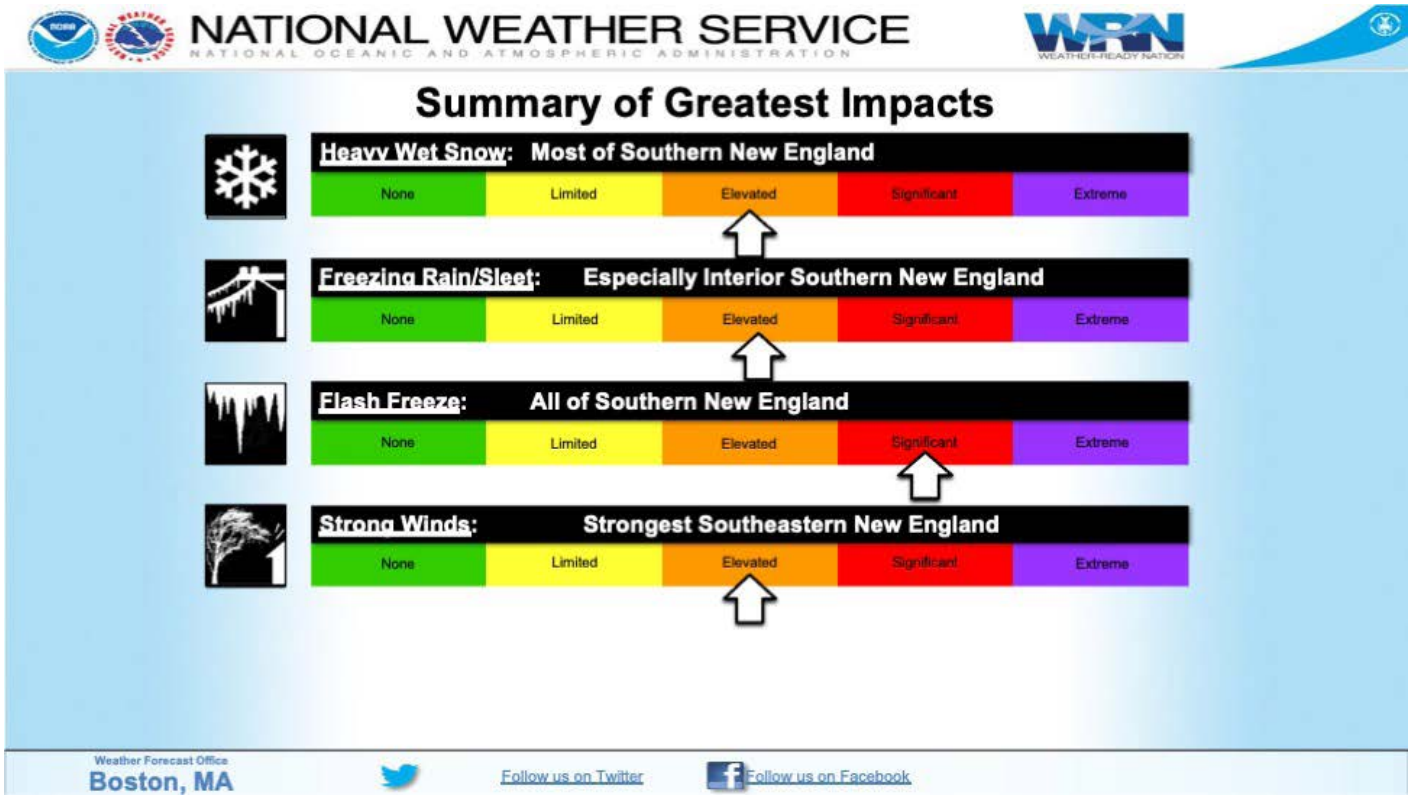

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Main Points
Hazard
Impacts
Location
Timing
Heavy Wet Snow
Hazardous travel. 1-2+ inch/hour rates.
All of Southern New England, except the extreme south coast.
10 PM Sat – 7 AM Sun NW MA remains all snow through Sunday.
Freezing Rain/ Sleet
Hazardous travel. Scattered power outages. 0.25 to 0.5 inch icing possible.
Greatest icing in CT, northern RI, and interior E MA.
Sunday morning – early afternoon.
Flash Freeze
Hazardous travel. Rapid temperature drop causes quick icing of wet surfaces. Bitter cold by Sunday night.
All of Southern New England
Early Sunday afternoon – Sunday Night
Strong Winds
Some power outages, exacerbated by snow/ice.
Southern Rhode Island and Southeastern Massachusetts.
Sunday morning – Sunday afternoon.


NATIONAL WEATHER SERVICE
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Summary of Greatest Impacts
Heavy Wet Snow: Most of Southern New England
None
Limited
Elevated
Significant
Extreme
Freezing Rain/Sleet: Especially Interior Southern New England
None
Limited
Elevated
Significant
Extreme
Flash Freeze: All of Southern New England
None
Limited
Elevated
Significant
Extreme
Strong Winds: Strongest Southeastern New England
None
Limited
Elevated
Significant
Extreme
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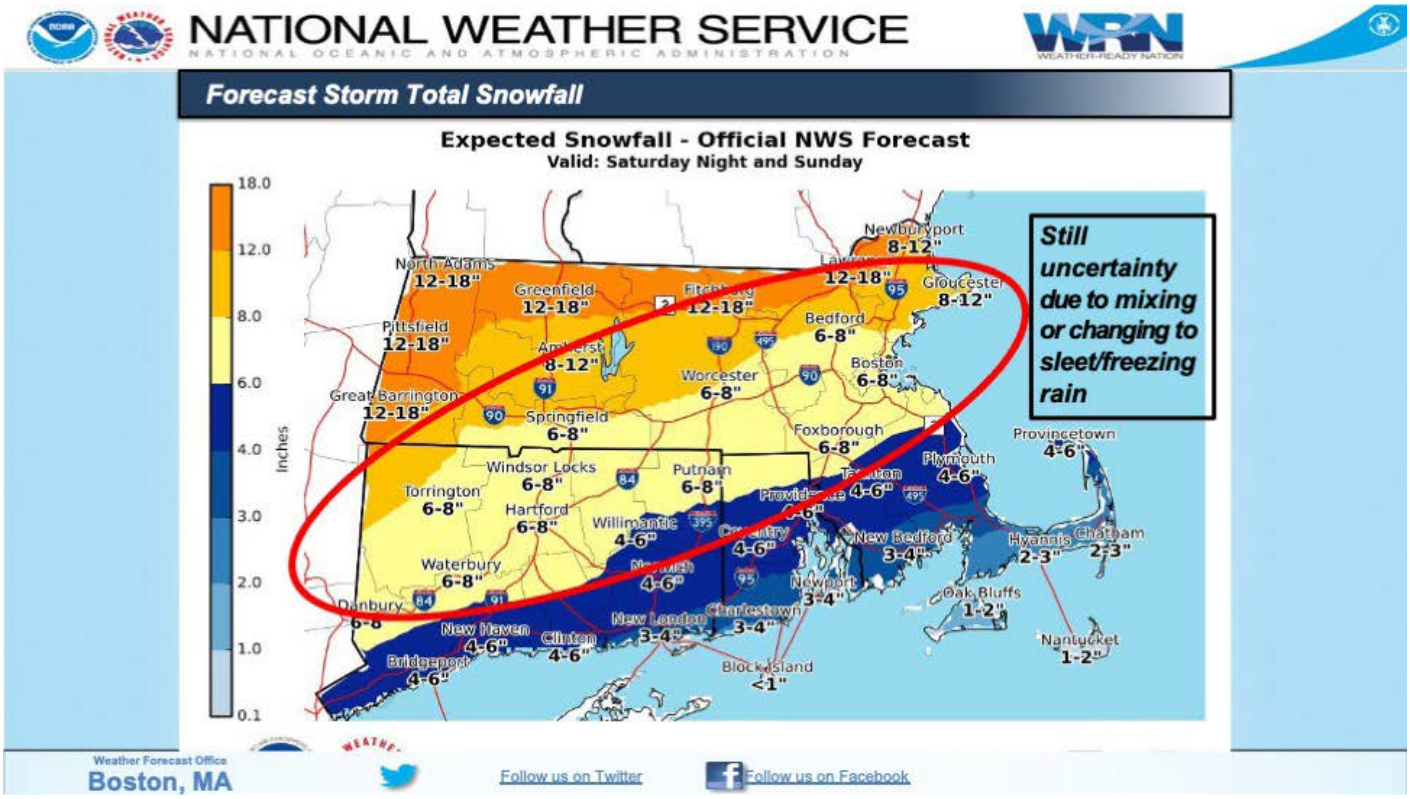
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Forecast Storm Total Snowfall
Expected Snowfall - Official NWS Forecast
Valid: Saturday Night and Sunday
Inches
18.0
12.0
8.0
6.0
4.0
3.0
2.0
1.0
0.1
Still uncertainty due to mixing or changing to sleet/freezing rain
Newburyport 8-12"
Lawrence 12-18"
Gloucester 8-12"
North Adams 12-18"
Greenfield 12-18"
Fitchburg 12-18"
Pittsfield 12-18"
Amherst 8-12"
Bedford 6-8"
Boston 6-8"
Worcester 6-8"
Great Barrington 12-18"
Springfield 6-8"
Foxborough 6-8"
Provincetown 4-6"
Windsor Locks 6-8"
Putnam 6-8"
Plymouth 4-6"
Torrington 6-8"
Hartford 6-8"
Providence 4-6"
Willimantic 4-6"
Coventry 4-6"
New Bedford 3-4"
Hyannis 2-3"
Chatham 2-3"
Waterbury 6-8"
Norwich 4-6"
Newport 3-4"
Oak Bluffs 1-2"
Danbury 6-8"
New London 3-4"
Charlestown 3-4"
New Haven 4-6"
Clinton 4-6"
Nantucket 1-2"
Bridgeport 4-6"
Block Island <1"
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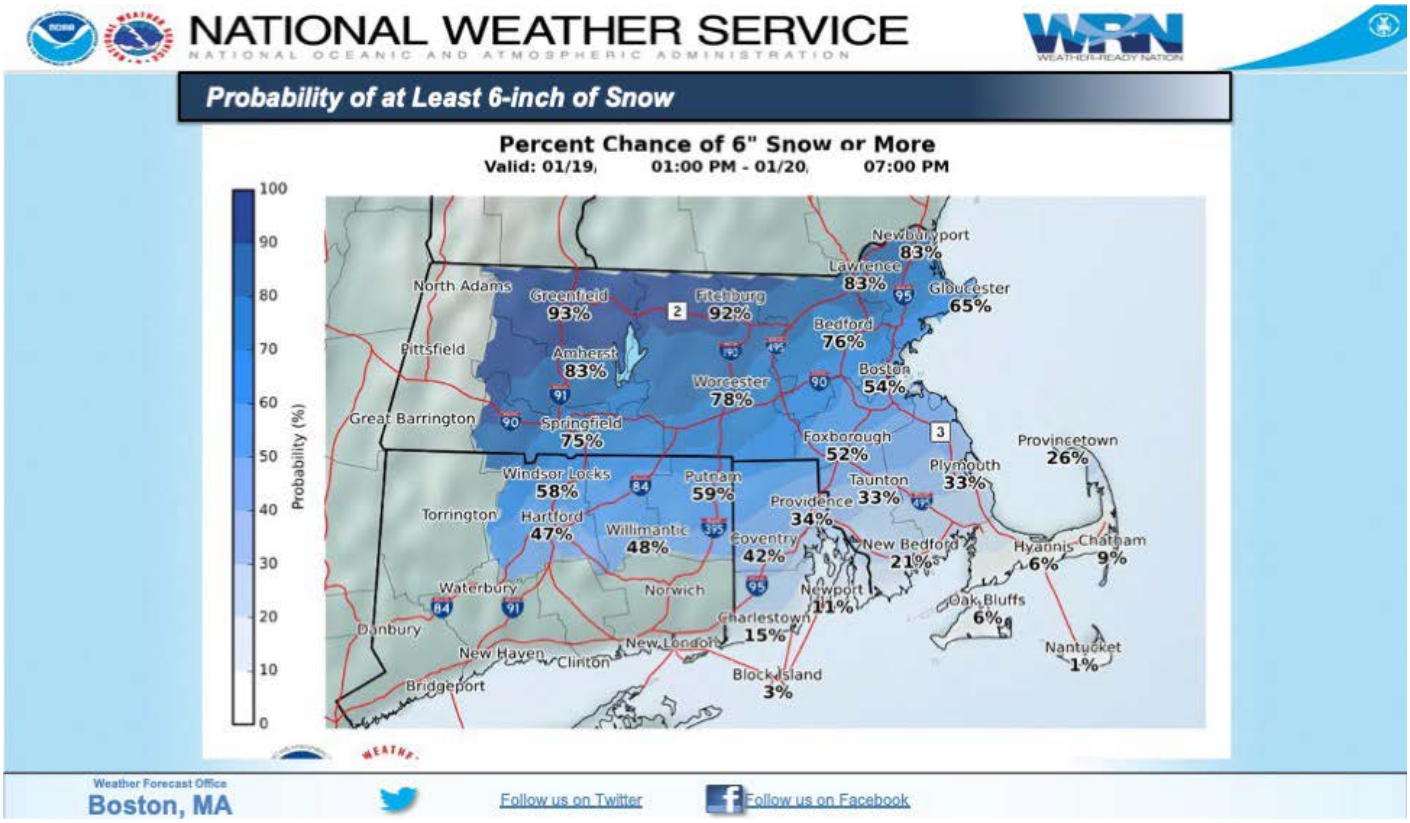
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Probability of at Least 6-inch of Snow
Percent Chance of 6" Snow or More
Valid: 01/19, 01:00 PM - 01/20, 07:00 PM
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Newburyport 83%
Lawrence 83%
Gloucester 65%
North Adams
Greenfield 93%
Fitchburg 92%
Bedford 76%
Pittsfield
Amherst 83%
Boston 54%
Worcester 78%
Great Barrington
Springfield 75%
Foxborough 52%
Provincetown 26%
Windsor Locks 58%
Putnam 59%
Plymouth 33%
Taunton 33%
Providence 34%
Torrington
Hartford 47%
Willimantic 48%
Coventry 42%
New Bedford 21%
Hyannis 6%
Chatham 9%
Waterbury
Norwich
Newport 11%
Oak Bluffs 6%
Charlestown 15%
Danbury
New London
New Haven
Clinton
Nantucket 1%
Block Island 3%
Bridgeport
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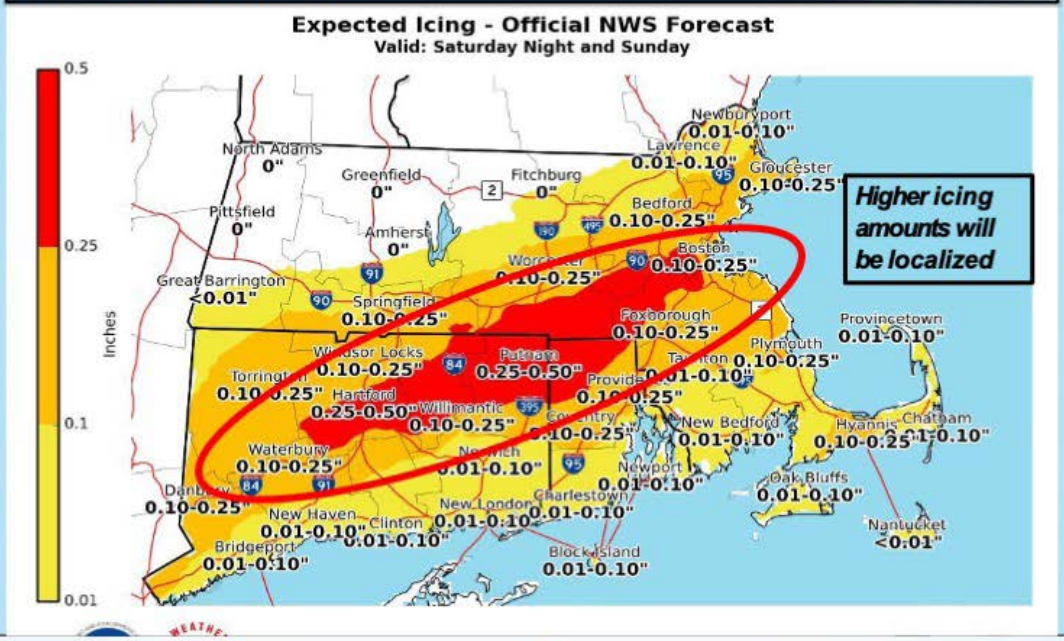
Forecast Storm Total Ice



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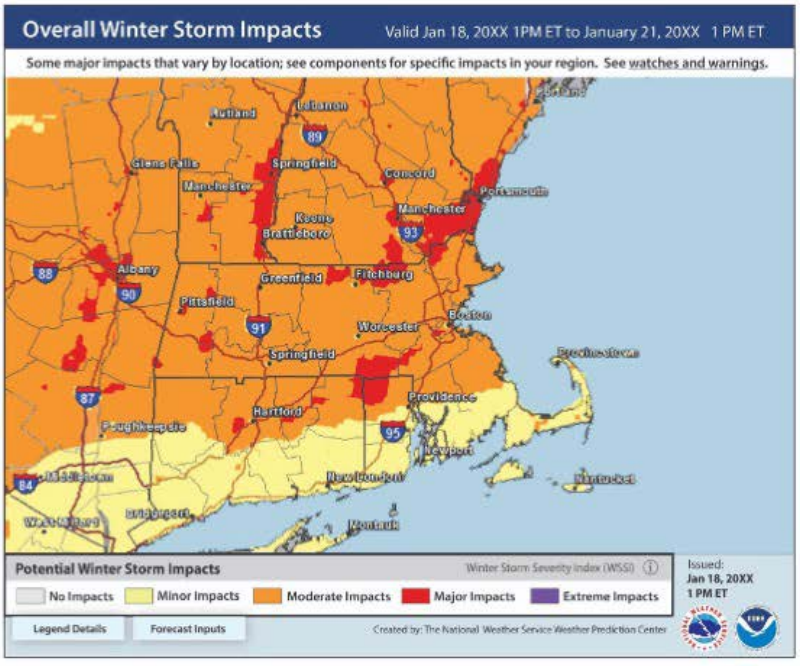
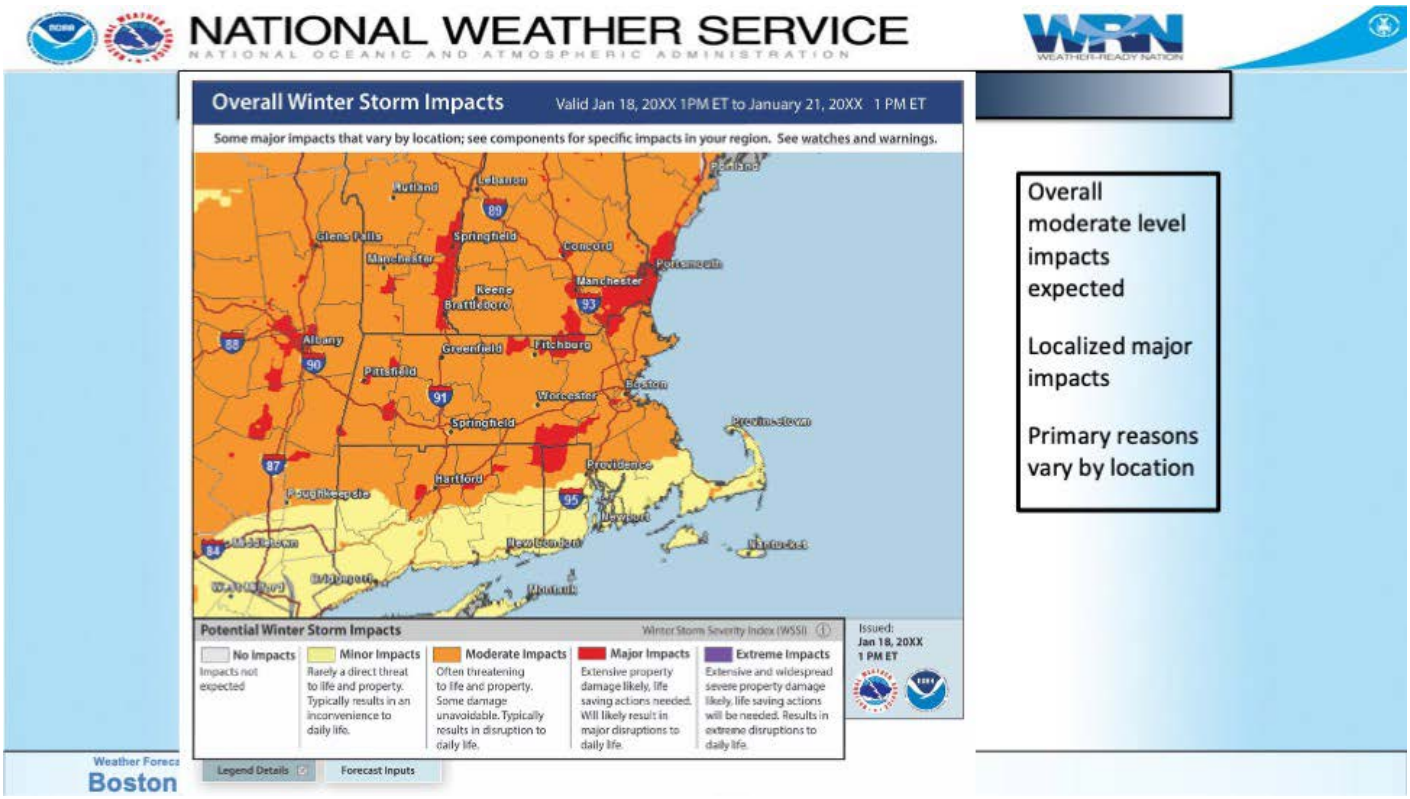
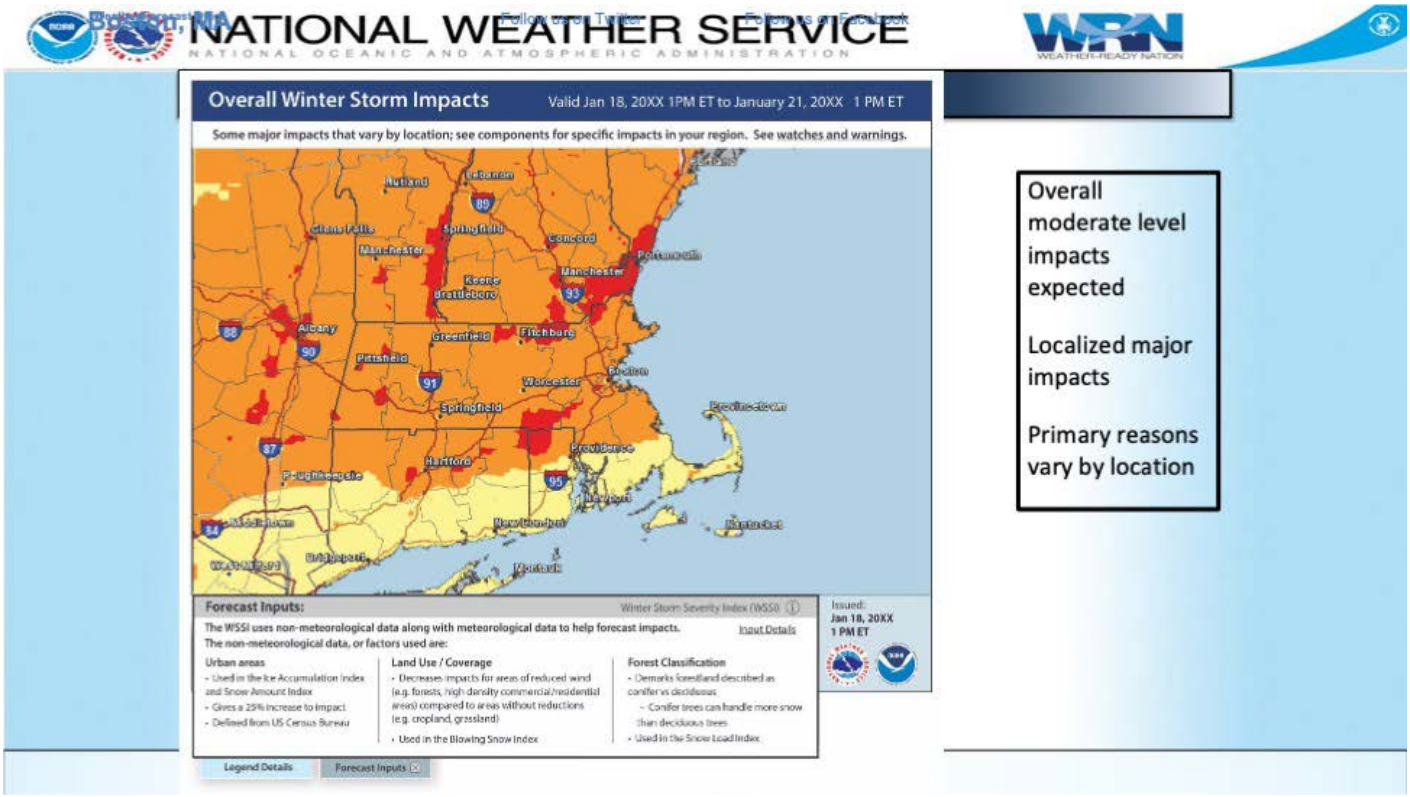


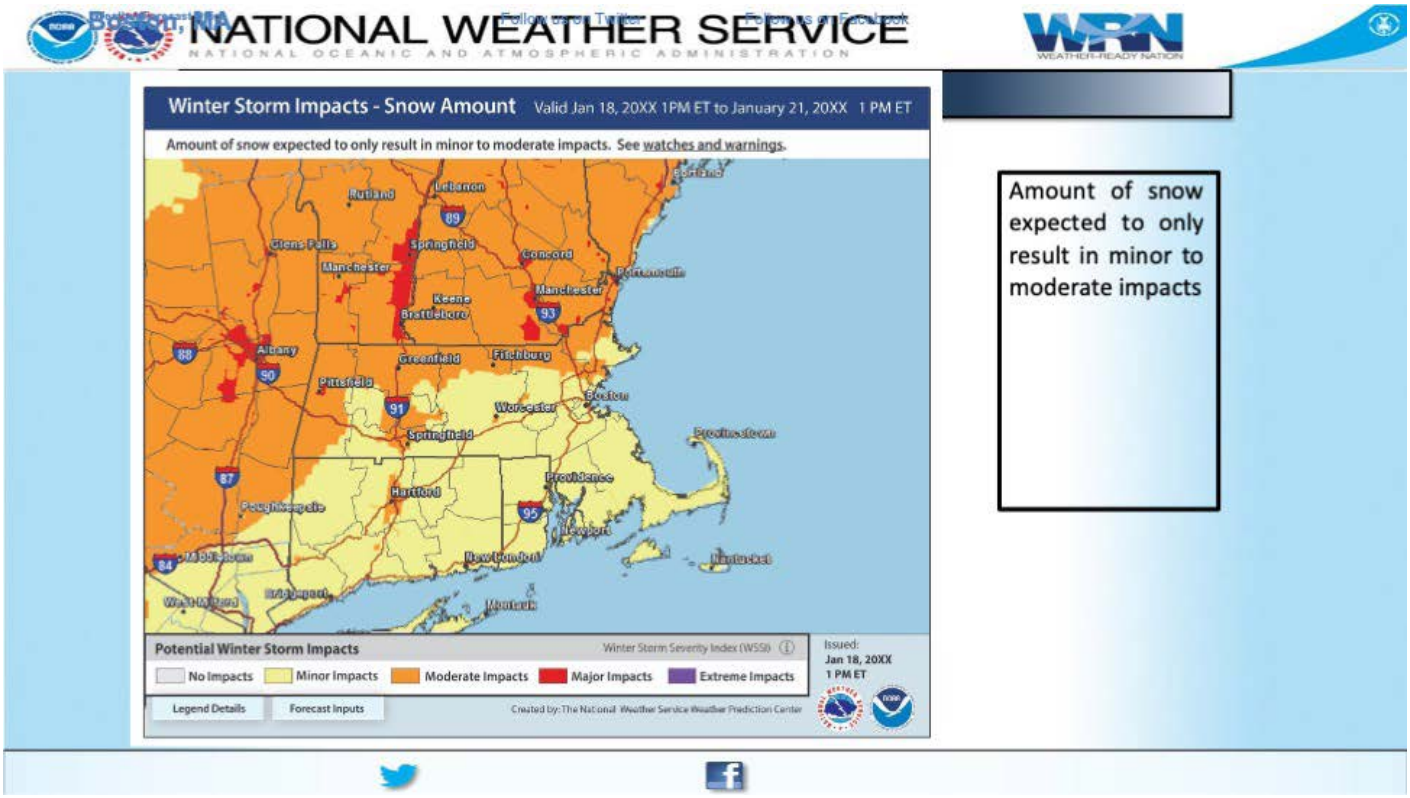
Overall moderate level impacts expected

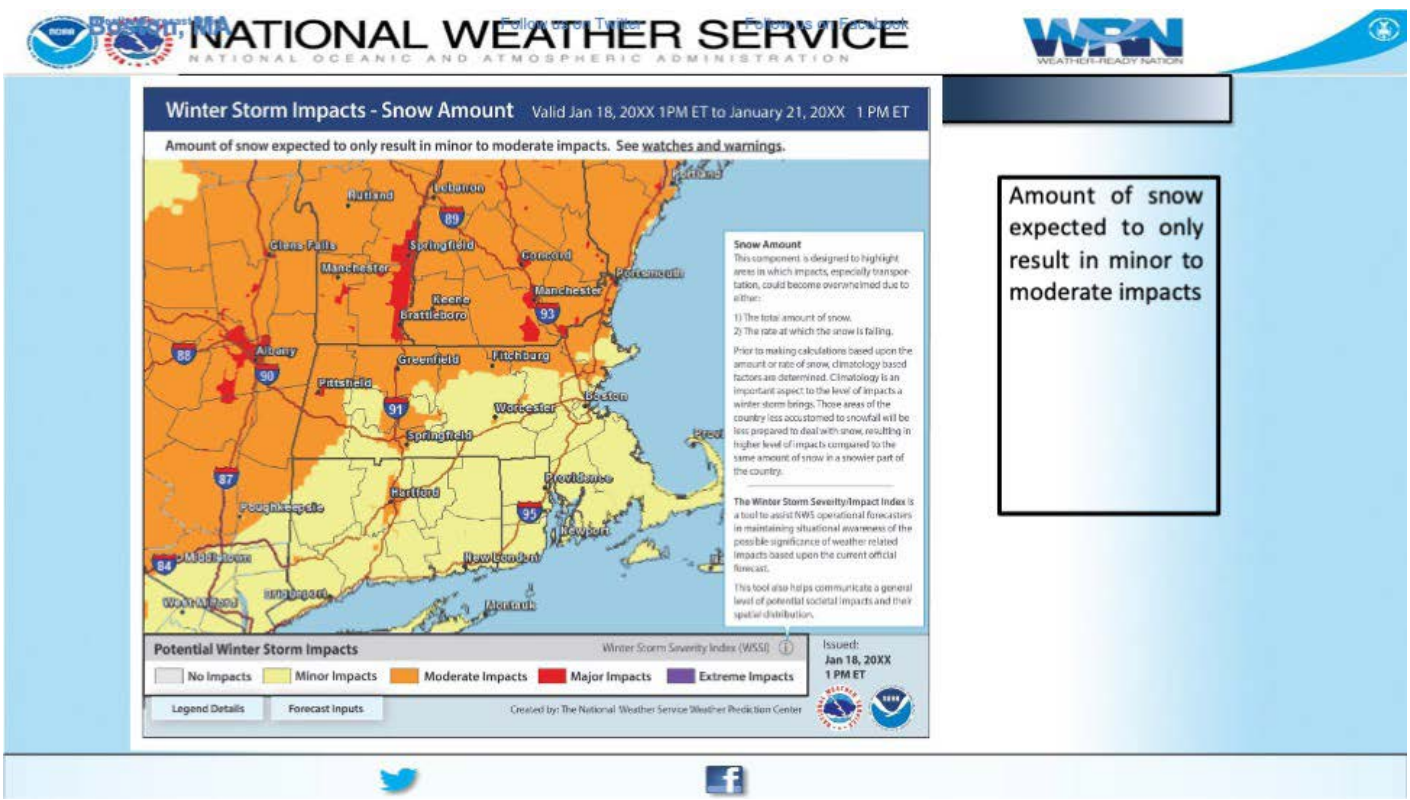
Localized major impacts

Primary reasons vary by location


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WEATHER-READY NATION
Overall Winter Storm Impacts
Valid Jan 18, 20XX 1PM ET to January 21, 20XX 1 PM ET
Some major impacts that vary by location; see components for specific impacts in your region. See watches and warnings.
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Impacts not expected
Minor Impacts
Rarely a direct threat to life and property. Typically results in an inconvenience to daily life.
Moderate Impacts
Often threatening to life and property. Some damage unavoidable. Typically results in disruption to daily life.
Major Impacts
Extensive property damage likely, life saving actions needed. Will likely result in major disruptions to daily life.
Extreme Impacts
Extensive and widespread severe property damage likely, life saving actions will be needed. Results in extreme disruptions to daily life.
Issued:
Jan 18, 20XX
1 PM ET
Legend Details
Forecast Inputs
Overall moderate level impacts expected
Localized major impacts
Primary reasons vary by location


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WEATHER-READY NATION
Overall Winter Storm Impacts
Valid Jan 18, 20XX 1PM ET to January 21, 20XX 1 PM ET
Some major impacts that vary by location; see components for specific impacts in your region. See watches and warnings.
Forecast Inputs:
Winter Storm Severity Index (WSSI)
The WSSI uses non-meteorological data along with meteorological data to help forecast impacts.
Input Details
The non-meteorological data, or factors used are:
Urban areas
- Used in the Ice Accumulation Index and Snow Amount Index
- Gives a 25% increase to impact
- Defined from US Census Bureau
Land Use / Coverage
- Decreases impacts for areas of reduced wind (e.g. forests, high density commercial/residential areas) compared to areas without reductions (e.g. cropland, grassland)
- Used in the Blowing Snow Index
Forest Classification
- Demarks forestland described as conifer vs deciduous
- Conifer trees can handle more snow than deciduous trees
- Used in the Snow Load Index
Issued:
Jan 18, 20XX
1 PM ET
Legend Details
Forecast Inputs
Overall moderate level impacts expected
Localized major impacts
Primary reasons vary by location


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Winter Storm Impacts - Snow Amount
Valid Jan 18, 20XX 1PM ET to January 21, 20XX 1 PM ET
Amount of snow expected to only result in minor to moderate impacts. See watches and warnings.
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Issued:
Jan 18, 20XX
1 PM ET
Legend Details
Forecast Inputs
Created by: The National Weather Service Weather Prediction Center
Amount of snow expected to only result in minor to moderate impacts


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Winter Storm Impacts - Snow Amount
Valid Jan 18, 20XX 1PM ET to January 21, 20XX 1 PM ET
Amount of snow expected to only result in minor to moderate impacts. See watches and warnings.
Snow Amount
This component is designed to highlight areas in which impacts, especially transportation, could become overwhelmed due to either:
1) The total amount of snow.
2) The rate at which the snow is falling.
Prior to making calculations based upon the amount or rate of snow, climatology based factors are determined. Climatology is an important aspect to the level of impacts a winter storm brings. Those areas of the country less accustomed to snowfall will be less prepared to deal with snow, resulting in higher level of impacts compared to the same amount of snow in a snowier part of the country.
The Winter Storm Severity/Impact Index is a tool to assist NWS operational forecasters in maintaining situational awareness of the possible significance of weather related impacts based upon the current official forecast.
This tool also helps communicate a general level of potential societal impacts and their spatial distribution.
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Issued:
Jan 18, 20XX
1 PM ET
Legend Details
Forecast Inputs
Created by: The National Weather Service Weather Prediction Center
Amount of snow expected to only result in minor to moderate impacts

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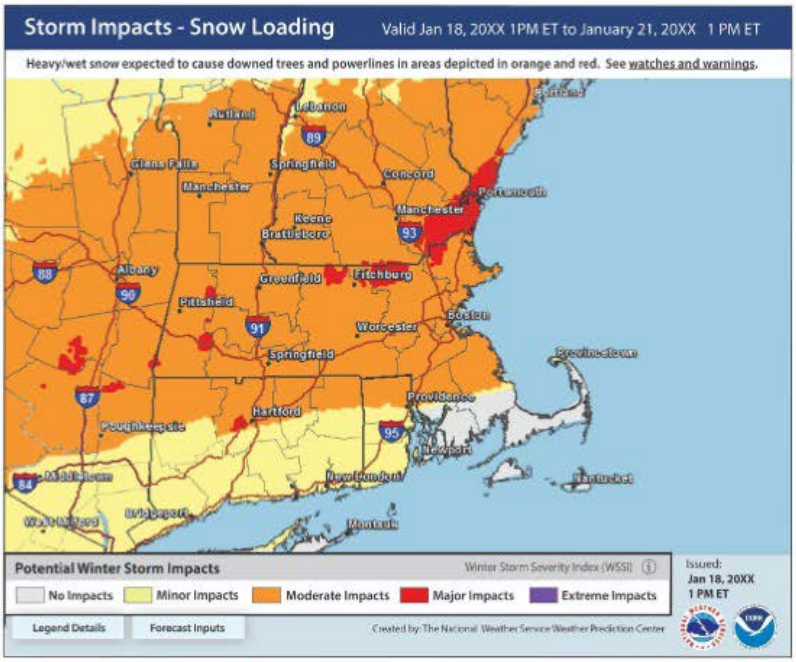

Heavy/wet snow expected to cause downed trees and powerlines in areas depicted in orange and red

No concerns across southern areas, Cape and Islands

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Threat Event Summary

- ✔ **Confidence**: High confidence for a moderate to high impact event. Low confidence on exact details/timing.
- ✔ **What**:
  - Heavy wet snow with high snowfall rates.
  - Strong winds exacerbates power outage risk.
  - Freezing Rain/Sleet with some ice accumulation likely.
  - Flash Freeze late Sunday and Sunday night. Bitter cold follows.
- ✔ **Where**: All of Southern New England
- ✔ **When**: Saturday Night – Sunday Night. Bitter cold follows early next week.

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WEATHER-READY NATION

Saturday Afternoon Briefing
T-1 pm

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

WEATHER-READY NATION

Multi-Faceted Winter Storm Tonight – Monday Morning

National Weather Service
Decision Support Briefing # 3
Saturday Afternoon

What Has Changed?

- ✓ Decrease in snowfall amounts towards N&W Massachusetts.
- ✓ N&W shift in forecast heaviest icing.
- ✓ Winter Storm Warning for Hartford County CT.

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Hazard	Impacts	Location	Timing
Heavy Wet Snow (also sleet)	Weight of snow contributing to scattered tree damage, power outages, road closures; hazardous travel conditions on all surfaces	All of S New England except extreme S-coast New England 6-12" N&W MA 3-6" N CT / N RI / E&SE MA 1-3" S-Coastal CT / RI / MA	10 pm tonight – 7 am Sunday Fluffy to heavy wet snow transitioning N&W throughout Snowfall rates 1-2"+ / hour
Freezing Rain	Weight of ice atop snow and/or sleet contributing as well to impacts highlighted above; hazardous travel conditions on all surfaces.	From Northwest CT northeastward across MA into Northeast MA.	Developing around midnight tonight concluding into Sunday evening
Strong Winds	Scattered tree damage, power outages … especially if trees are weighted by snow and/or ice which would exacerbate impacts outlined above	Southern RI & Southeast MA Higher terrain (i.e., Berkshires, Worcester, Tolland, Litchfield Hills) Watch N&W MA late Sunday into Monday morn; winds + fallen snow	Developing tonight continuing through Monday morning Blustery NW winds contributing to bitter cold wind chills Sunday night
Flash Freeze	Rapid freezing of wet surfaces, standing water, resulting in slick surfaces, hazardous travel; exposed vehicles having frozen closed doors	Greatest area of concern is Southeast New England **Providence – Boston corridor and southeast … especially for the Monday AM commute**	Early Sunday afternoon into Sunday Night Bitter cold, single digit temperatures settling into the region

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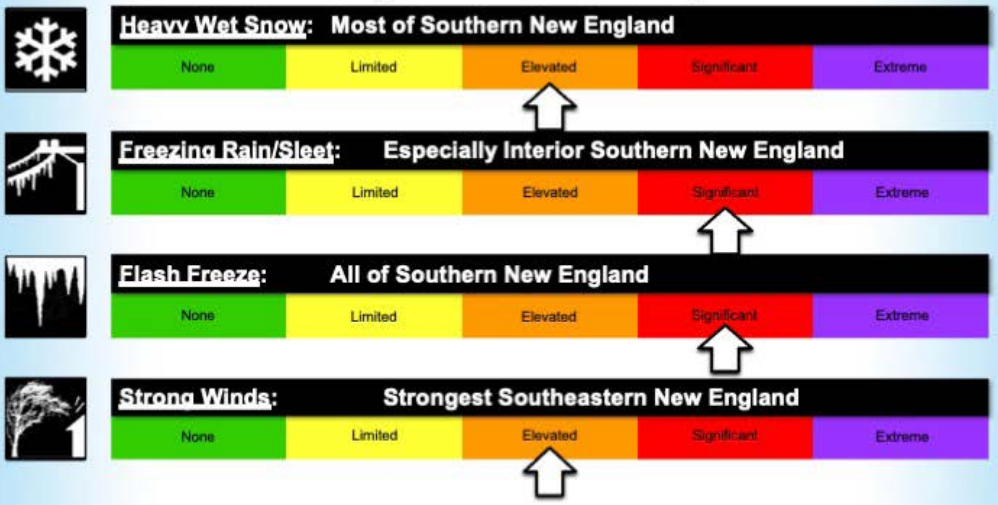
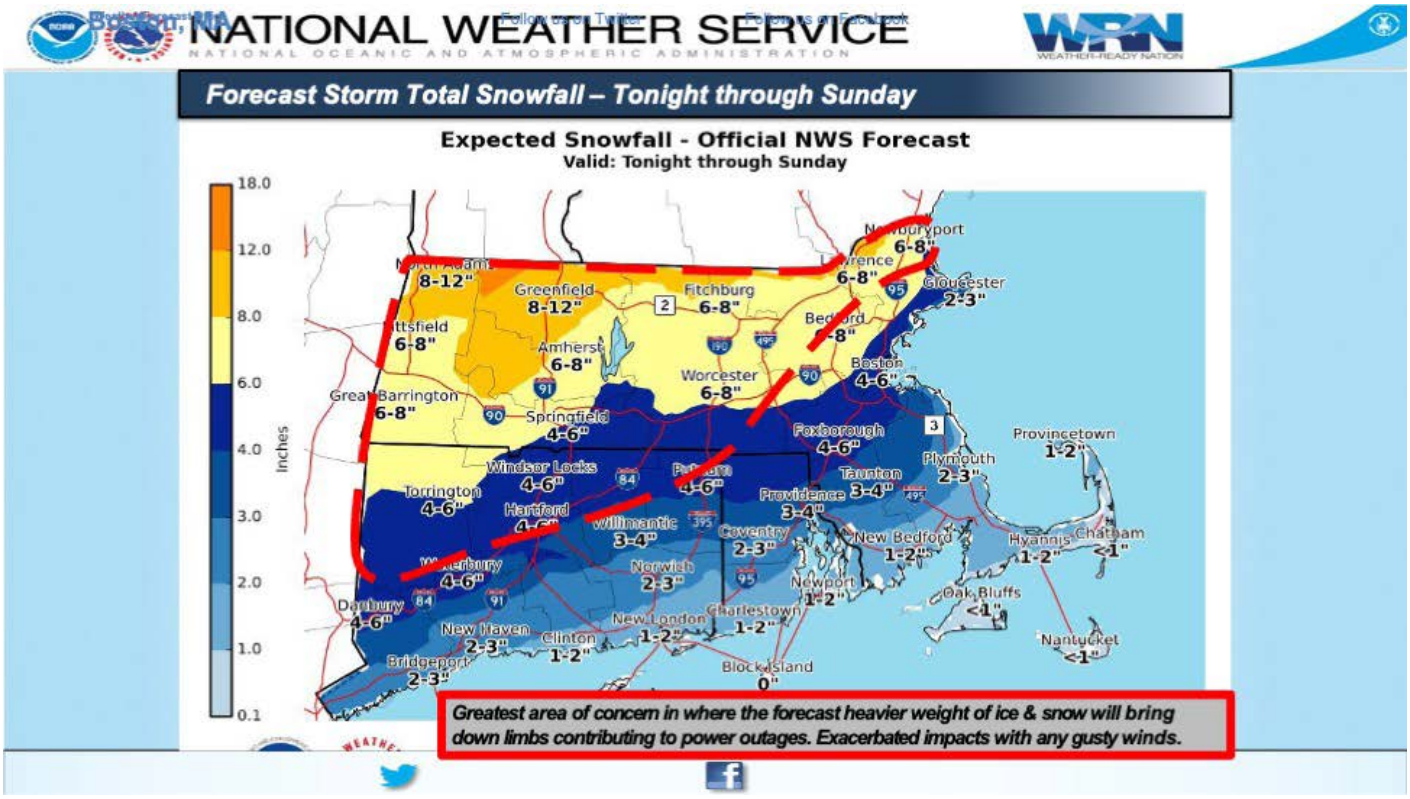
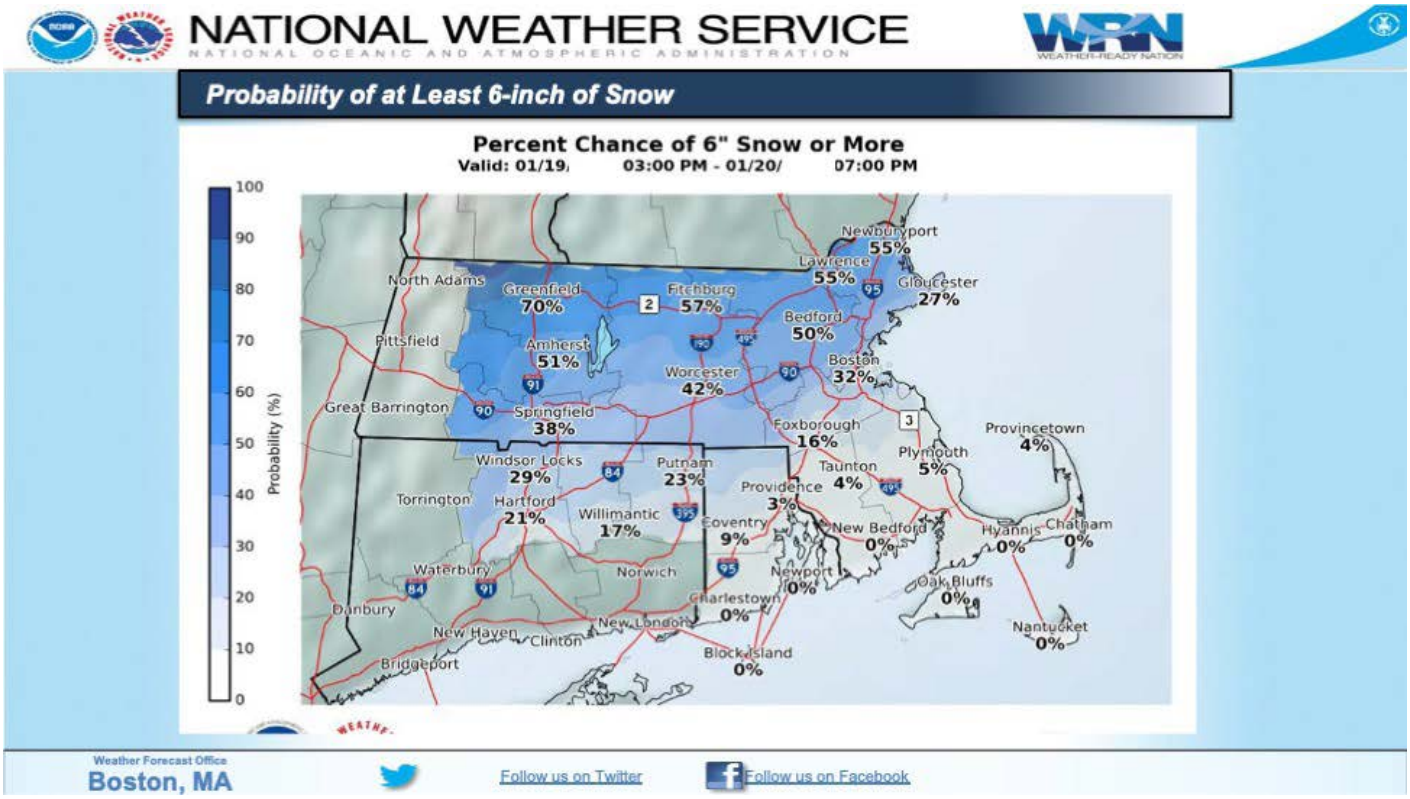
Summary of Greatest Impacts




NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Forecast Storm Total Snowfall – Tonight through Sunday
Expected Snowfall - Official NWS Forecast
Valid: Tonight through Sunday
Inches
18.0
12.0
8.0
6.0
4.0
3.0
2.0
1.0
0.1
North Adams 8-12"
Greenfield 8-12"
Fitchburg 6-8"
Newburyport 6-8"
Lawrence 6-8"
Gloucester 2-3"
Pittsfield 6-8"
Amherst 6-8"
Bedford 6-8"
Boston 4-6"
Worcester 6-8"
Great Barrington 6-8"
Springfield 4-6"
Foxborough 4-6"
Provincetown 1-2"
Windsor Locks 4-6"
Putnam 4-6"
Plymouth 2-3"
Taunton 3-4"
Torrington 4-6"
Hartford 4-6"
Providence 3-4"
Willimantic 3-4"
Coventry 2-3"
New Bedford 1-2"
Hyannis 1-2"
Chatham <1"
Waterbury 4-6"
Norwich 2-3"
Newport 1-2"
Oak Bluffs <1"
Danbury 4-6"
New London 1-2"
Charlestown 1-2"
New Haven 2-3"
Clinton 1-2"
Nantucket <1"
Bridgeport 2-3"
Block Island 0"
Greatest area of concern in where the forecast heavier weight of ice & snow will bring down limbs contributing to power outages. Exacerbated impacts with any gusty winds.


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Probability of at Least 6-inch of Snow
Percent Chance of 6" Snow or More
Valid: 01/19/ 03:00 PM - 01/20/ 07:00 PM
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Newburyport 55%
Lawrence 55%
Gloucester 27%
North Adams
Greenfield 70%
Fitchburg 57%
Pittsfield
Amherst 51%
Bedford 50%
Worcester 42%
Boston 32%
Great Barrington
Springfield 38%
Foxborough 16%
Provincetown 4%
Windsor Locks 29%
Putnam 23%
Plymouth 5%
Taunton 4%
Torrington
Hartford 21%
Providence 3%
Willimantic 17%
Coventry 9%
New Bedford 0%
Hyannis 0%
Chatham 0%
Waterbury
Norwich
Newport 0%
Oak Bluffs 0%
Charlestown 0%
Danbury
New London
New Haven
Clinton
Nantucket 0%
Bridgeport
Block Island 0%
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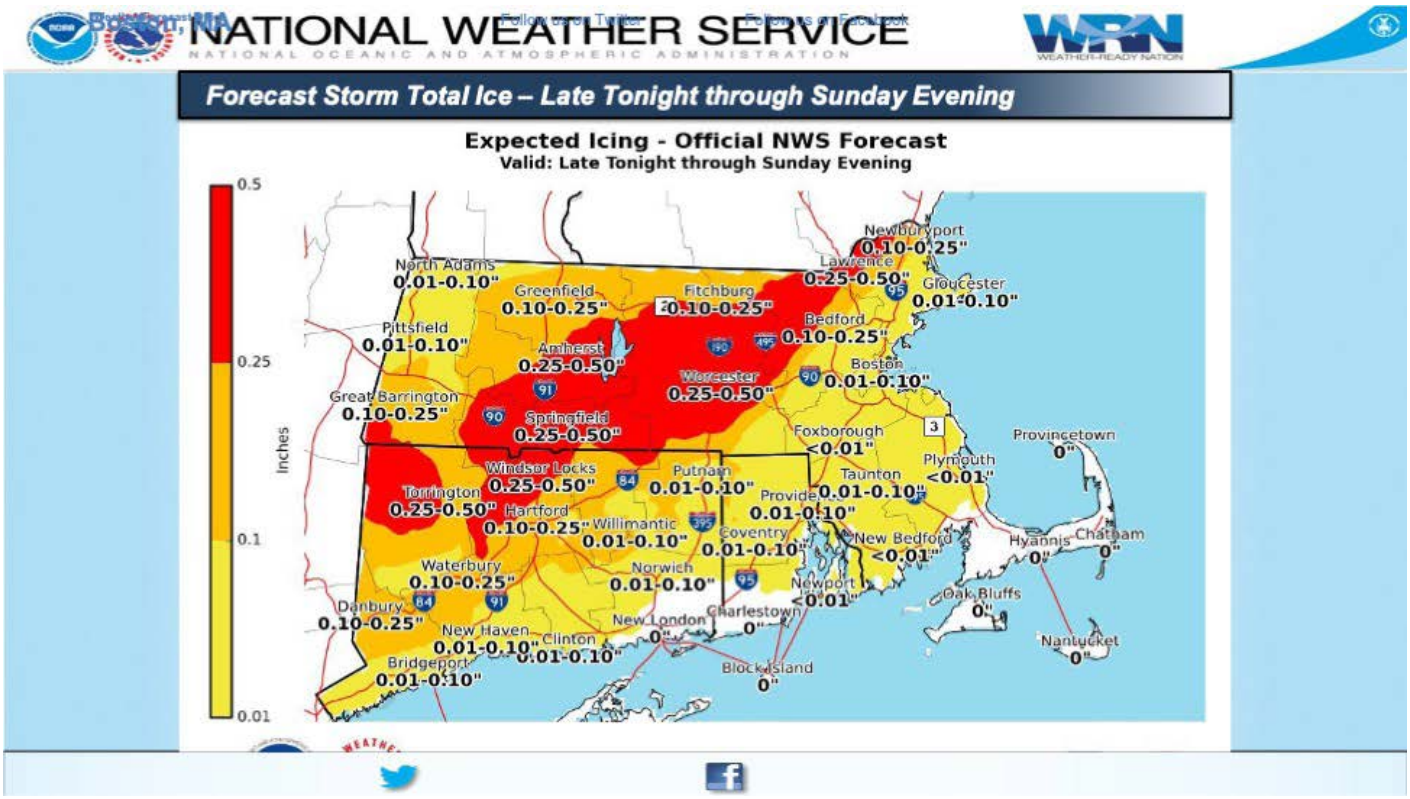
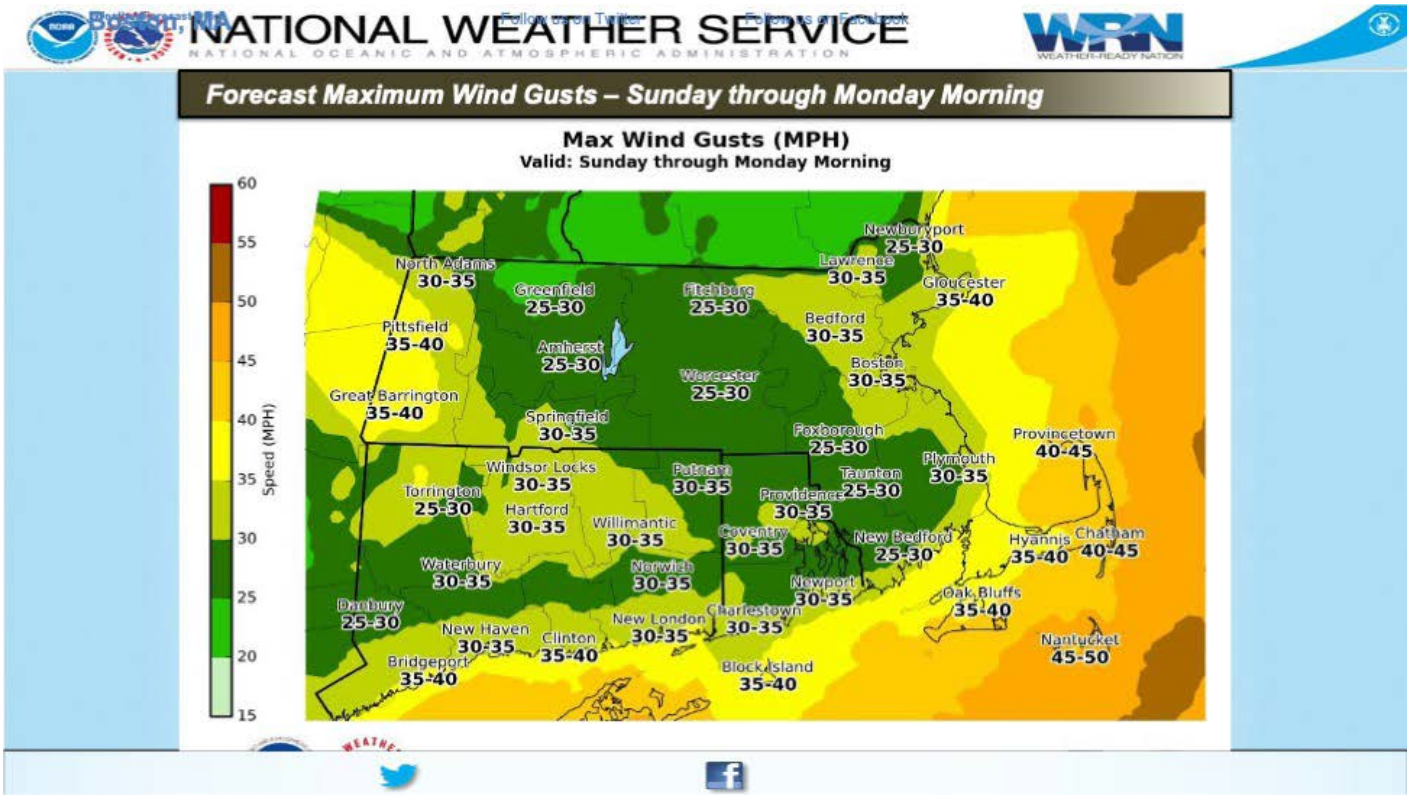

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Forecast Storm Total Ice – Late Tonight through Sunday Evening
Expected Icing - Official NWS Forecast
Valid: Late Tonight through Sunday Evening
Inches
0.5
0.25
0.1
0.01
Newburyport 0.10-0.25"
Lawrence 0.25-0.50"
Gloucester 0.01-0.10"
North Adams 0.01-0.10"
Greenfield 0.10-0.25"
Fitchburg 0.10-0.25"
Bedford 0.10-0.25"
Pittsfield 0.01-0.10"
Amherst 0.25-0.50"
Boston 0.01-0.10"
Worcester 0.25-0.50"
Great Barrington 0.10-0.25"
Springfield 0.25-0.50"
Foxborough <0.01"
Provincetown 0"
Plymouth <0.01"
Windsor Locks 0.25-0.50"
Putnam 0.01-0.10"
Taunton 0.01-0.10"
Torrington 0.25-0.50"
Hartford 0.10-0.25"
Willimantic 0.01-0.10"
Providence 0.01-0.10"
Coventry 0.01-0.10"
New Bedford <0.01"
Hyannis 0"
Chatham 0"
Waterbury 0.10-0.25"
Norwich 0.01-0.10"
Newport <0.01"
Oak Bluffs 0"
Danbury 0.10-0.25"
New Haven 0.01-0.10"
Clinton 0.01-0.10"
New London 0"
Charlestown 0"
Nantucket 0"
Bridgeport 0.01-0.10"
Block Island 0"


NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Forecast Maximum Wind Gusts – Sunday through Monday Morning
Max Wind Gusts (MPH)
Valid: Sunday through Monday Morning
Speed (MPH)
60
55
50
45
40
35
30
25
20
15
Newburyport 25-30
Lawrence 30-35
Gloucester 35-40
North Adams 30-35
Greenfield 25-30
Fitchburg 25-30
Bedford 30-35
Pittsfield 35-40
Amherst 25-30
Boston 30-35
Worcester 25-30
Great Barrington 35-40
Springfield 30-35
Foxborough 25-30
Provincetown 40-45
Windsor Locks 30-35
Putnam 30-35
Taunton 25-30
Plymouth 30-35
Torrington 25-30
Hartford 30-35
Willimantic 30-35
Providence 30-35
Coventry 30-35
New Bedford 25-30
Hyannis 35-40
Chatham 40-45
Waterbury 30-35
Norwich 30-35
Newport 30-35
Oak Bluffs 35-40
Danbury 25-30
New Haven 30-35
Clinton 35-40
New London 30-35
Charlestown 30-35
Nantucket 45-50
Bridgeport 35-40
Block Island 35-40

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

WRN WEATHER-READY NATION

Threat Event Summary

- ✔ **Confidence**: High confidence for a moderate-high impact event. Moderate confidence on exact details / timing.
- ✔ **What**:

Heavy wet snow and/or sleet.
- Weighing down tree limbs + gusty winds, contributing to scattered tree damage, power outages, and road closures … especially N&W MA.
- Amounts up around a foot in N&W MA. Snowfall rates of 1-2"+ / hour forecast.
- Tonight into early Sunday.

Strong winds.
- Contributing to scattered down limbs, power outages, especially if weighted by snow, sleet and/or ice.
- Developing tonight, continuing through Monday morning.
- Generated dangerous wind chills Sunday night through Monday morning

Freezing rain.
- Any icing contributing to the weight on trees, exacerbating impacts outlined above.
- As much as half an inch of ice accretion forecast roughly W to E over central portions of S New England.
- Late tonight through Sunday.

Follow-up bitter cold.
- Flash freeze icing up any residual water, encasing surfaces in ice.
- Blustery NW winds and temperatures falling into the single digits contributing to wind chills 15 to 25 degrees below zero.
- Late Sunday into Monday morning.

- ✔ **Where**: All of Southern New England.
- ✔ **When**: Winter impacts developing tonight, concluding into Sunday evening. Bitter cold ushers in Sunday evening into Monday morning.

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Sunday Morning Briefing
T-12 hours

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Ice Accretion/Flash Freeze -- Main Concerns Into This Evening.

National Weather Service
Decision Support Briefing
Sunday Morning

What Has Changed?

- Winter Storm Warning expanded into Tolland and Windham counties CT. Mainly for the northern portions of those counties for ice on top of snow.
- Growing concern for ice accretion exceeding 0.25" and power outages northwest of the Boston to Providence corridor. Greatest risk across the CT River Valley into the Worcester Hills and interior northeast MA.

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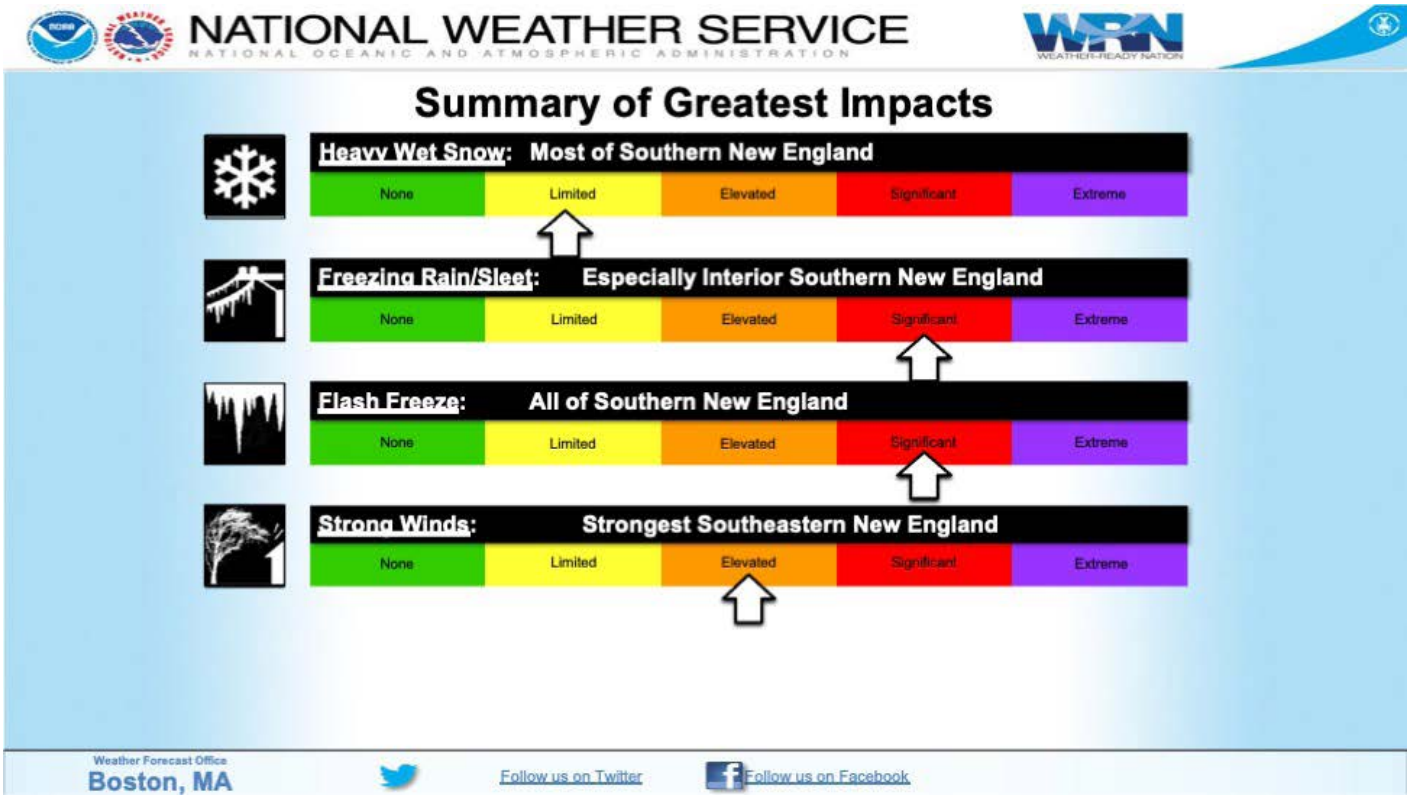
Hazard	Impacts	Location	Timing
Snow And Sleet	Snow covered roads, poor visibility, and hazardous travel.	Accumulating snow will pretty have changed to ice/rain across all of southern New England by 7 am.	Snow will be transitioning to sleet then rain along and southeast of the Boston to Providence corridor, while areas north and west change to sleet and freezing rain by 7 am.
Freezing Rain mixed With sleet.	Potential for some downed trees and scattered power outages. Gusty winds into tonight may result in additional power outages, where ice/snow remain on trees.	The concern is northwest of the Boston to Providence corridor, especially from the CT River Valley into Central and interior Northeast MA.	This morning into the afternoon to the northwest of the Boston to Providence corridor. Rain changes to freezing rain along and southeast of the Boston to Providence corridor between noon and 5 pm.
Flash Freeze	Rapid freezing of wet surfaces, standing water, resulting in slick surfaces, hazardous travel; exposed vehicles having frozen closed doors	Greatest concern is along the **Providence – Boston corridor and southeast … especially this afternoon and early evening.**	Temperatures will fall below freezing between noon and 5 pm along and southeast of the Boston to Providence corridor. Quick drop in temps will result in a flash freeze.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WRN
WEATHER-READY NATION
Summary of Greatest Impacts
Heavy Wet Snow: Most of Southern New England
None
Limited
Elevated
Significant
Extreme
Freezing Rain/Sleet: Especially Interior Southern New England
None
Limited
Elevated
Significant
Extreme
Flash Freeze: All of Southern New England
None
Limited
Elevated
Significant
Extreme
Strong Winds: Strongest Southeastern New England
None
Limited
Elevated
Significant
Extreme
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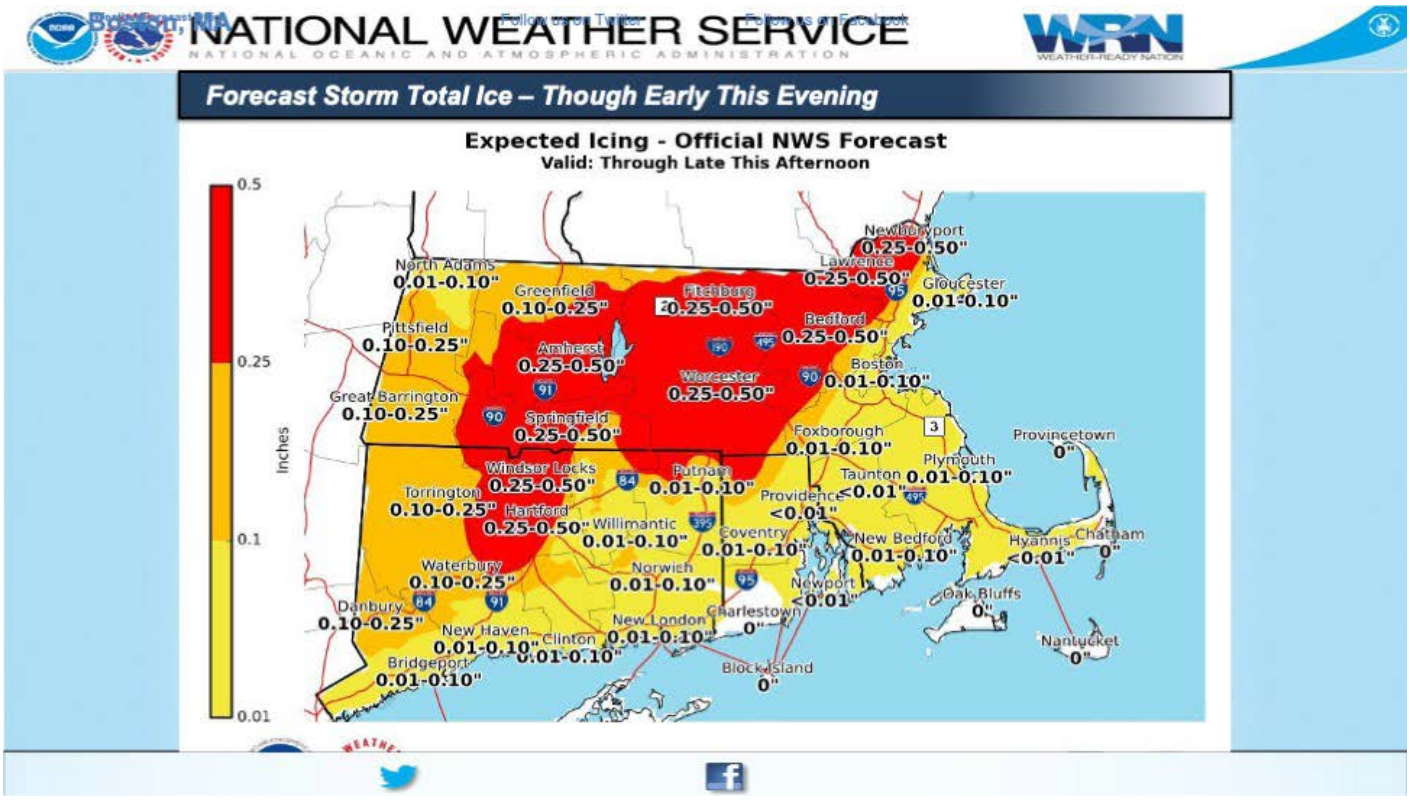
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Forecast Storm Total Ice – Though Early This Evening
Expected Icing - Official NWS Forecast
Valid: Through Late This Afternoon
Inches
0.5
0.25
0.1
0.01
North Adams 0.01-0.10"
Greenfield 0.10-0.25"
Fitchburg 0.25-0.50"
Lawrence 0.25-0.50"
Newburyport 0.25-0.50"
Gloucester 0.01-0.10"
Pittsfield 0.10-0.25"
Bedford 0.25-0.50"
Amherst 0.25-0.50"
Boston 0.01-0.10"
Worcester 0.25-0.50"
Great Barrington 0.10-0.25"
Springfield 0.25-0.50"
Foxborough 0.01-0.10"
Provincetown 0"
Plymouth 0.01-0.10"
Windsor Locks 0.25-0.50"
Putnam 0.01-0.10"
Taunton <0.01"
Torrington 0.10-0.25"
Hartford 0.25-0.50"
Providence <0.01"
Willimantic 0.01-0.10"
Coventry 0.01-0.10"
New Bedford 0.01-0.10"
Hyannis <0.01"
Chatham 0"
Waterbury 0.10-0.25"
Norwich 0.01-0.10"
Newport <0.01"
Oak Bluffs 0"
Danbury 0.10-0.25"
Charlestown 0"
New London 0.01-0.10"
New Haven 0.01-0.10"
Clinton 0.01-0.10"
Nantucket 0"
Bridgeport 0.01-0.10"
Block Island 0"

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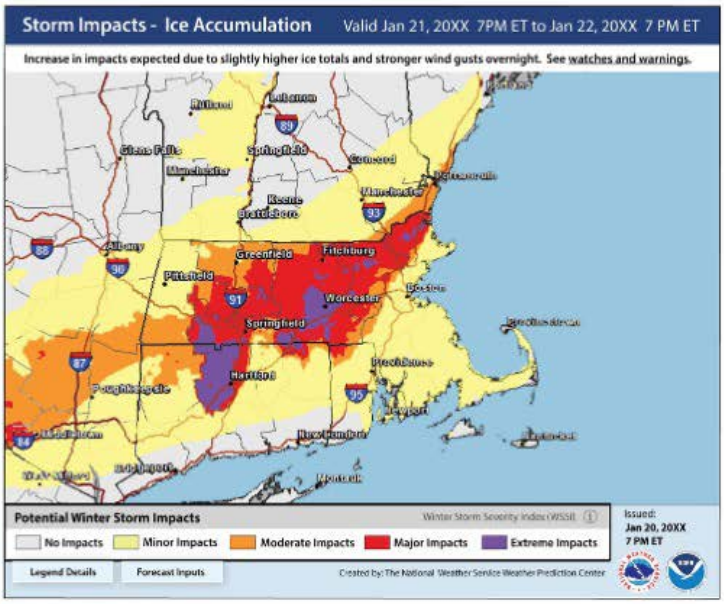
WSSI Ice



Greatest concern for tree damage and power outages extend from NE Massachusetts into the CT River Valley

Increase in impacts expected due to slightly higher ice totals and stronger wind gusts overnight ***after*** the freezing rain ends

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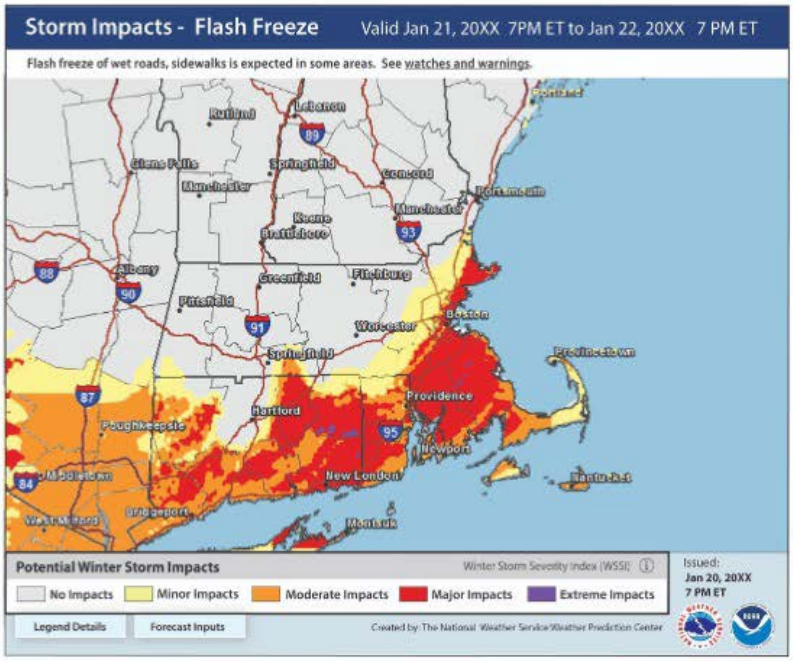

Expecting a quick drop of temperatures during the afternoon

Temperatures in the 30s will quickly fall into the teens

Flash freeze of wet roads, sidewalks is expected

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WRN WEATHER-READY NATION

Threat Event Summary

- **Confidence**: High confidence in freezing rain/sleet, flash freeze, and bitterly cold wind chills. Lower confidence on exact freezing rain/ice accretion amounts and extent of power outage threat. Also, specific timing of flash freeze uncertain.
- 

  Heavy snow
  - Bulk of accumulating snow ends by 7 am.
  - Sleet and especially freezing rain the greatest concern this morning and afternoon northwest of Boston to Providence corridor.

Freezing rain with some sleet
- Potential for downed trees/scattered power outages northwest of Bos-Pvd corridor.
- Greatest concern CT River Valley into the Worcester Hills and interior northeast MA.
- Freezing rain and sleet ends between 4 and 8 pm this evening.

Flash Freeze.
- Flash freeze occurs along and southeast of the Boston to Providence corridor between noon and 5 pm.

- **Where**: All of Southern New England.
- **When**: Heaviest icing threat this morning, but precipitation does not come to a complete end until 4 and 8 pm this eve. Flash Freeze between noon and 5 pm along and southeast of the Boston to Providence corridor.

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Scenario 2

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Monday Afternoon Briefing
T-3

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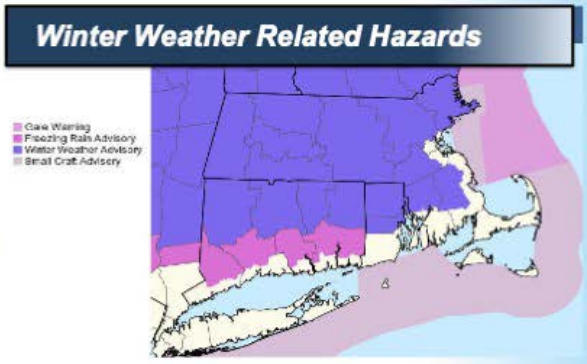
Potential Major Storm Thursday
Light Wintry Mix Late Tuesday to Wednesday Morning

National Weather Service
Decision Support Briefing
Monday Afternoon

What Has Changed?

- ✓ First briefing
- ✓ Winter Weather Advisory away from the immediate coast
- ✓ Combination of snow, sleet and freezing rain



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WEATHER-READY NATION

Summary of Greatest Impacts

Snow: Entire Region But Higher Chances Southeast Areas

None | Limited | Elevated | Significant | Extreme

Freezing Rain: Especially Interior Southern New England

None | Limited | Elevated | Significant | Extreme

Flash Freeze: North-Central/Northeast Massachusetts

None | Limited | Elevated | Significant | Extreme

Strong Winds: Strongest Southeastern New England

None | Limited | Elevated | Significant | Extreme

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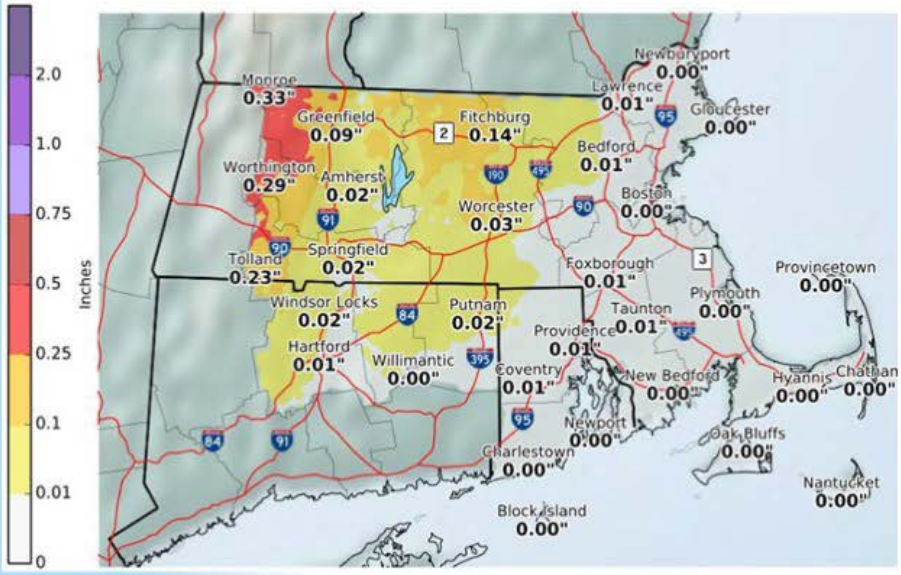
Most likely Ice Glaze

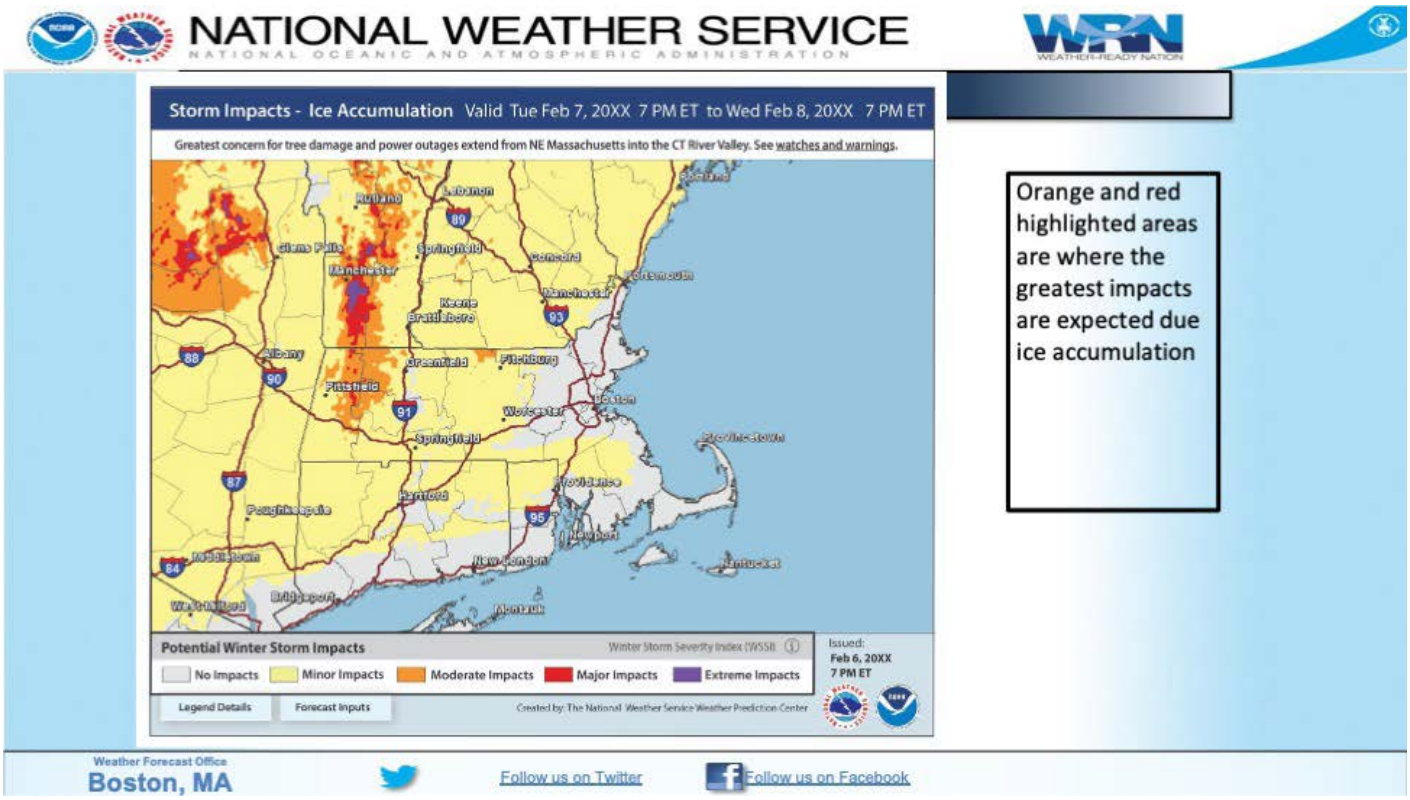
Valid: 02/07/ 01:00 AM - 02/08/ 07:00 AM



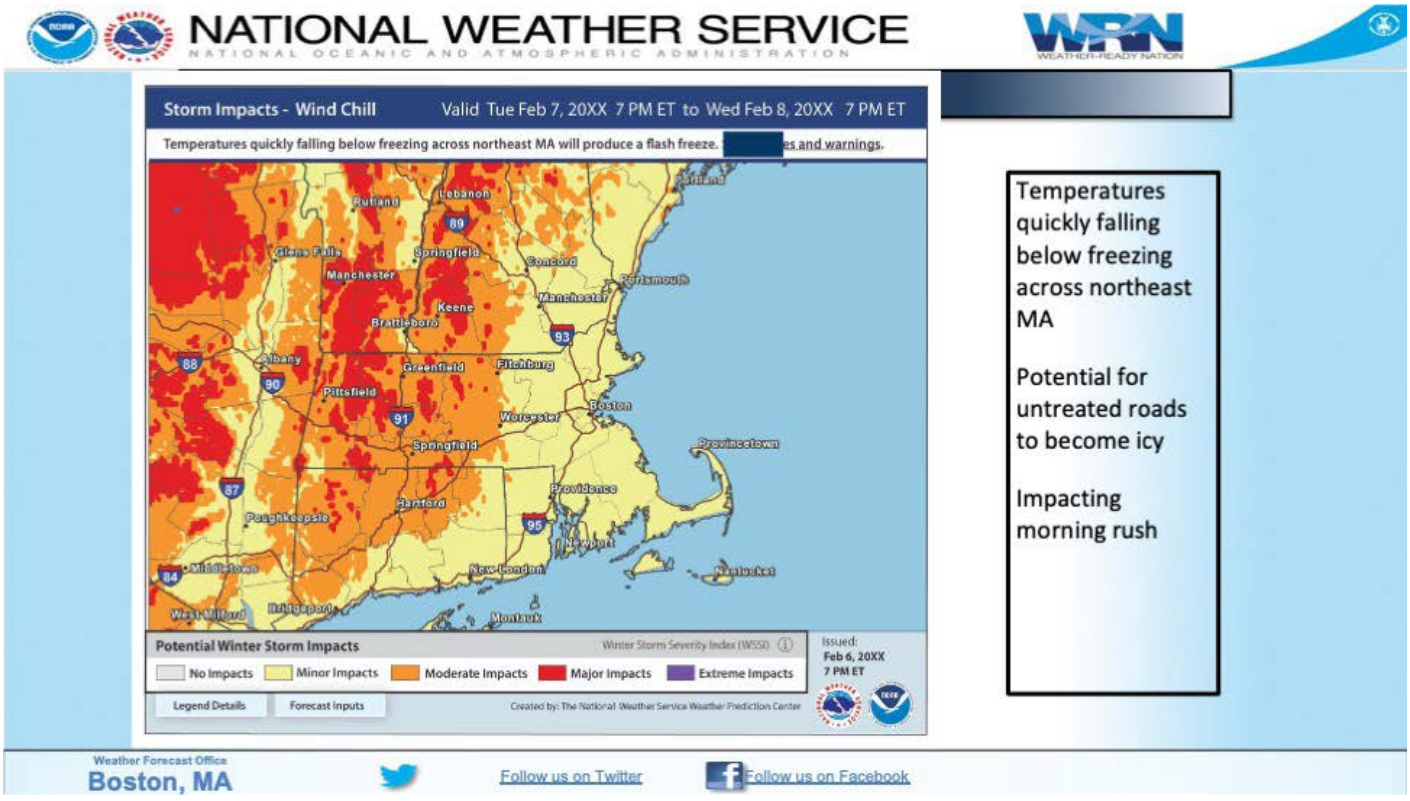
Freezing Rain late Tuesday into Wednesday morning

Highest totals in the Berkshires

Isolated power outages
Icy roads / poor driving conditions



Orange and red highlighted areas are where the greatest impacts are expected due ice accumulation



Temperatures quickly falling below freezing across northeast MA

Potential for untreated roads to become icy

Impacting morning rush

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Tuesday Morning Briefing
T-2 am

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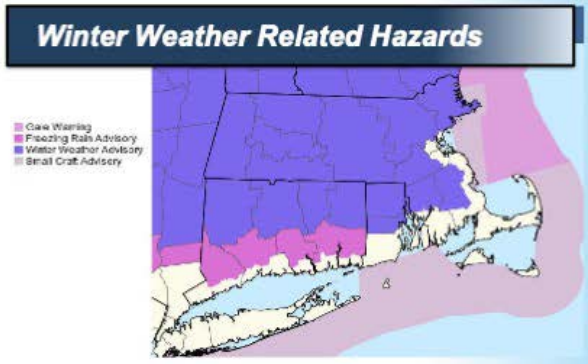
Potential Major Storm Thursday
Light Wintry Mix Late Tuesday to Wednesday Morning

National Weather Service
Decision Support Briefing
Tuesday Morning

What Has Changed?

- ✓ No changes in headlines
- ✓ Increasing confidence in Flash Freeze tonight
- ✓ Increasing confidence in Thursday storm



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WRN WEATHER-READY NATION

Tuesday Afternoon Briefing
T-2 pm

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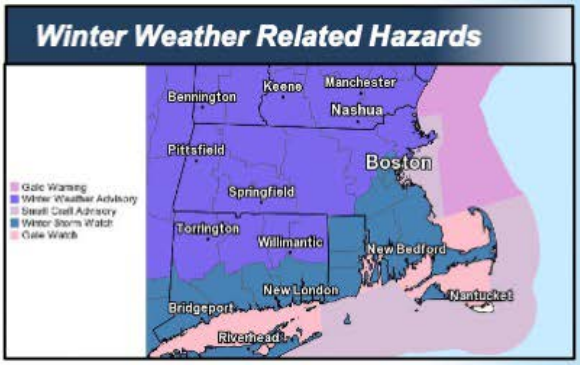
Potential Major Storm Thursday
Light Wintry Mix Late Tuesday to Wednesday Morning

National Weather Service
Decision Support Briefing
Tuesday Afternoon

What Has Changed?

- ✓ High confidence in light freezing rain and flash freeze tonight
- ✓ Winter Storm Watch issued for Thursday storm for 6+ inches of snow



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Wednesday Afternoon Briefing
T-1

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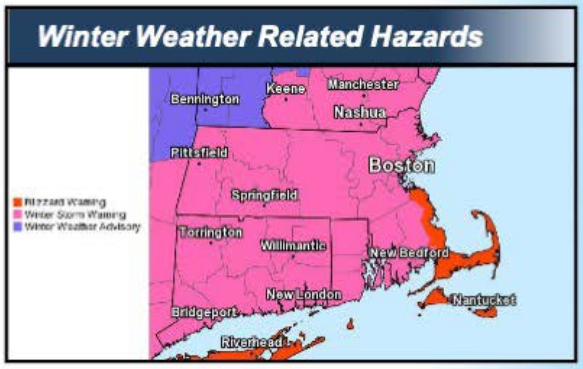
Major Storm Thursday

National Weather Service
Decision Support Briefing
Wednesday Afternoon

What Has Changed?

- ✓ Blizzard Warning for coastal MA, Cape and Islands
- ✓ Winter Storm Warnings for the remainder of Southern New England



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Thursday Morning Briefing
T-12 hours

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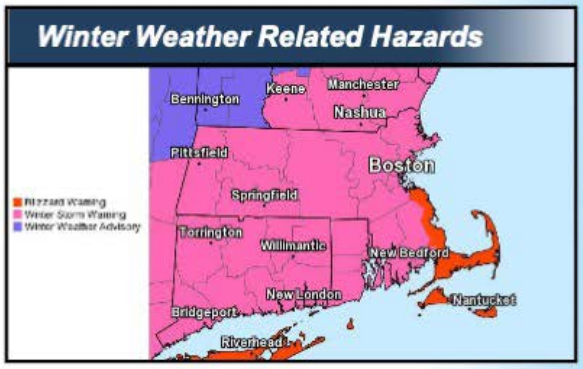
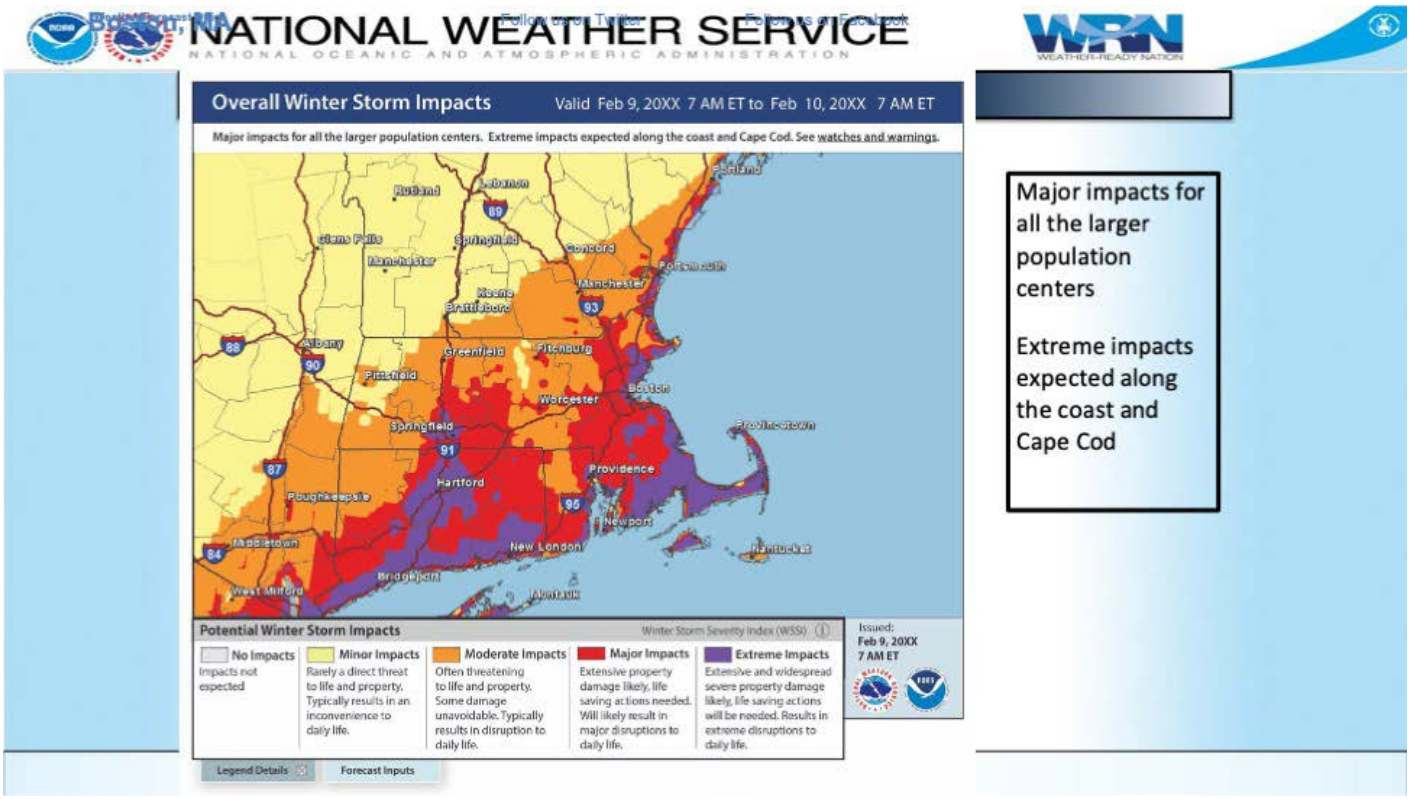
Major Storm With Blizzard Conditions Today

National Weather Service
Decision Support Briefing
Thursday Morning

What Has Changed?

- ✓ Increased snowfall total forecast
- ✓ Increase to wind gusts across Cape and Islands

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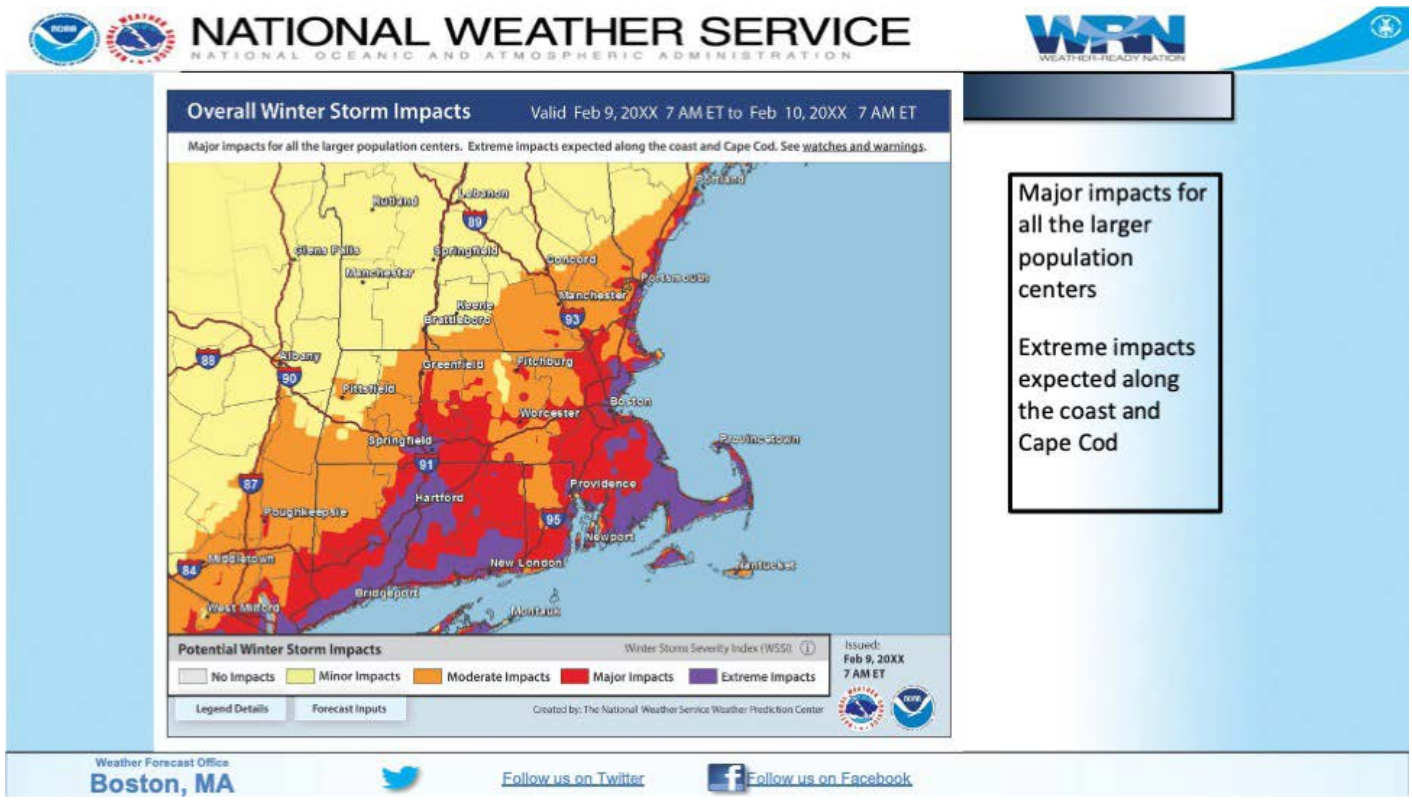
WEATHER-READY NATION
Overall Winter Storm Impacts
Valid Feb 9, 20XX 7 AM ET to Feb 10, 20XX 7 AM ET
Major impacts for all the larger population centers. Extreme impacts expected along the coast and Cape Cod. See watches and warnings.
Rutland
Lebanon
Concord
Manchester
Keene
Brattleboro
Albany
Greenfield
Fitchburg
Pittsfield
Worcester
Boston
Springfield
Provincetown
Hartford
Providence
Poughkeepsie
Newport
New London
Nantucket
Bridgeport
Montauk
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Impacts not expected
Minor Impacts
Rarely a direct threat to life and property. Typically results in an inconvenience to daily life.
Moderate Impacts
Often threatening to life and property. Some damage unavoidable. Typically results in disruption to daily life.
Major Impacts
Extensive property damage likely, life saving actions needed. Will likely result in major disruptions to daily life.
Extreme Impacts
Extensive and widespread severe property damage likely, life saving actions will be needed. Results in extreme disruptions to daily life.
Issued:
Feb 9, 20XX
7 AM ET
Legend Details
Forecast Inputs
Major impacts for all the larger population centers
Extreme impacts expected along the coast and Cape Cod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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
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Overall Winter Storm Impacts
Valid Feb 9, 20XX 7 AM ET to Feb 10, 20XX 7 AM ET
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Rutland
Lebanon
Concord
Manchester
Keene
Brattleboro
Albany
Greenfield
Fitchburg
Pittsfield
Worcester
Boston
Springfield
Provincetown
Hartford
Providence
Poughkeepsie
Newport
New London
Nantucket
Bridgeport
Montauk
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Issued:
Feb 9, 20XX
7 AM ET
Legend Details
Forecast Inputs
Created by: The National Weather Service Weather Prediction Center
Major impacts for all the larger population centers
Extreme impacts expected along the coast and Cape Cod
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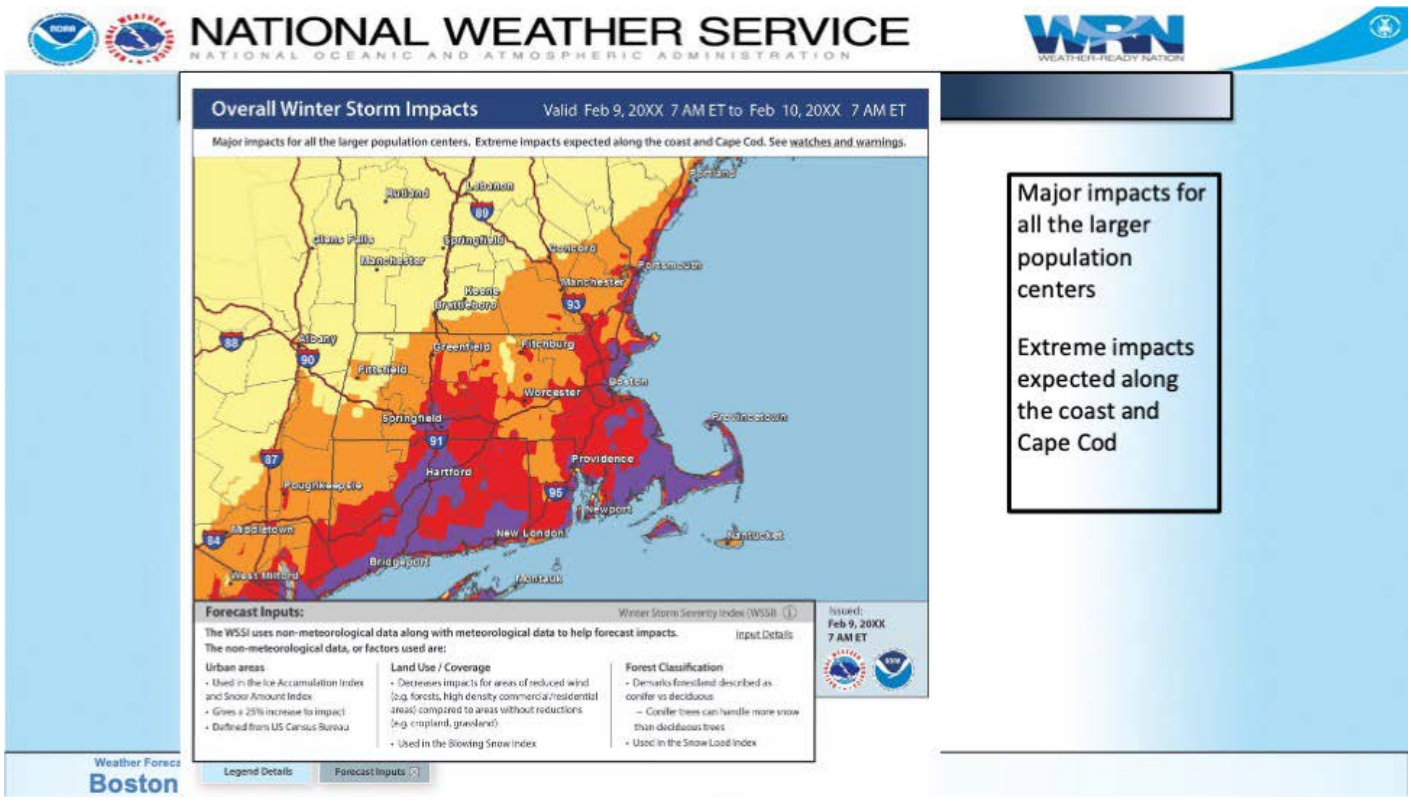
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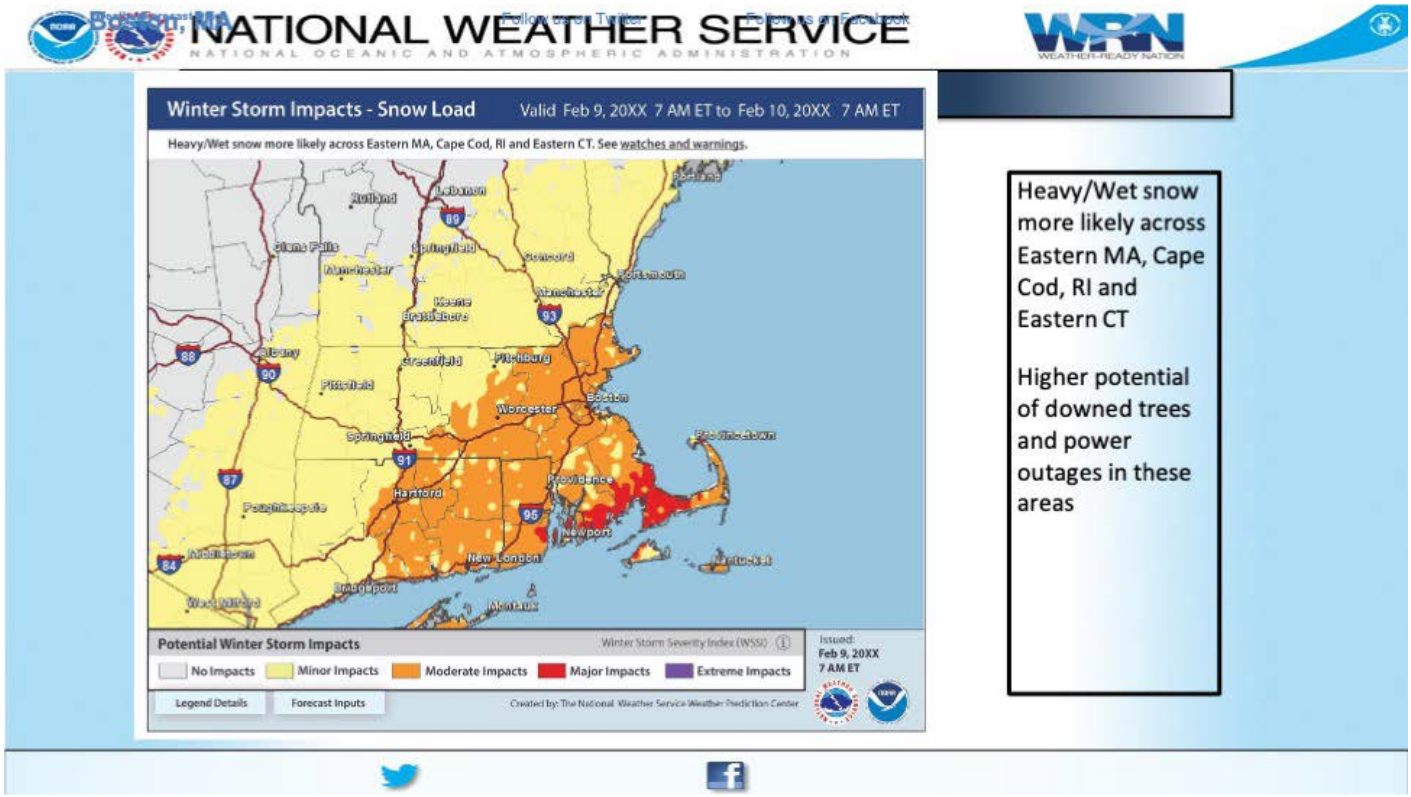
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WRN
WEATHER-READY NATION
Overall Winter Storm Impacts
Valid Feb 9, 20XX 7 AM ET to Feb 10, 20XX 7 AM ET
Major impacts for all the larger population centers. Extreme impacts expected along the coast and Cape Cod. See watches and warnings.
Forecast Inputs:
Winter Storm Severity Index (WSSI)
The WSSI uses non-meteorological data along with meteorological data to help forecast impacts.
Input Details
The non-meteorological data, or factors used are:
Urban areas
Land Use / Coverage
Forest Classification
Issued:
Feb 9, 20XX
7 AM ET
Legend Details
Forecast Inputs
Major impacts for all the larger population centers
Extreme impacts expected along the coast and Cape Cod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WRN
WEATHER-READY NATION
Winter Storm Impacts - Snow Load
Valid Feb 9, 20XX 7 AM ET to Feb 10, 20XX 7 AM ET
Heavy/Wet snow more likely across Eastern MA, Cape Cod, RI and Eastern CT. See watches and warnings.
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Issued:
Feb 9, 20XX
7 AM ET
Legend Details
Forecast Inputs
Created by: The National Weather Service Weather Prediction Center
Heavy/Wet snow more likely across Eastern MA, Cape Cod, RI and Eastern CT
Higher potential of downed trees and power outages in these areas

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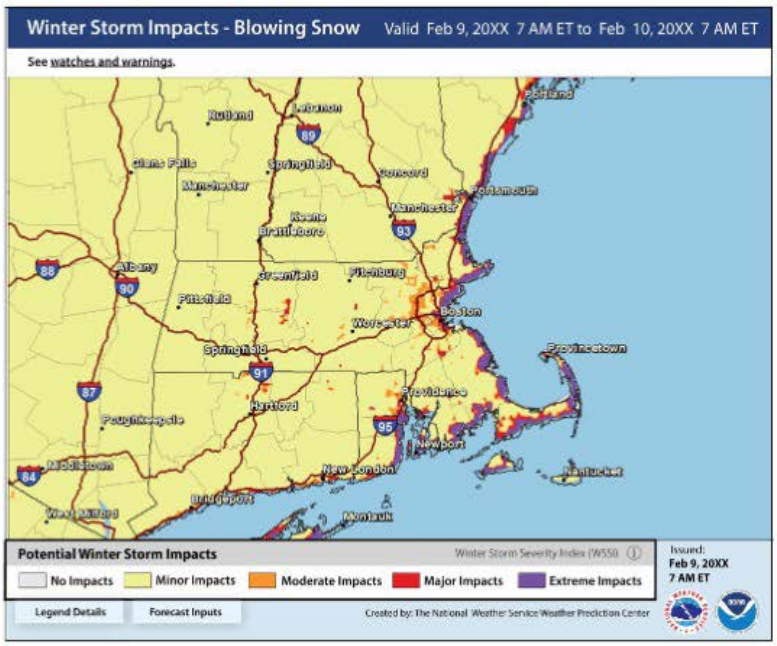
WRN WEATHER-READY NATION



Considerable blowing and drifting snow, especially along the coast and in more open areas (CT River Valley)

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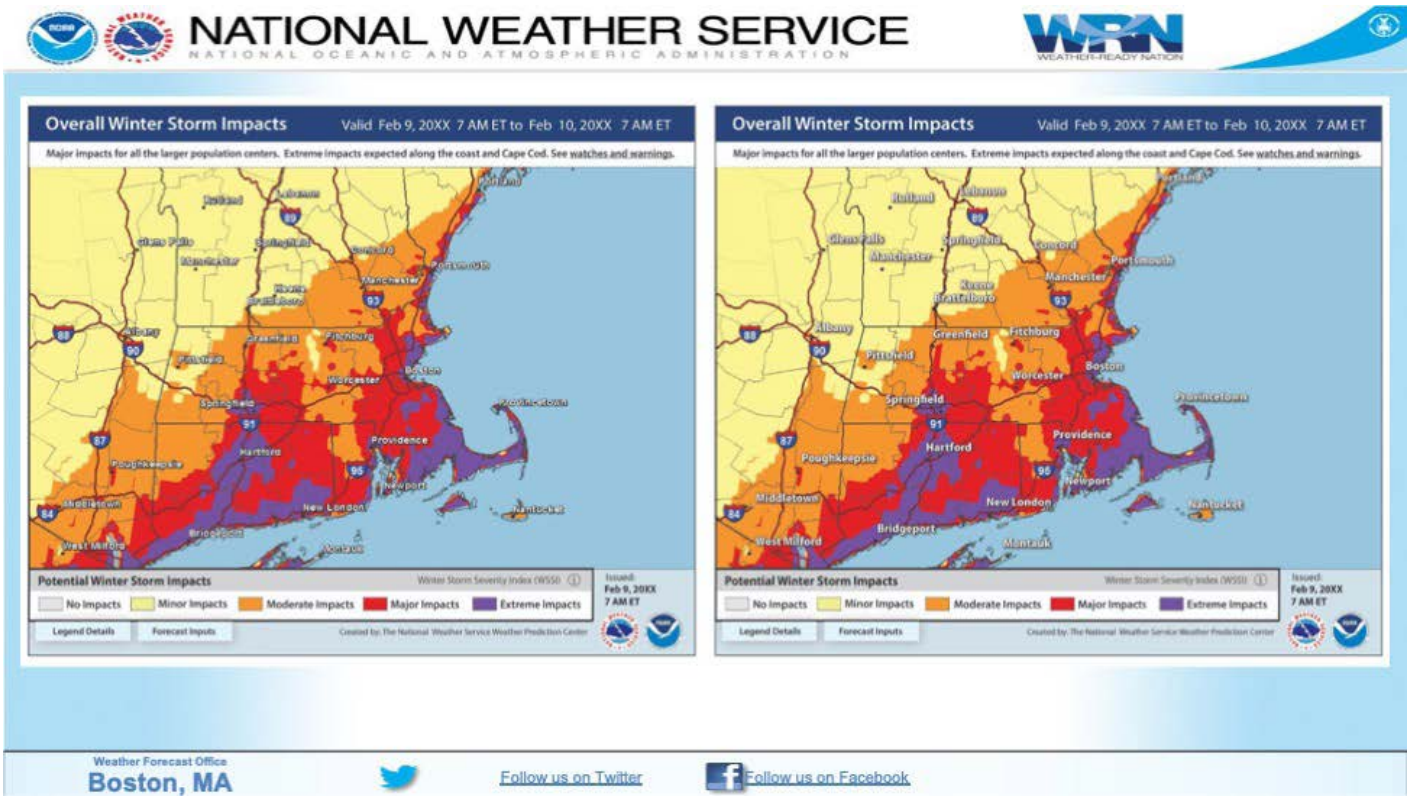
Threat Event Summary

- ✔ **Confidence**: High confidence for a major storm Thursday
- ✔ **What**:
  - Widespread heavy accumulations, low visibilities
  - Strong to damaging wind gusts. Blizzard conditions along the coast.
- ✔ **Where**: All of Southern New England
- ✔ **When**: Thursday morning through Thursday evening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WEATHER-READY NATION
Overall Winter Storm Impacts
Valid Feb 9, 20XX 7 AM ET to Feb 10, 20XX 7 AM ET
Major impacts for all the larger population centers. Extreme impacts expected along the coast and Cape Cod. See watches and warnings.
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Minor Impacts
Moderate Impacts
Major Impacts
Extreme Impacts
Issued: Feb 9, 20XX 7 AM ET
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Major Impacts
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Issued: Feb 9, 20XX 7 AM ET
Legend Details
Forecast Inputs
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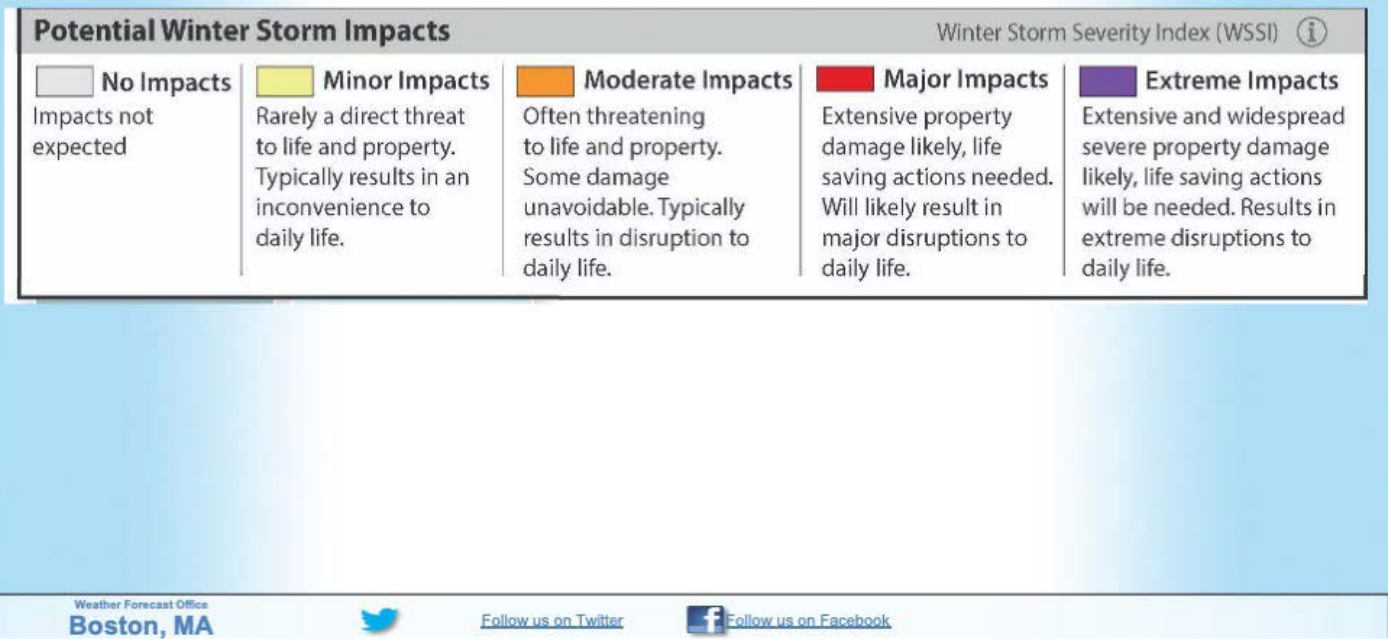
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WEATHER-READY NATION
Potential Winter Storm Impacts
Winter Storm Severity Index (WSSI)
No Impacts
Impacts not expected
Minor Impacts
Rarely a direct threat to life and property. Typically results in an inconvenience to daily life.
Moderate Impacts
Often threatening to life and property. Some damage unavoidable. Typically results in disruption to daily life.
Major Impacts
Extensive property damage likely, life saving actions needed. Will likely result in major disruptions to daily life.
Extreme Impacts
Extensive and widespread severe property damage likely, life saving actions will be needed. Results in extreme disruptions to daily life.
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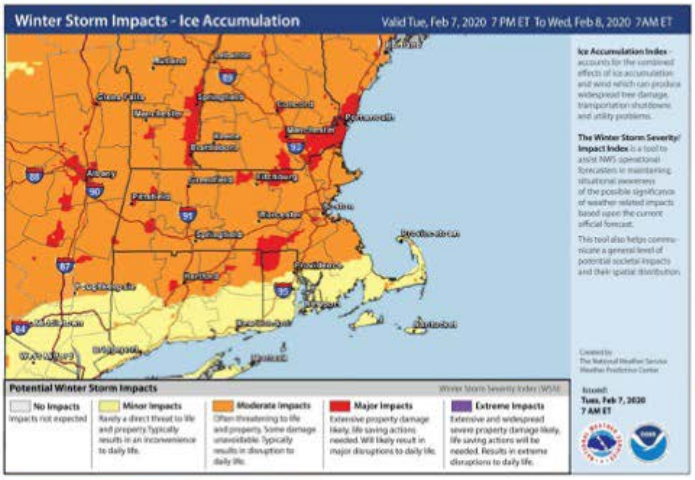
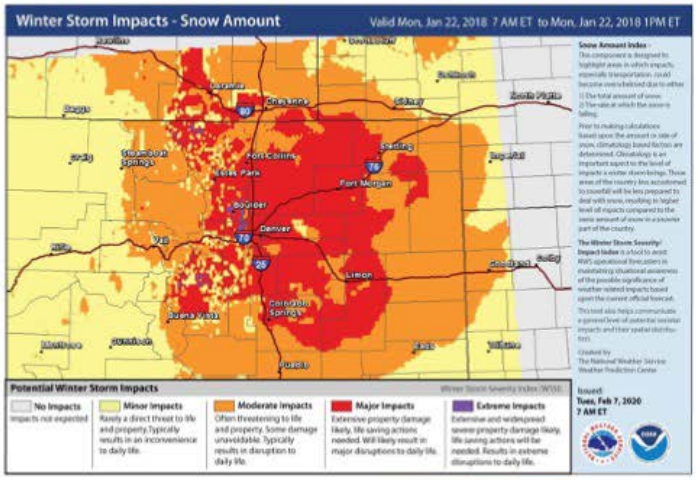
Website and Static Images





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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Snow Amount Index

PURPOSE: This component is designed to highlight areas in which impacts, especially transportation, could become overwhelmed due to either:

1) The total amount of snow.
2) The rate at which the snow is falling.

Prior to making calculations based upon the amount or rate of snow, climatology is an important aspect to the level of impacts a winter storm brings. Those areas of the country less accustomed to snowfall will be less prepared to deal with snow, resulting in higher levels of impacts compared to the same amount of snow in a snowier part of the country.

Blowing Snow Index

PURPOSE: The component highlights areas where blowing/drifting snow or ground blizzards are expected to occur and result in transportation related problems. In general, the blowing snow significance increases as the SLR and winds both increase. Prior blowing snow research indicates that in general it takes just under 20 mph of wind to start to move snow around.

Snow Load Index

PURPOSE: This component is to highlight areas where the weight of the snow could result in damage to trees and powerlines. In general, the lower the snow-liquid ratio (SLR) is and the greater the total snow accumulation, the higher the index.

Wind Chill Index

PURPOSE: The component is the apparent temperature, which takes into account air temperature, relative humidity and wind speed, binned into the 5 impact levels. For a reference point 2 degrees F is the warmest end of the moderate impacts and extreme starts at -38F.

Ice Accumulation Index

PURPOSE: This component was developed to account for the combined effects of ice accumulation and wind which can produce widespread tree damage, transportation shutdowns and utility problems.

Flash Freeze Index

PURPOSE: The component depicts severity primarily to transportation of situations where temperatures rapidly fall below freezing during or just after precipitation.

Weather Forecast Office
Boston, MA

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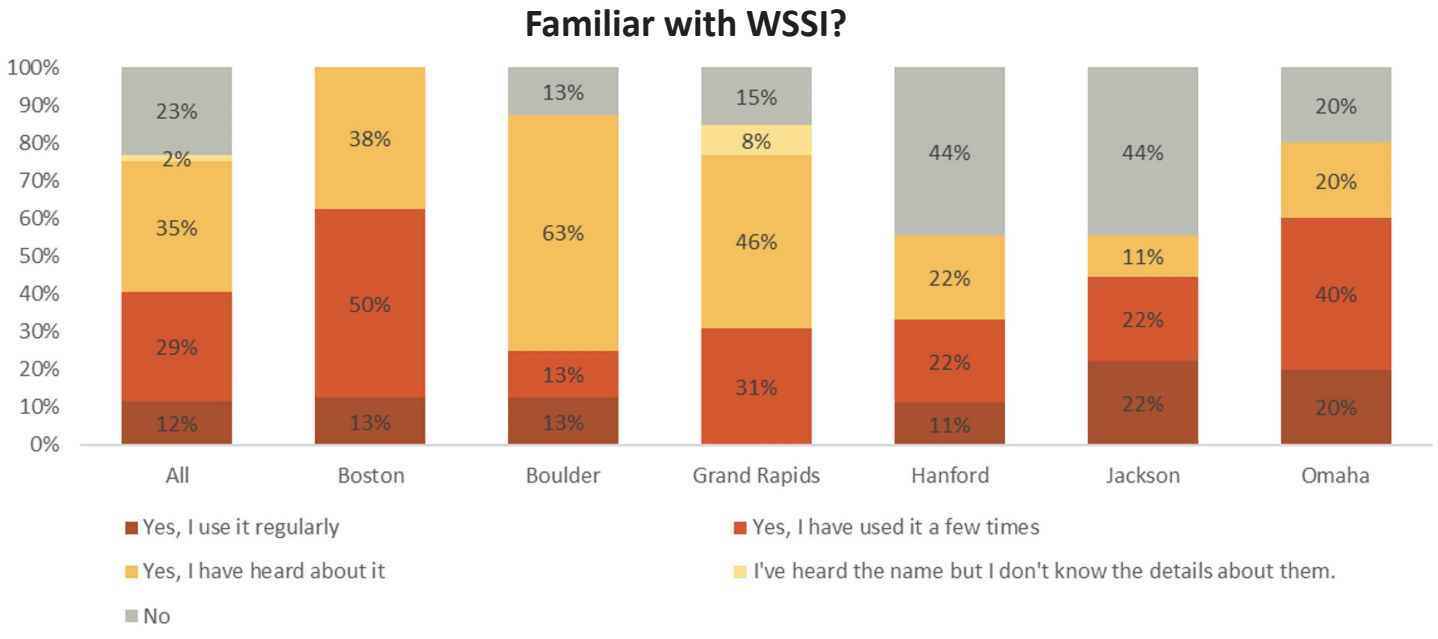
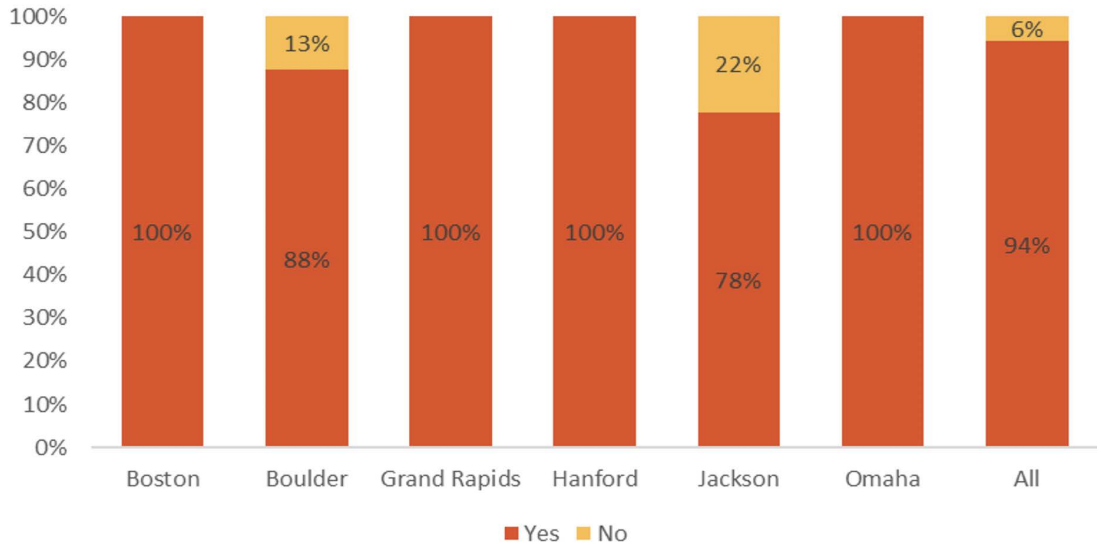
APPENDIX B -
DETAILED SURVEY RESULTS FROM ROUND ONE AND ROUND TWO INCLUDING DEMOGRAPHICS AND RANKINGS OF ALL ELEMENTS IN THE WSSI

WSSI SOCIAL SCIENCE STUDY ROUND 1

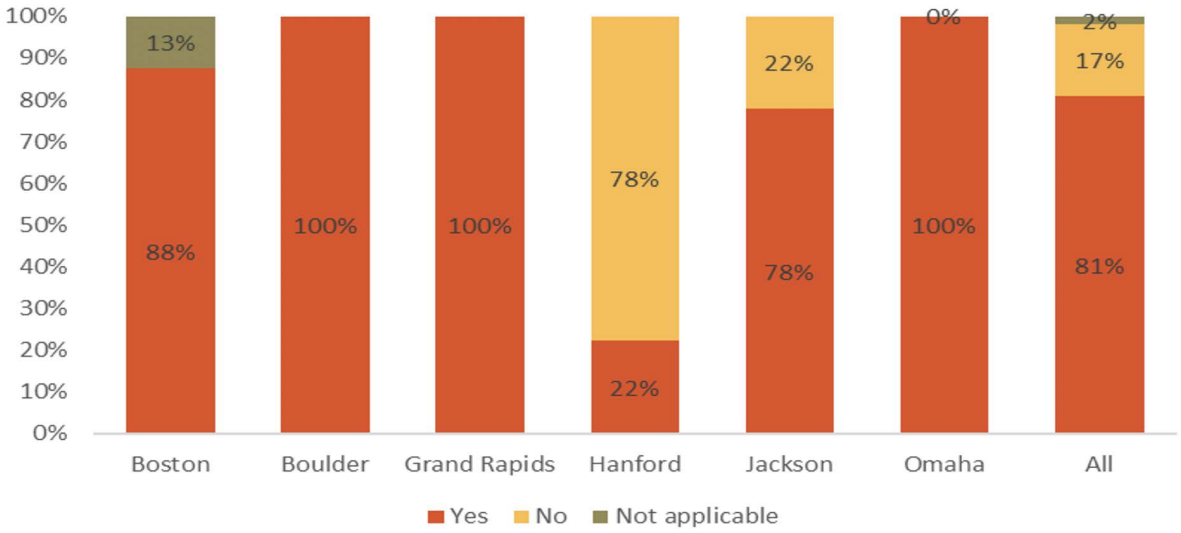
	Focus Group	Pre-Session Survey	Post-Session Survey
Boston	8	8	8
Boulder	8	8	8
Grand Rapids	13	13	12
Hanford	11	9	9
Jackson	9	9	9
Omaha	7	5	6



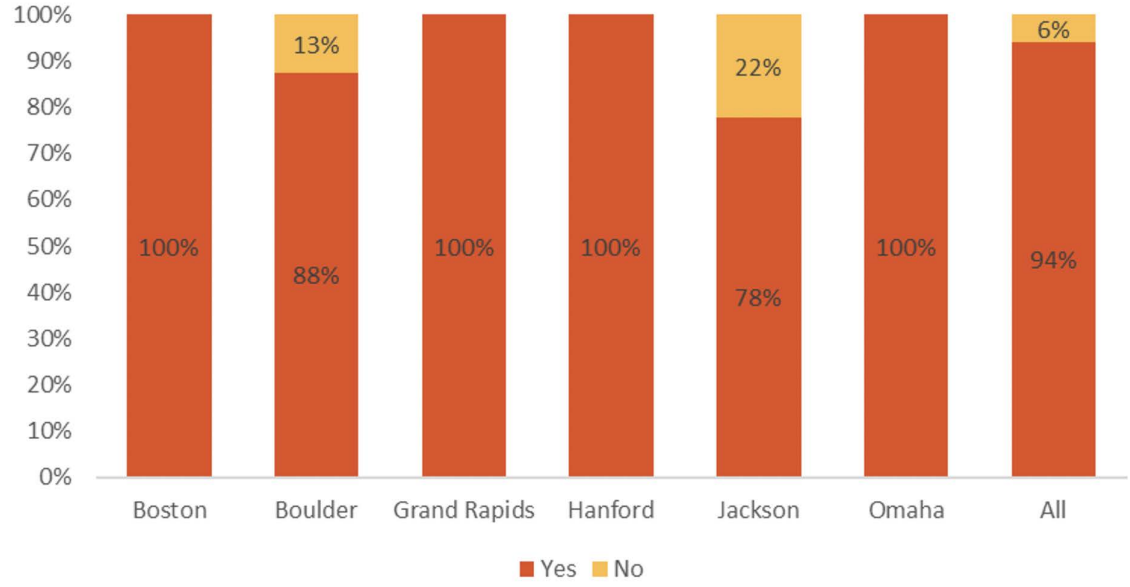
Experience with Severe Winter Weather?



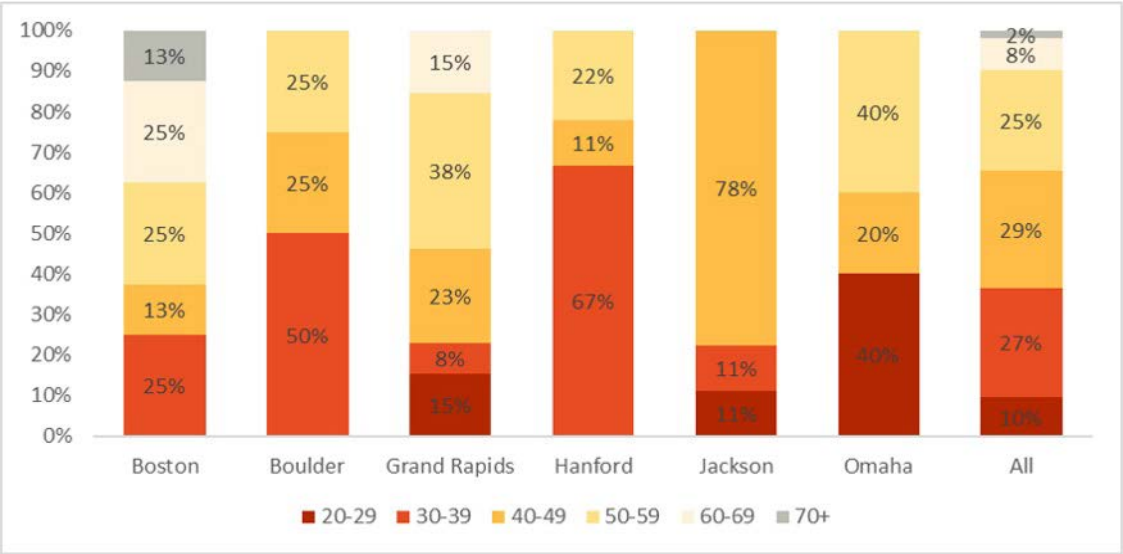
Shared Official Warning Messages



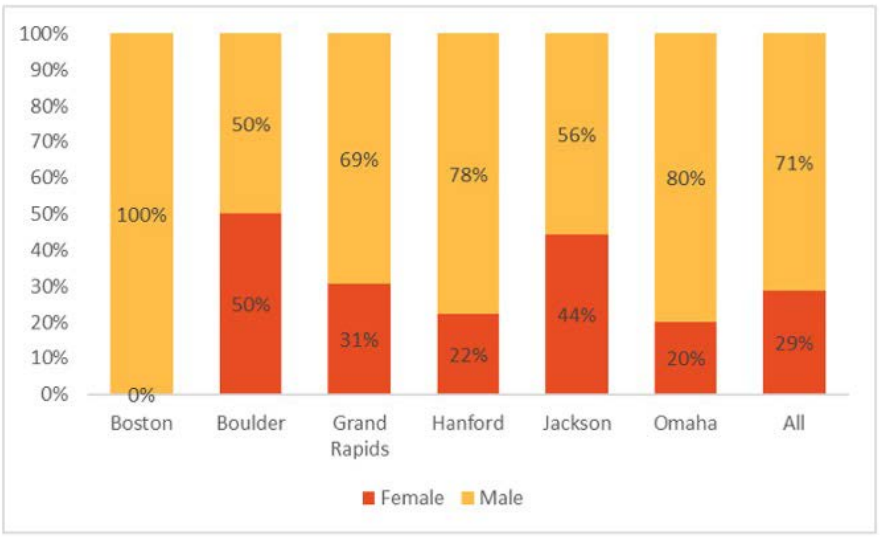
Prepared for or Directed Others to Prepare for Winter Storm?



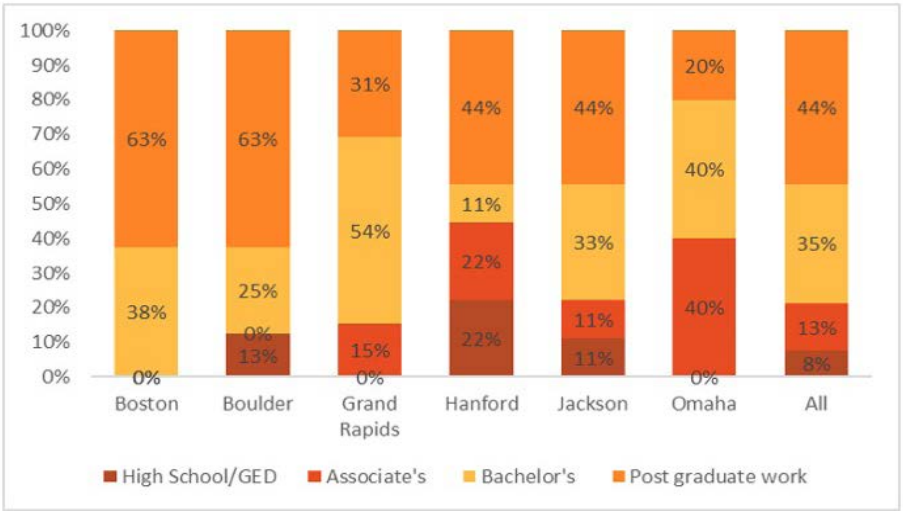
Age



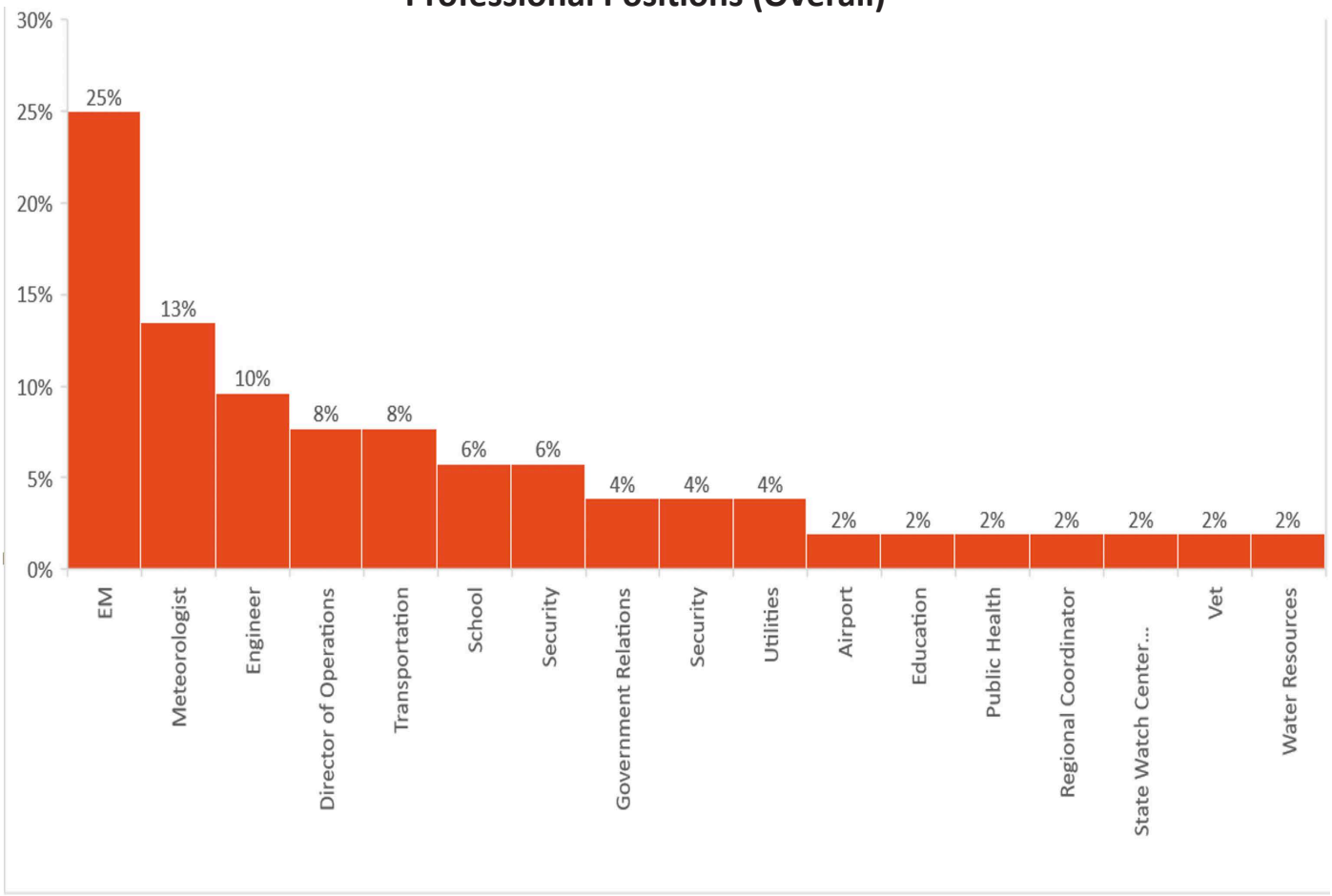
Gender



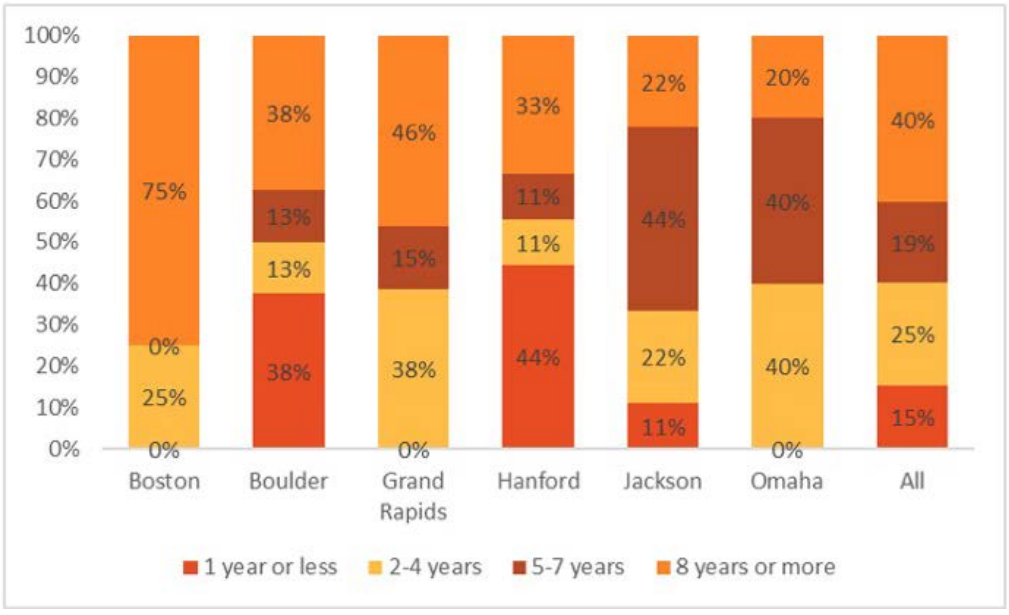
Education



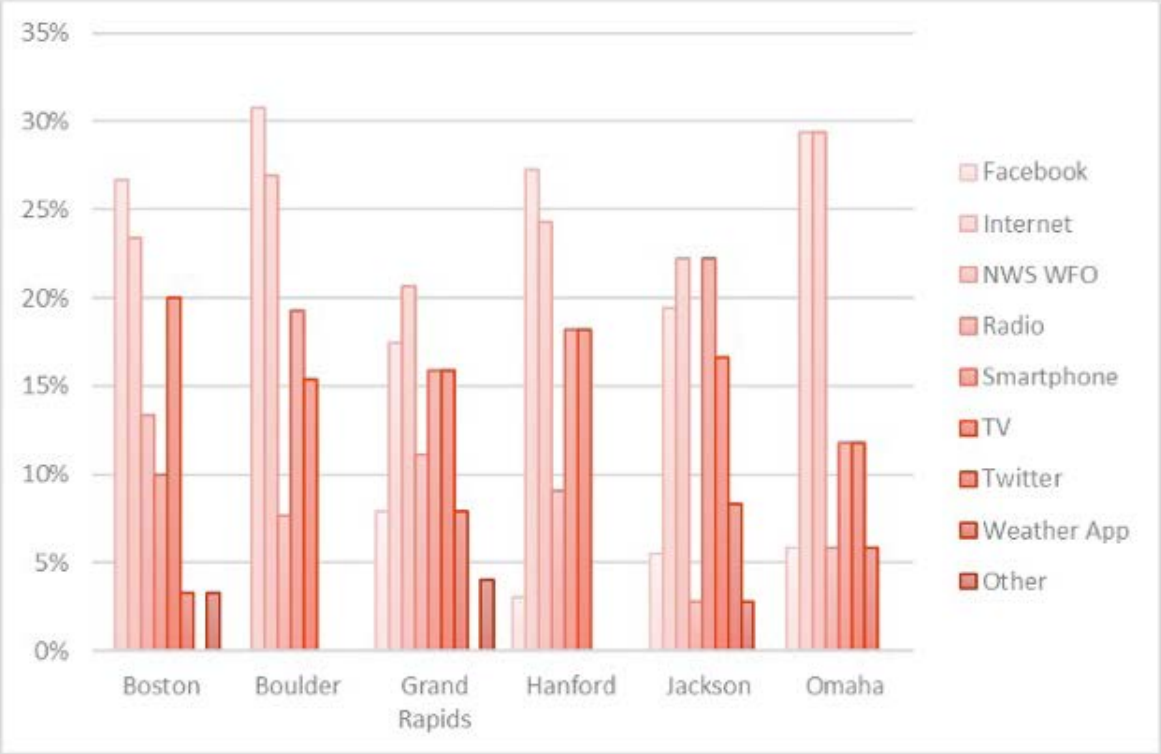
Professional Positions (Overall)



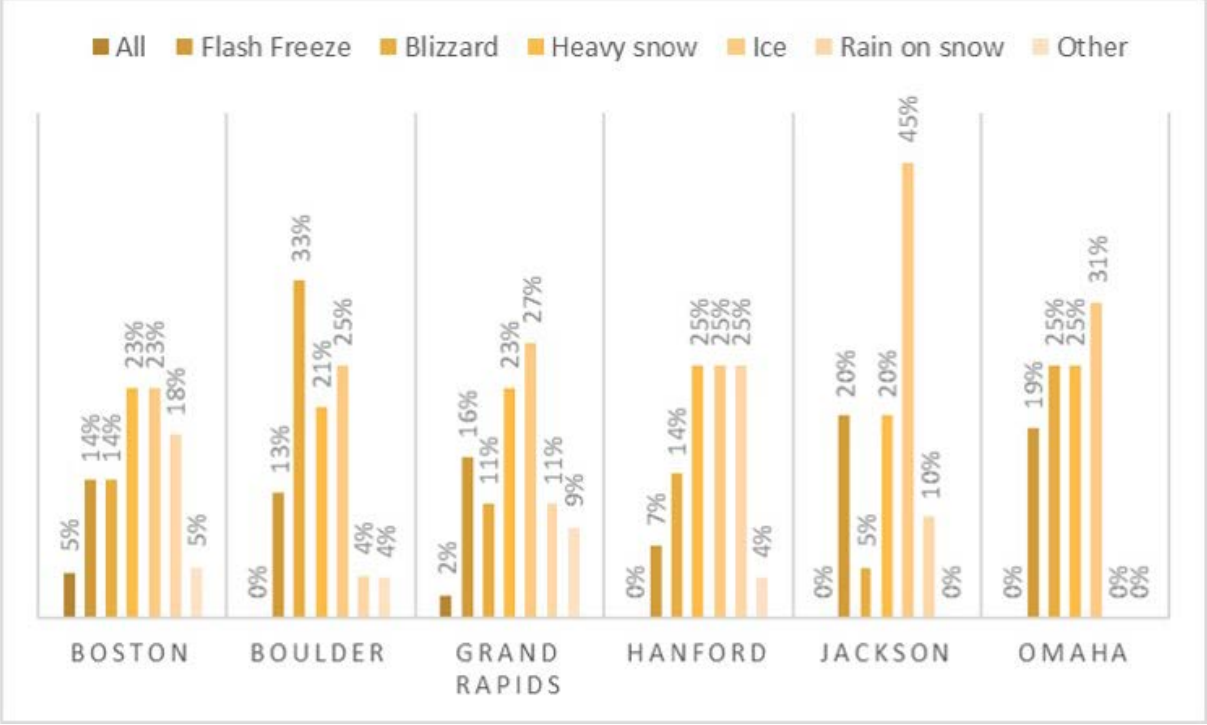
Length of Time in Position



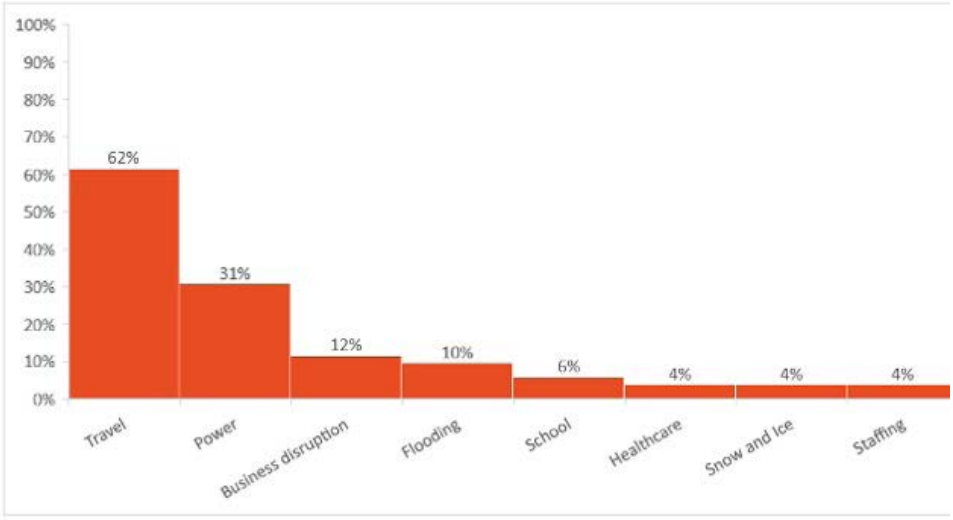
Where Do You Get Info About Severe Winter Weather?



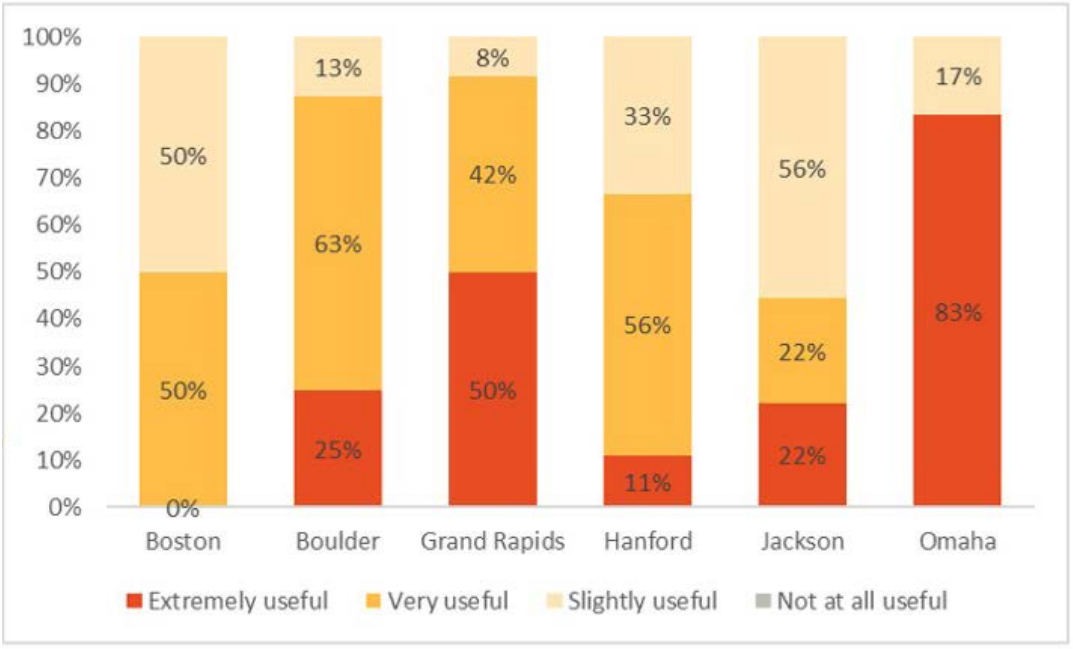
Winter Weather of Most Concern



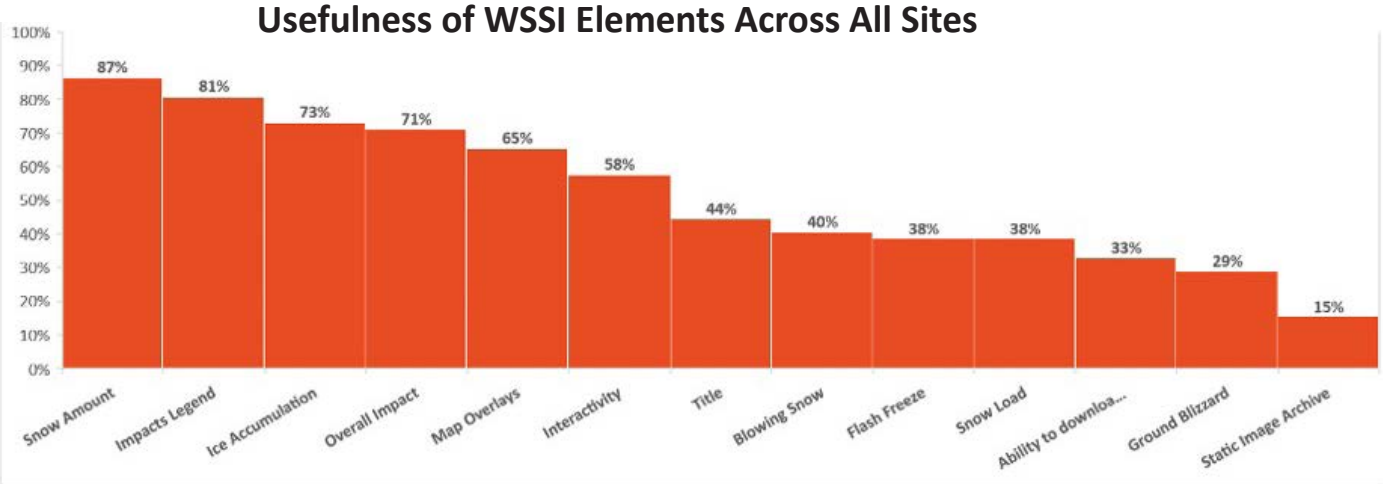
Most Significant Community Impact of Winter Weather (All Sites)



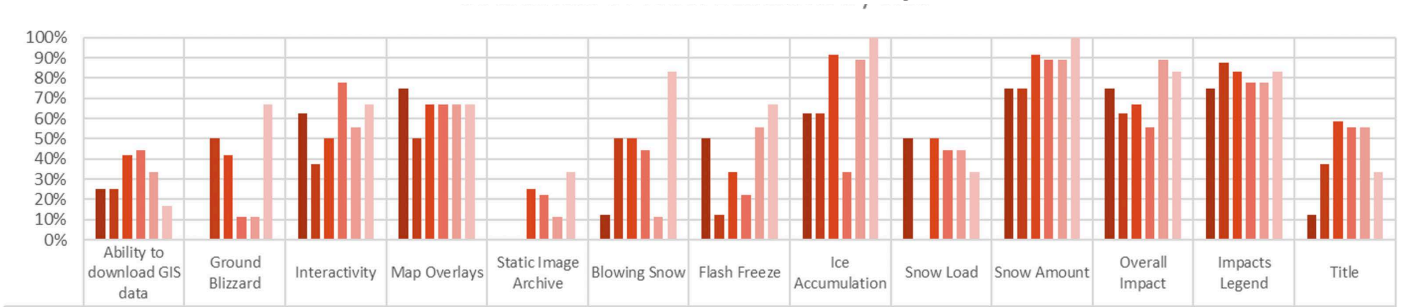
Usefulness of WSSI Round 1



Usefulness of WSSI Elements Across All Sites

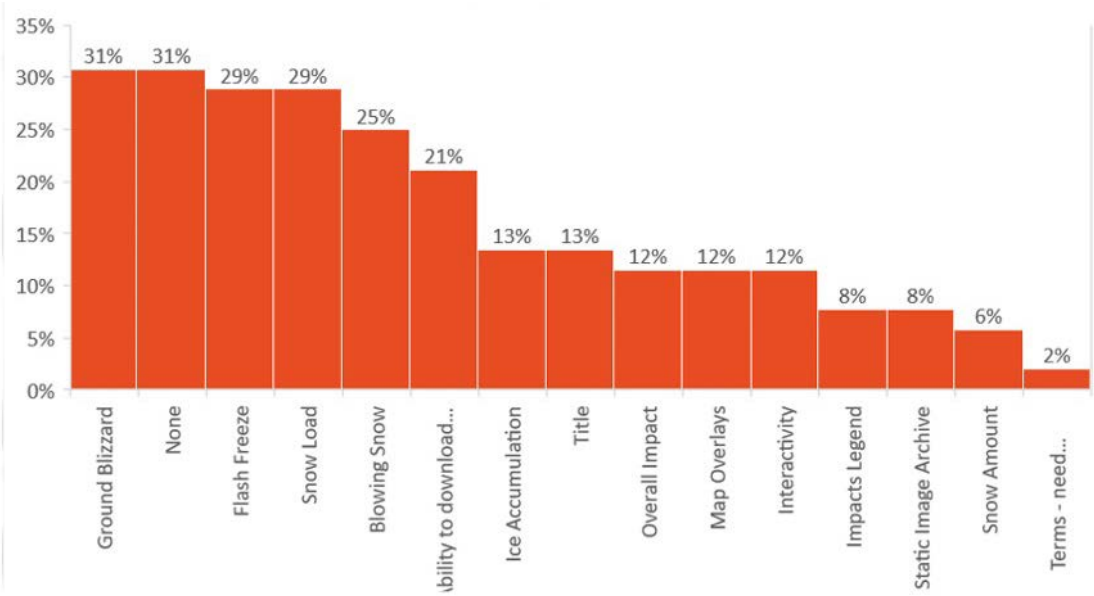


Usefulness of WSSI Elements by Site

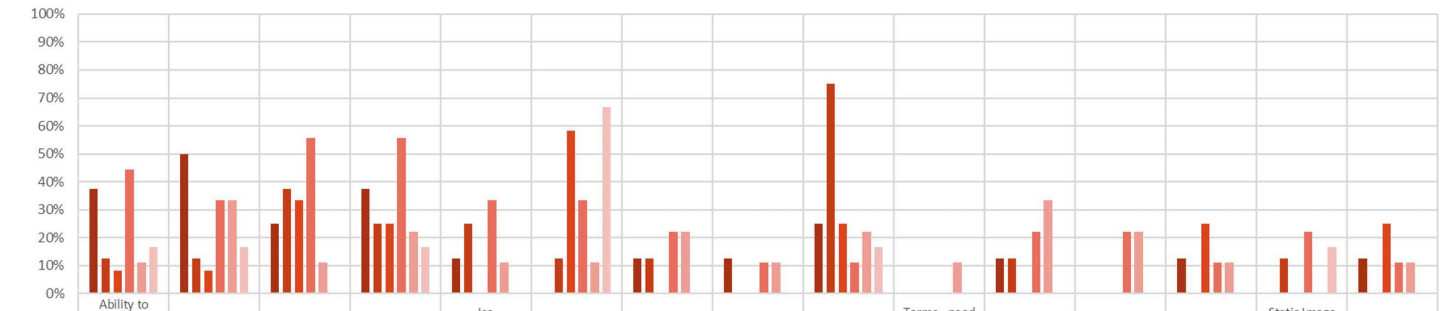


	Ability to download GIS data	Ground Blizzard	Interactivity	Map Overlays	Static Image Archive	Blowing Snow	Flash Freeze	Ice Accumulation	Snow Load	Snow Amount	Overall Impact	Impacts Legend	Title
Boston	25%	0%	63%	75%	0%	13%	50%	63%	50%	75%	75%	75%	13%
Boulder	25%	50%	38%	50%	0%	50%	13%	63%	0%	75%	63%	88%	38%
GRR	42%	42%	50%	67%	25%	50%	33%	92%	50%	92%	67%	83%	58%
Hanford	44%	11%	78%	67%	22%	44%	22%	33%	44%	89%	56%	78%	56%
Jackson	33%	11%	56%	67%	11%	11%	56%	89%	44%	89%	89%	78%	56%
Omaha	17%	67%	67%	67%	33%	83%	67%	100%	33%	100%	83%	83%	33%

Not Useful Elements Across All Sites



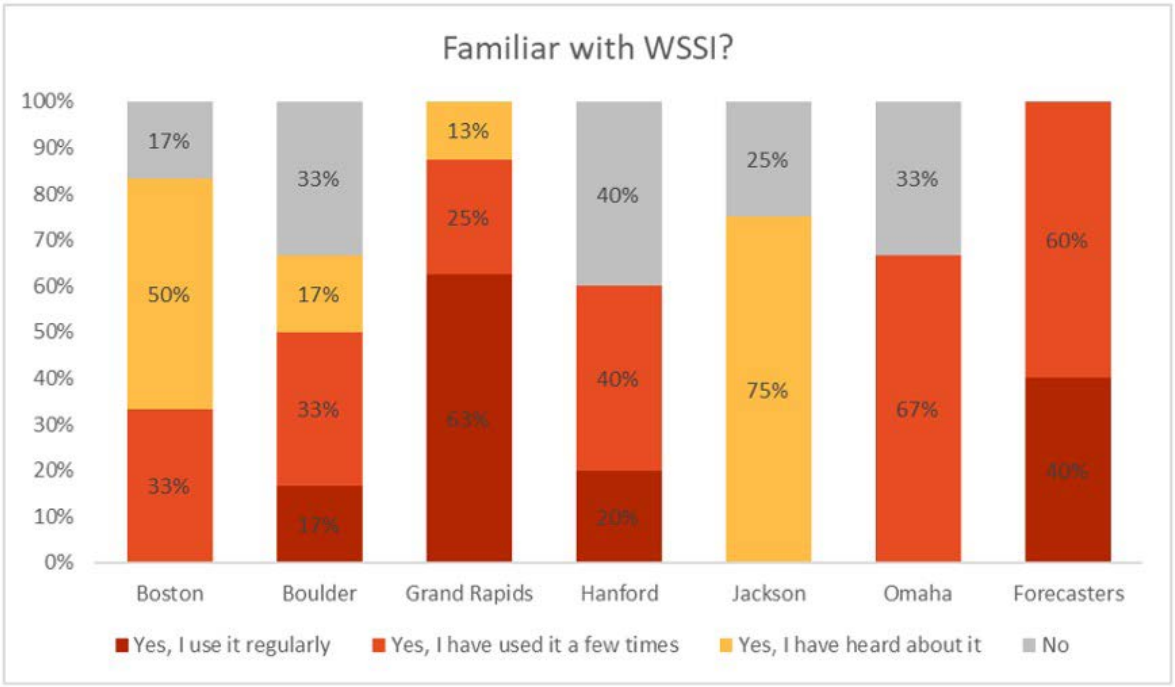
Not Useful WSSI Elements

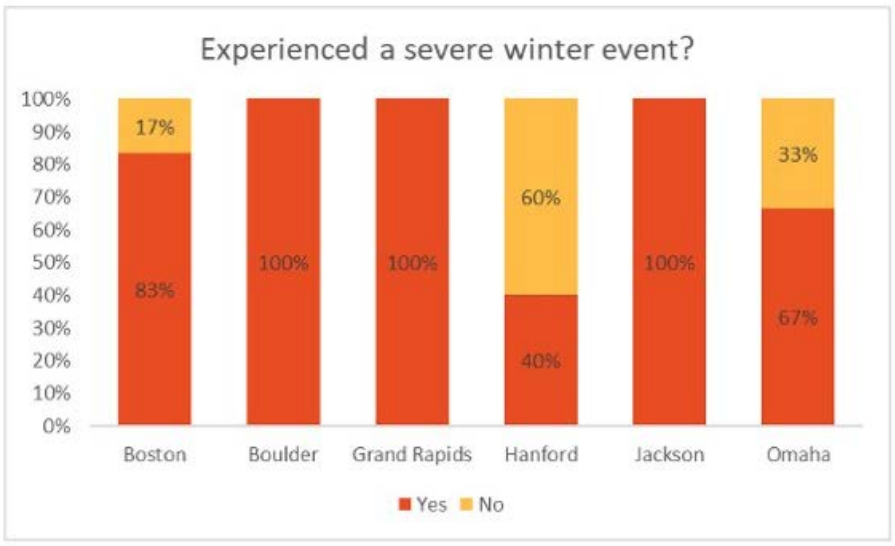


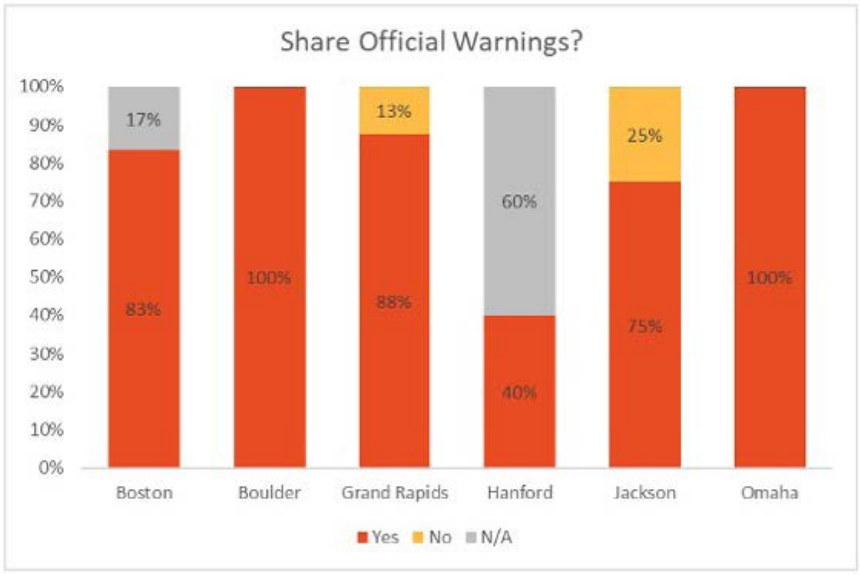
	Ability to download GIS data	Blowing Snow	Flash Freeze	Ground Blizzard	Ice Accumulation	None	Overall Impact	Snow Amount	Snow Load	Terms - need description	Title	Impacts Legend	Map Overlays	Static Image Archive	Interactivity
Boston	38%	50%	25%	38%	13%	0%	13%	13%	25%	0%	13%	0%	13%	0%	13%
Boulder	13%	13%	38%	25%	25%	13%	13%	0%	75%	0%	13%	0%	0%	13%	0%
GRR	8%	8%	33%	25%	0%	58%	0%	0%	25%	0%	0%	0%	25%	0%	25%
Hanford	44%	33%	56%	56%	33%	33%	22%	11%	11%	0%	22%	22%	11%	22%	11%
Jackson	11%	33%	11%	22%	11%	11%	22%	11%	22%	11%	33%	22%	11%	0%	11%
Omaha	17%	17%	0%	17%	0%	67%	0%	0%	17%	0%	0%	0%	0%	17%	0%

WSSI SOCIAL SCIENCE STUDY ROUND 2

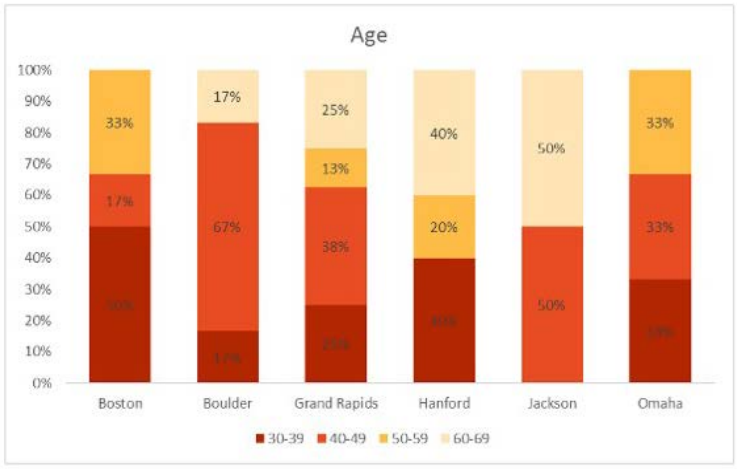
	Focus Group	Pre-Session Survey	Post-Session Survey
Boston	6	6	6
Boulder	6	6	5
Grand Rapids	8	8	8
Hanford	6	5	5
Jackson	4	4	4
Omaha	3	3	3
Forecasters	5	5	5

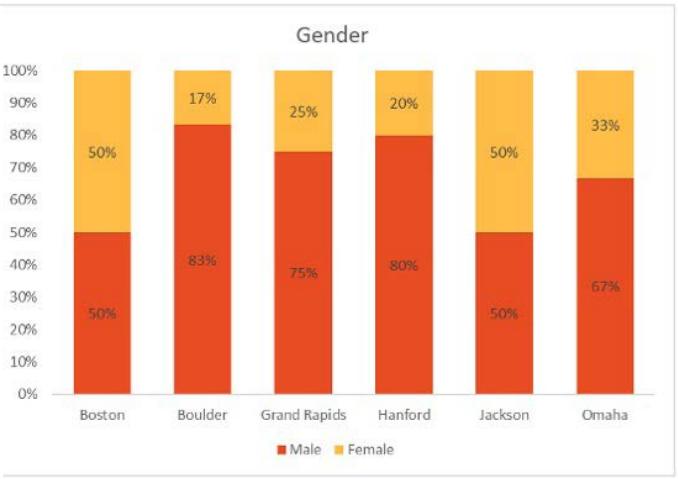


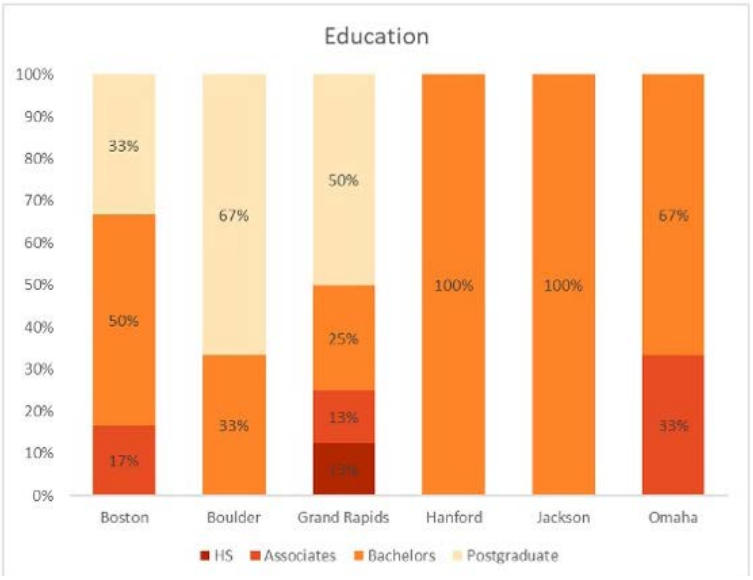

Experienced a severe winter event?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
17%
83%
100%
100%
60%
40%
100%
33%
67%
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Yes
No

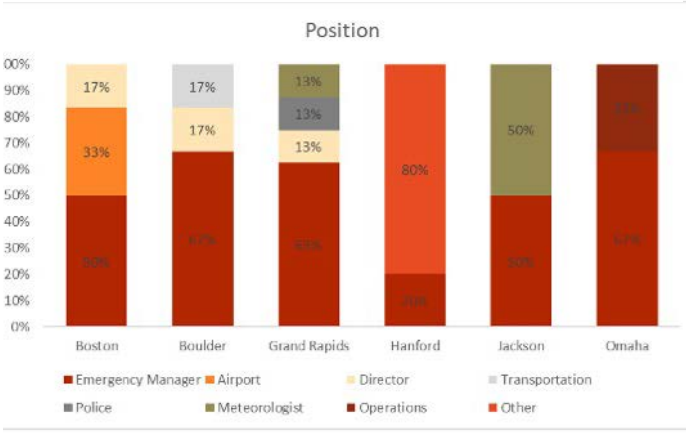

Share Official Warnings?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
17%
83%
100%
13%
88%
60%
40%
25%
75%
100%
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Yes
No
N/A

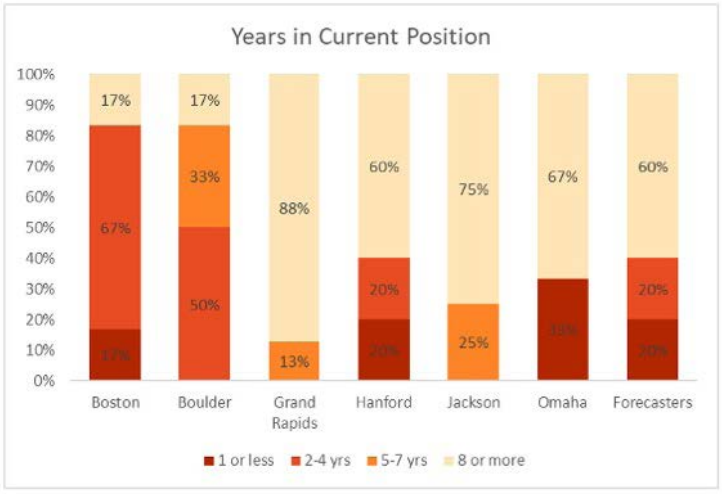

Have you prepared for or directed others to prepare for a winter storm?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
100%
100%
100%
40%
60%
25%
75%
100%
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Yes
No

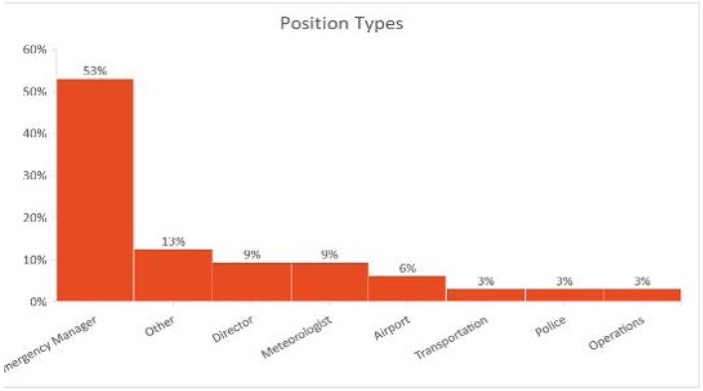

Age
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
30-39
40-49
50-59
60-69


Gender
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Male
Female

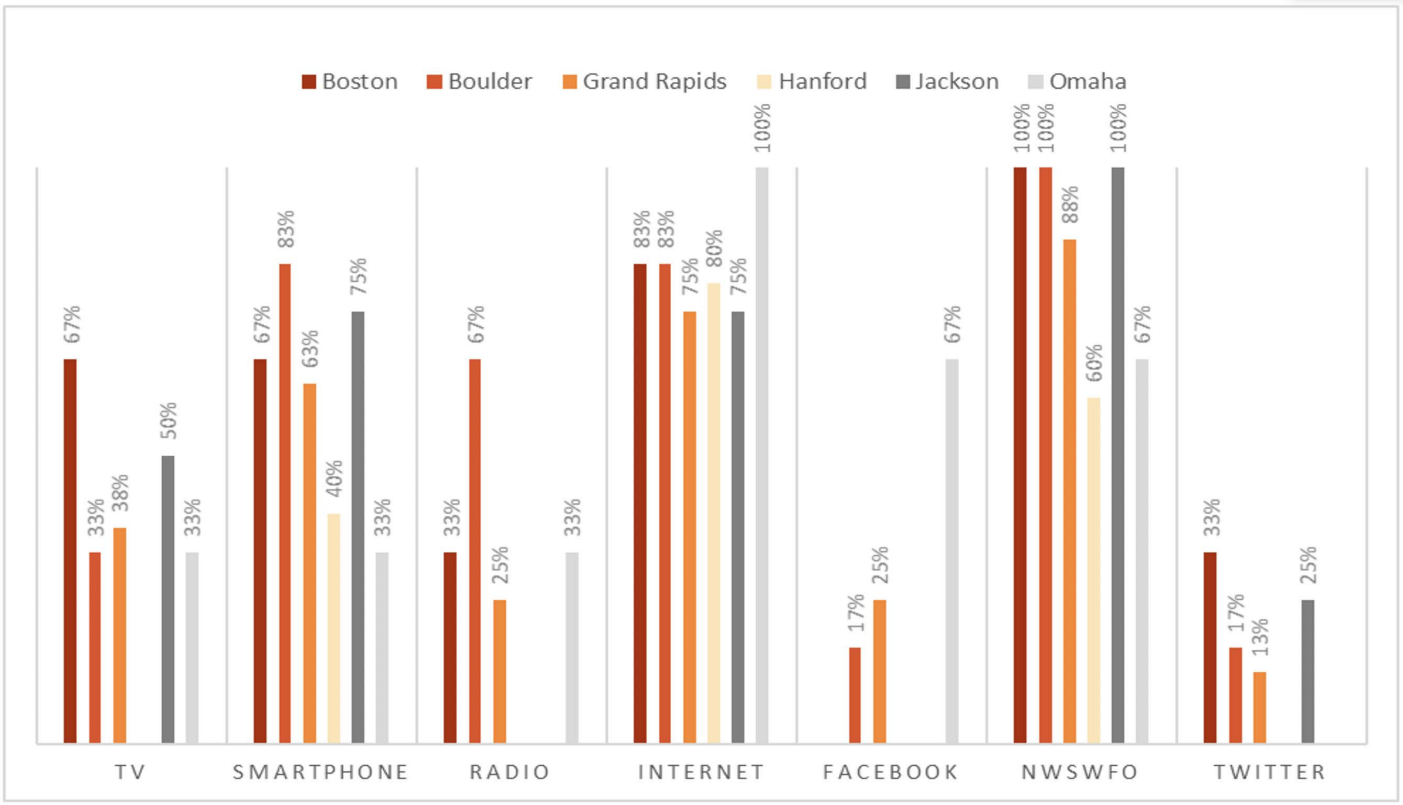

Education
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
HS
Associates
Bachelors
Postgraduate

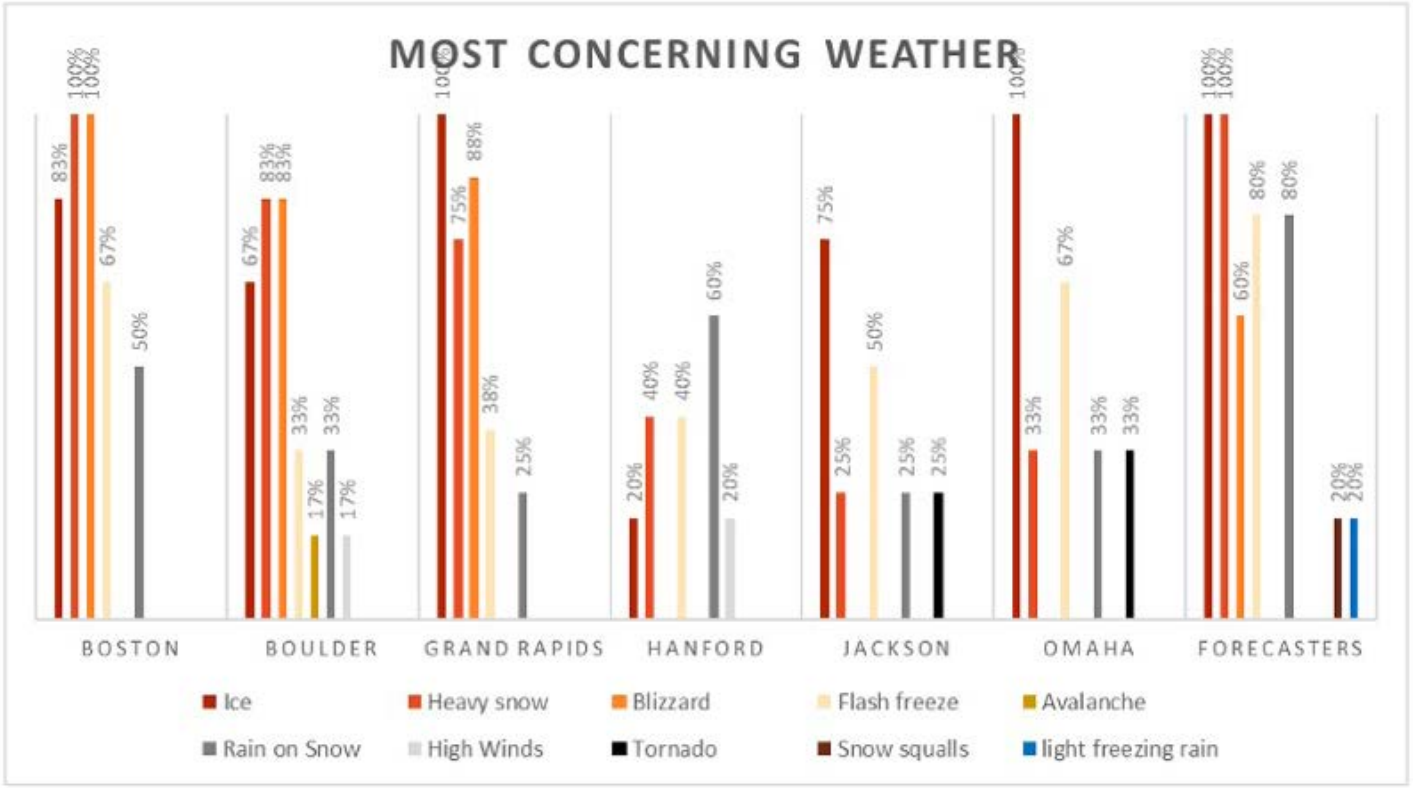

Position
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Emergency Manager
Airport
Director
Transportation
Police
Meteorologist
Operations
Other


Years in Current Position
Boston
Boulder
Grand Rapids
Hanford
Jackson
Omaha
Forecasters
1 or less
2-4 yrs
5-7 yrs
8 or more

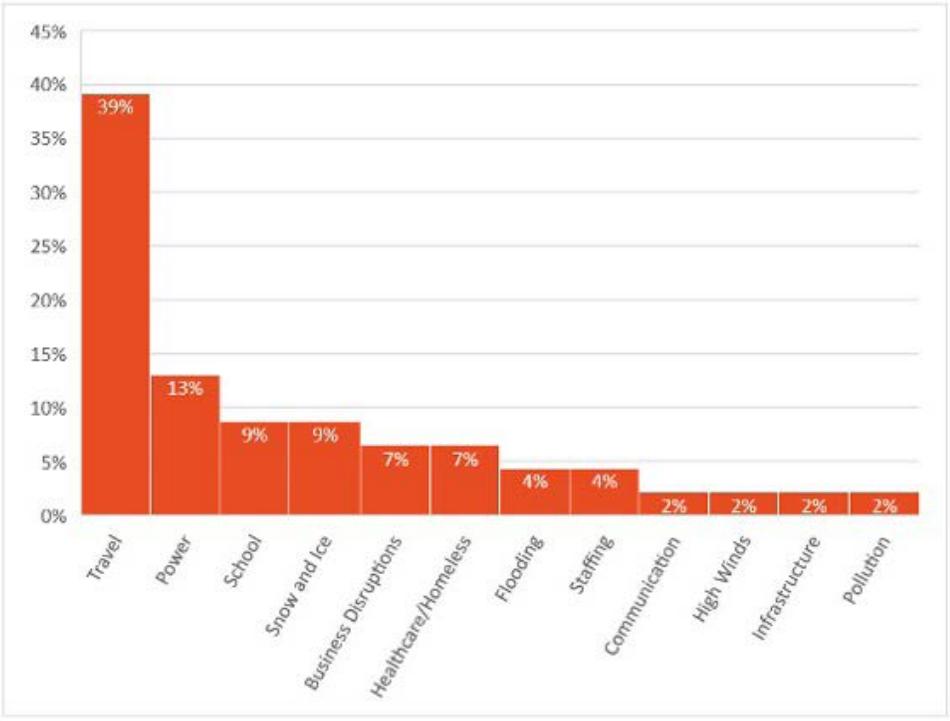

Position Types
53%
13%
9%
9%
6%
3%
3%
3%
Other
Director
Meteorologist
Airport
Transportation
Police
Operations

Where Do You Get Info About Severe Winter Weather?

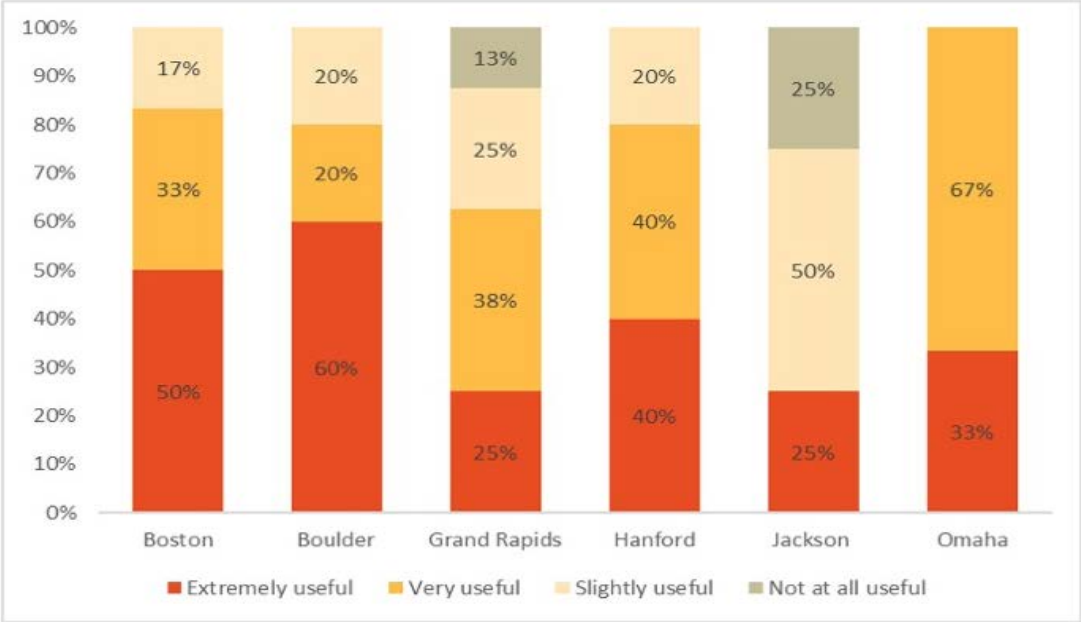




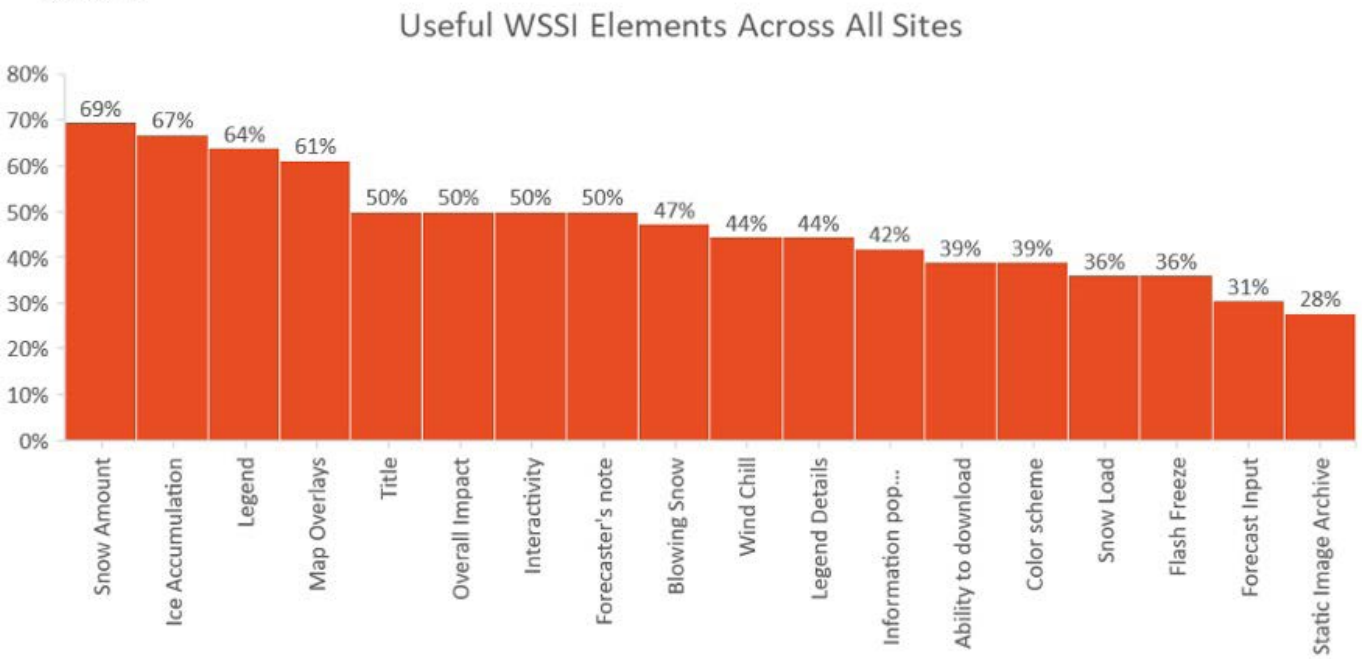
Most Significant Community Impact of Winter Weather (All Sites)

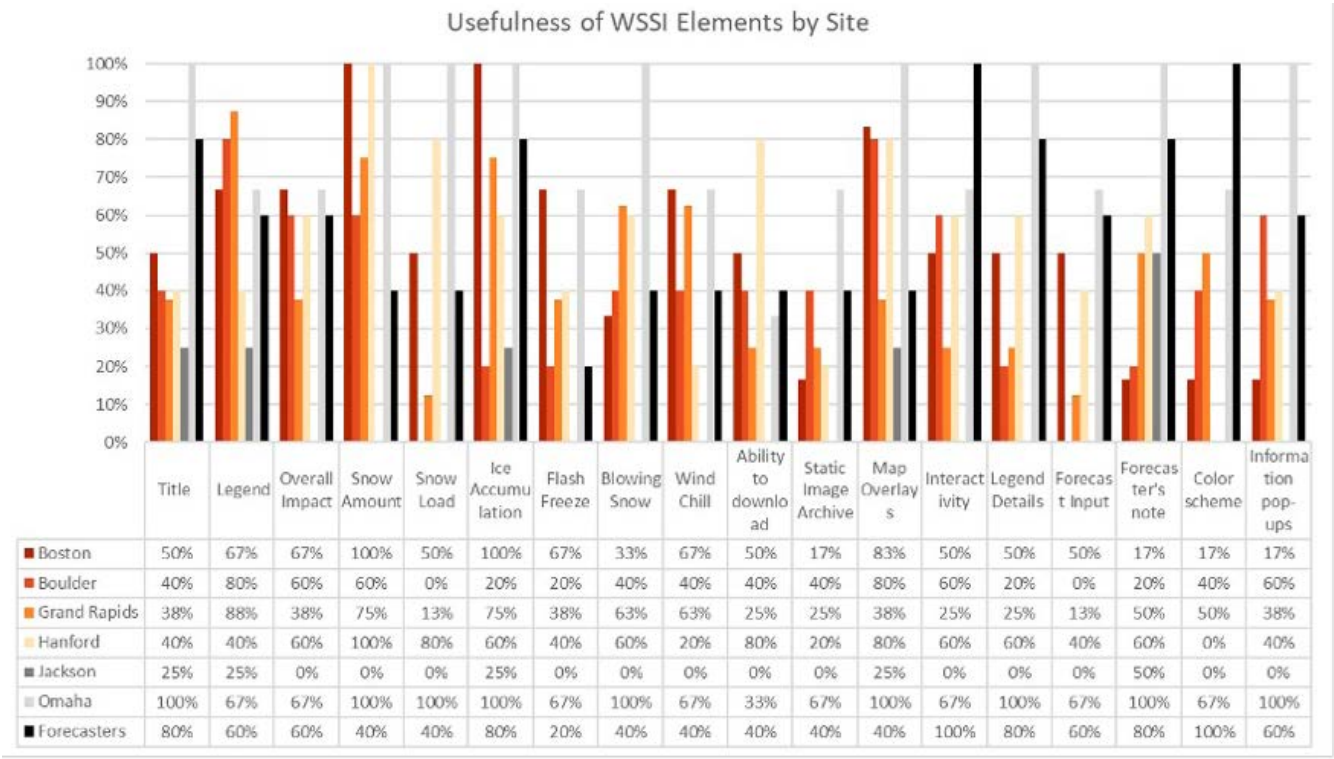


Usefulness of WSSI Round 2

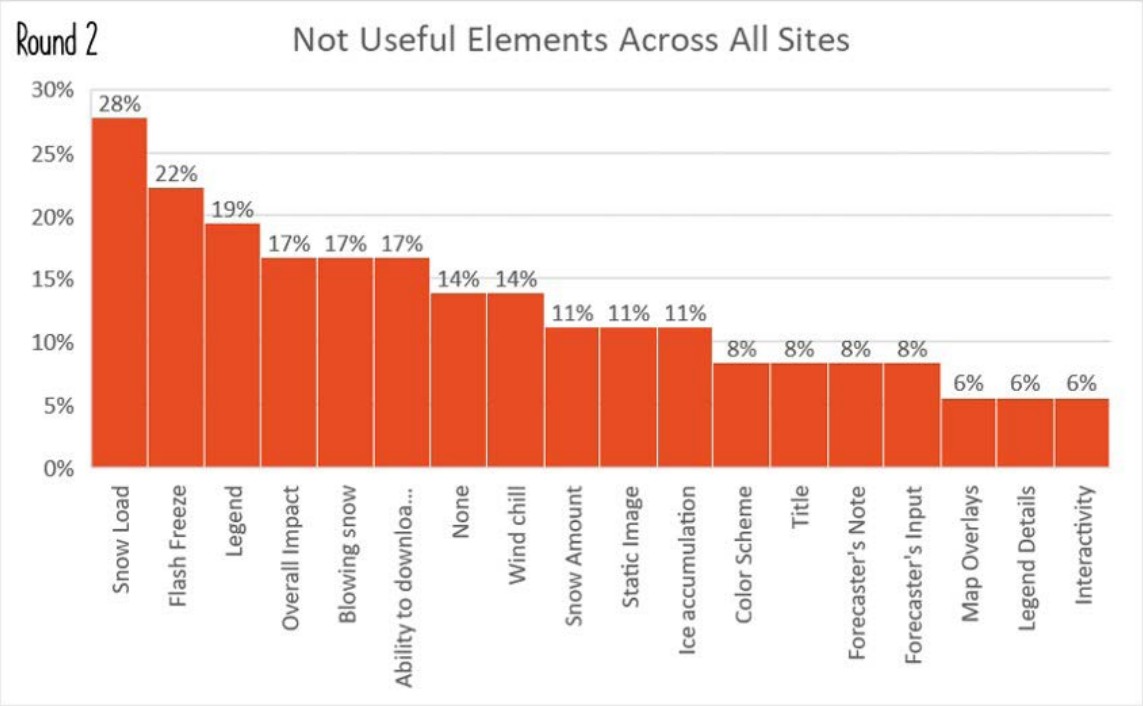


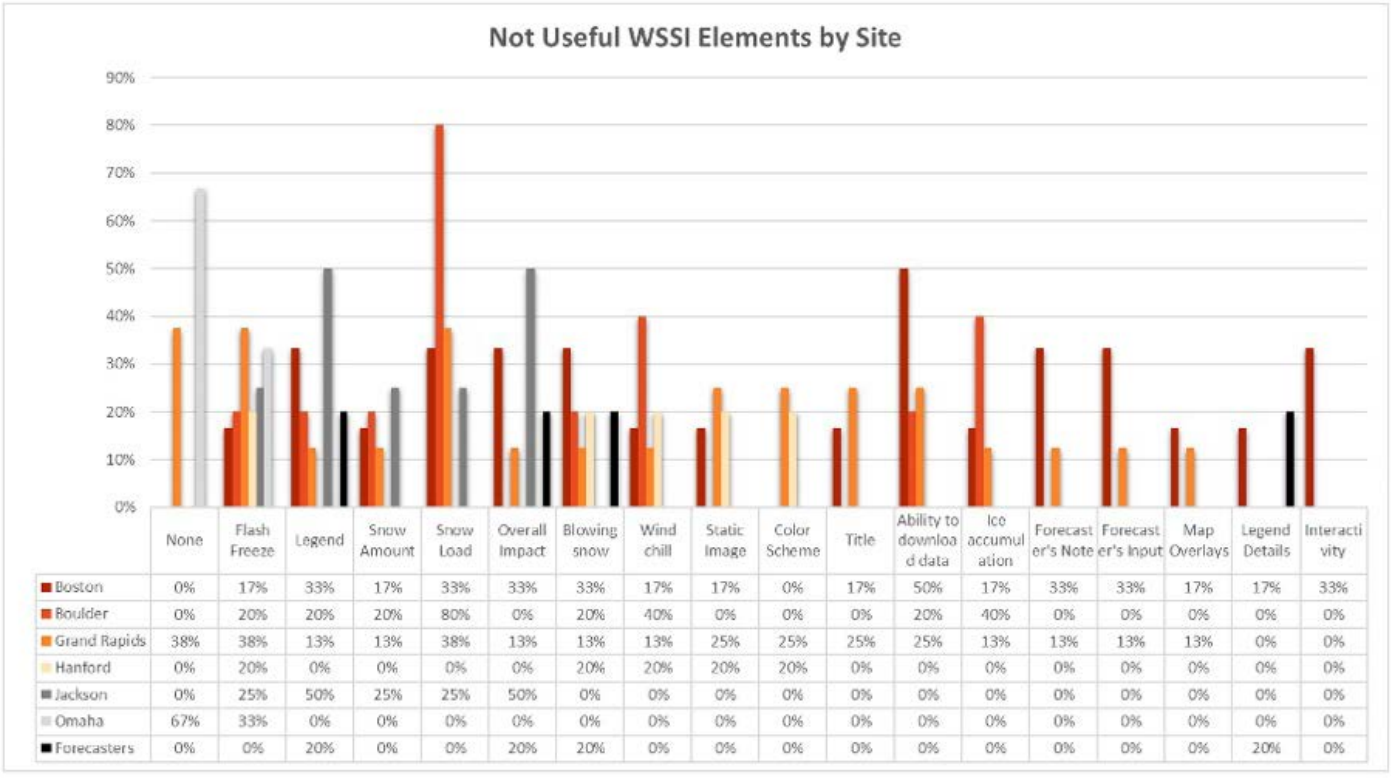
Round 2





	Title	Legend	Overall Impact	Snow Amount	Snow Load	Ice Accumulation	Flash Freeze	Blowing Snow	Wind Chill	Ability to download	Static Image Archive	Map Overlays	Interactivity	Legend Details	Forecast Input	Forecaster's note	Color scheme	Information pop-ups
Boston	50%	67%	67%	100%	50%	100%	67%	33%	67%	50%	17%	83%	50%	50%	50%	17%	17%	17%
Boulder	40%	80%	60%	60%	0%	20%	20%	40%	40%	40%	40%	80%	60%	20%	0%	20%	40%	60%
Grand Rapids	38%	88%	38%	75%	13%	75%	38%	63%	63%	25%	25%	38%	25%	25%	13%	50%	50%	38%
Hanford	40%	40%	60%	100%	80%	60%	40%	60%	20%	80%	20%	80%	60%	60%	40%	60%	0%	40%
Jackson	25%	25%	0%	0%	0%	25%	0%	0%	0%	0%	0%	25%	0%	0%	0%	50%	0%	0%
Omaha	100%	67%	67%	100%	100%	100%	67%	100%	67%	33%	67%	100%	67%	100%	67%	100%	67%	100%
Forecasters	80%	60%	60%	40%	40%	80%	20%	40%	40%	40%	40%	40%	100%	80%	60%	80%	100%	60%





	None	Flash Freeze	Legend	Snow Amount	Snow Load	Overall Impact	Blowing snow	Wind chill	Static Image	Color Scheme	Title	Ability to download data	Ice accumulation	Forecaster's Note	Forecaster's Input	Map Overlays	Legend Details	Interactivity
Boston	0%	17%	33%	17%	33%	33%	33%	17%	17%	0%	17%	50%	17%	33%	33%	17%	17%	33%
Boulder	0%	20%	20%	20%	80%	0%	20%	40%	0%	0%	0%	20%	40%	0%	0%	0%	0%	0%
Grand Rapids	38%	38%	13%	13%	38%	13%	13%	13%	25%	25%	25%	25%	13%	13%	13%	13%	0%	0%
Hanford	0%	20%	0%	0%	0%	0%	20%	20%	20%	20%	0%	0%	0%	0%	0%	0%	0%	0%
Jackson	0%	25%	50%	25%	25%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Omaha	67%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Forecasters	0%	0%	20%	0%	0%	20%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%

Potential Winter Storm Impacts

THE NURTURE NATURE CENTER

ECU

Prepared by Nurture Nature Center and East Carolina University, 2023 with funding from NOAA's JTTI Program

OAR JTTI Award #: NA20OAR4590355