Winter Storm Severity Index in Alaska: Understanding the Usefulness for Impact-Based Winter Weather Severity Forecast Information

KATHRYN SEMMENS,[a] RACHEL HOGAN CARR,[a] BURRELL MONTZ,[b] KERI MAXFIELD,[a] DANA M. TOBIN,[c,d] JOSHUA KASTMAN,[d] JAMES A. NELSON,[d] KIRSTIN HARNOS,[d] MARGARET BEETSTRA,[a] AND PATRICK PAINTER[a]

[a] *Nurture Nature Center, Easton, Pennsylvania*
[b] *East Carolina University, Greenville, North Carolina*
[c] *Cooperative Institute for Research in Environmental Sciences, Boulder, Colorado*
[d] *NOAA/NWS/Weather Prediction Center, College Park, Maryland*

(Manuscript received 17 January 2024, in final form 29 April 2024, accepted 30 May 2024)

ABSTRACT: There is growing interest in impact-based decision support services to address complex decision-making, especially for winter storm forecasting. Understanding users' needs for winter storm forecast information is necessary to make such impact-based winter forecasts relevant and useful to the diverse regions affected. A mixed-method social science research study investigated extending the winter storm severity index (WSSI) [operational for the contiguous United States (CONUS)] to Alaska, with consideration of the distinct needs of Alaskan stakeholders and the Alaskan climate. Data availability differences suggest the need for an Alaska-specific WSSI, calling for user feedback to inform the direction of product modifications. Focus groups and surveys in six regions of Alaska provided information on how the WSSI components, definitions, and categorization of impacts could align with stakeholder expectations and led to recommendations for the Weather Prediction Center to consider in developing the WSSI Alaska product. Overall, wind (strength and direction) and precipitation are key components to include. Air travel is a critical concern requiring wind and visibility information, while road travel is less emphasized (contrasting with CONUS needs). Special Weather Statements and Winter Storm Warnings are highly valued, and storm trajectory and transition (between precipitation types) information are the important contexts for decision-makers. Alaska is accustomed to and prepared for winter impacts but being able to understand how components (wind, snow, and ice) contribute to overall impact enhances the ability to respond and mitigate damage effectively. The WSSI adapted for Alaska can help address regional forecast needs, particularly valuable as the climate changes and typical winter conditions become more variable.

SIGNIFICANCE STATEMENT: Impact-based support services can assist decision-makers in prioritizing preparedness and mitigation actions related to winter storm events. The winter storm severity index adapted for specific considerations in Alaska (such as including wind and visibility components) can extend winter weather impact-based forecasting's utility. Additionally, lessons learned from the process of adapting a national product to specific regional needs may inform best practices for gathering stakeholder input and feedback.

KEYWORDS: Social science; Communications/decision-making; Decision support; Emergency preparedness; Risk assessment; Societal impacts

1. Introduction

Winter storms can have significant impacts in many locations, and effectively communicating forecasts is a critical need to support decision-making to lessen impacts to travel, property, services, and health. Advances in operational observations, physical understanding, and modeling capabilities have improved winter storm forecasting, but challenges remain due to the sensitivity of snow and ice predictions to storm trajectories and precipitation rates, types, and ratios (Novak et al. 2023). Further, forecasters need support to move beyond quantitative, deterministic forecasts to provide impact-based decision support services (IDSS; Demuth et al. 2020) which in turn support better understanding and use of National Weather Service (NWS) information by considering societal impacts relevant to decision-making (Lazo et al. 2020). Given the inherent uncertainty in winter storm prediction, probabilistic frameworks are also seen as valuable tools in supporting decision-making, but there is less research about such approaches specifically for winter weather compared to other hazards (Novak et al. 2023).

It is necessary to understand users' needs for winter storm and hazard forecast information, including the forecast time scales that are most important for decision-making. Additionally, it is important to understand how different winter storm parameters, such as amounts, rates, and trajectories, affect decisions (Tripp et al. 2022; Novak et al. 2023). Forecasters are seeking new tools and training related to winter storm forecasting (including probabilistic information) to address these challenges and increase usefulness to local communities and partnerships (Tripp et al. 2022).

Denotes content that is immediately available upon publication as open access.

Corresponding author: Kathryn Semmens, ksemmens@nurturenature.org

DOI: 10.1175/WAF-D-24-0002.1

Most research addressing users' needs for, and use of, winter weather forecasts in the contiguous United States (CONUS) focuses on decisions about school closings (Call 2010; Call and Coleman 2014; Montz et al. 2015), managing transportation routes and issues (Ye et al. 2009; Strong et al. 2010; Tobin et al. 2022), and uncertainty in warnings (Drobot 2007; Drobot et al. 2008; LeClerc and Joslyn 2015). While there has been some recent research about winter weather impact-based warnings (Weyrich et al. 2018), there remains a scarcity of studies related to winter weather forecast needs (Sherman-Morris 2013). However, there is substantial research about IDSS and impact-based warnings (IBWs), investigating approaches to and effects of considering and communicating how a forecast will be experienced by end users (WMO 2015; Casteel 2016; Weyrich et al. 2018; Potter et al. 2021 and references therein). Specifically, it has been found that IBWs can be effective in informing about severe storm events, especially in providing situational awareness (Potter et al. 2021), but challenges include adequately addressing diverse target audience needs, understanding how much information to include, and identifying the most appropriate impact thresholds (Morss et al. 2016, 2018; Potter et al. 2018, 2021; Ripberger et al. 2015).

A relatively new impact-based winter weather forecast product is the winter storm severity index (WSSI), a graphical product designed in response to user needs to provide anticipated impacts from a forecasted storm and inform situational awareness of the severity and range of potential impacts from an impending winter weather event. The WSSI is an operational product for the CONUS at the Weather Prediction Center (WPC) that uses the geographic information system (GIS) to combine gridded forecast data from the NWS National Digital Forecast Database (NDFD) with nonmeteorological (e.g., urban areas and land use) and climatological datasets (climatology, land use, and urban areas) to result in a graphical depiction of impacts from winter weather (WPC 2020).

The operational WSSI breaks down a storm into six components—snow amount, ice accumulation, snow load, blowing snow, ground blizzard, and flash freeze—with a 72-h forecast window and scales the resulting forecast severity into five levels: extreme, major, moderate, minor, and winter weather area. Snow load is defined as the potential impact from the weight of snow on structures (this index only accounts for the weight of forecasted snowfall, not preexisting snow); blowing snow is the potential impact from falling snow combined with wind; and ground blizzard is the potential impact from snow on the ground (preexisting) combined with wind. Ice accumulation accounts for the combined impact of ice and wind, flash freeze is the potential impact of temperature rapidly falling below freezing during or after precipitation, and snow accumulation is the potential impact of the amount and rate of snow (this index accounts for climatology). The Overall Impact is a composite of the maximum impact from any of the six components with the severity of the winter weather predicted on a scale of 0–5 for the specific components. The WSSI does not account for preexisting conditions—it uses forecasted information and thus will not be representative of the full event in an ongoing weather situation.

This scaling is designed to help users quickly look at the product and identify anticipated/possible levels of social impacts. WSSI graphics are available publicly through WPC (https://www.wpc.ncep.noaa.gov/wwd/wssi/wssi.php) in an interactive interface (zoom to forecast area), as static images, and as downloadable data.

Since the WSSI is a graphical product, it has additional challenges including design considerations for effectively presenting impacts and descriptions in legends. Graphical forecast products can lead to inaccurate interpretations (Broad et al. 2007; Savelli and Joslyn 2013) and may not be sufficiently understandable to motivate action (Hogan Carr et al. 2016a). Thus, design factors such as the use of color require careful consideration to support users in making sense of the information (Hogan Carr et al. 2016b).

The utility of, and design considerations for, the CONUS WSSI were recently studied using a mixed-methods social science research study that focused on how professional stakeholders understand, interpret, and use this graphical impact-based product for communicating about impending winter weather (Semmens et al. 2023). That study, conducted in collaboration with the WPC, led to iterative refinements to some elements of the WSSI and design recommendation considerations (Nurture Nature Center 2023). Further, on-going verification of the WSSI allows for improvements to be made in forecasting to better inform the public about impacts (Pappas et al. 2022; Tobin et al. 2023). While these efforts help advance impact-based winter weather forecasting, these studies and efforts only address the CONUS WSSI. Additionally, most forecasting advances and research studying weather forecasting related to the U.S. NWS focus on the CONUS. For example, improvements in estimating snowfall have recently come about through the establishment of the first operational gridded snowfall analysis over the CONUS (NWS 2022; Novak et al. 2023). Further, studies about winter storm impacts tend to focus on the CONUS, for example, winter weather-related road fatalities as a significant impact of concern (Black and Mote 2015; Mills et al. 2019; Tobin et al. 2022; Call and Flynt 2022).

Alaska, in particular, has unique climatic and geographic considerations for forecasting. For instance, western Alaska experiences storm surge events that are difficult to forecast due to sea ice and wind-induced wave effects not considered previously in storm surge modeling, an issue being addressed with the recently developed Alaska Coastal Ocean Forecast System (ALCOFS) which considers sea ice and wave effects for real-time storm tide forecasting (Ling et al. 2023). Interest from the WPC in extending the WSSI to Alaska, with consideration of the distinct needs of Alaskan stakeholders and the Alaskan climate, spurred the social science research study described in this paper. Specifically, there was interest in understanding what winter hazards Alaskans experience and how they are affected (which may be similar to or different from hazards in the CONUS), what resources and limitations may exist (given geographical constraints and population size), the modes of transportation, and the adaptability/resilience of Alaskans (who are typically exposed to the winter hazards more frequently than many CONUS states). This understanding supports efforts to ensure the WSSI components, thresholds, and definitions align with

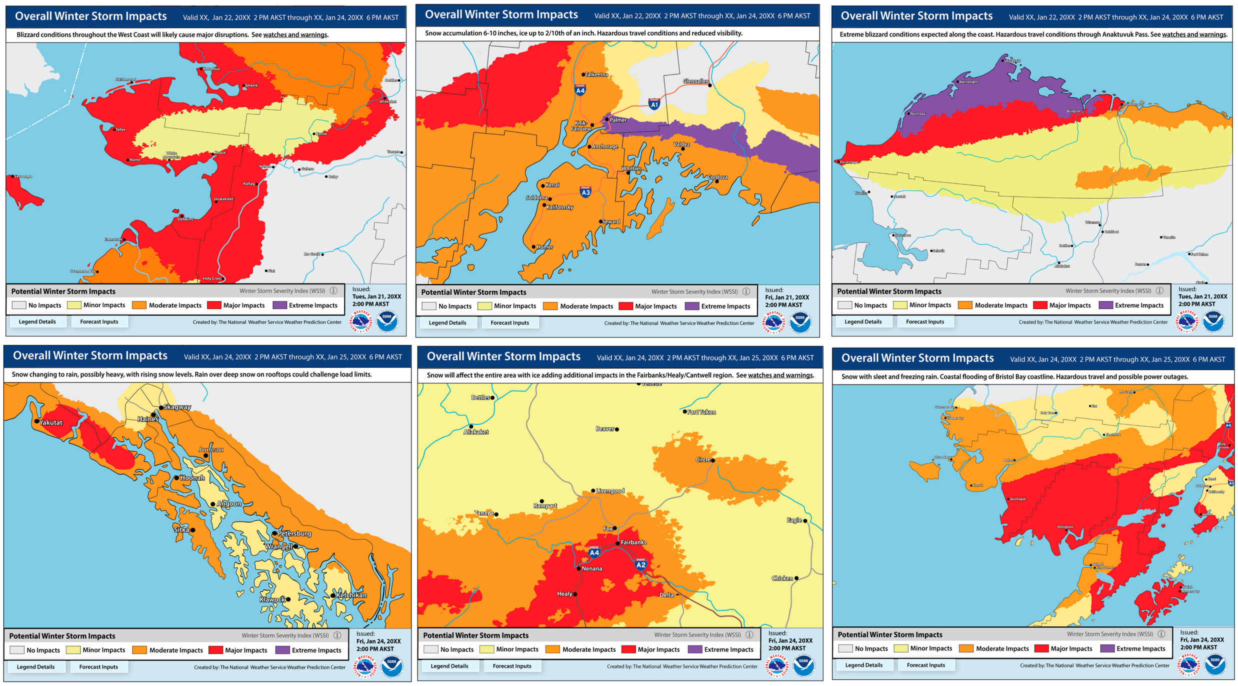

FIG. 1. Examples of the mocked-up WSSI Alaska product shown in each of the six virtual focus groups: (top, from left to right) West Coast, Southcentral/Anchorage, and North Slope; (bottom, from left to right) Juneau, Fairbanks, and Southwest/Bristol Bay.

user needs in Alaska. This is the first step in expanding the WSSI to include Alaska, while addressing stakeholder/public needs in order to create an equally useful product to users in Alaska as it is for CONUS stakeholders (which have been addressed in previous studies to ensure usefulness, see Semmens et al. 2023).

Since the data used for CONUS WSSI do not support a simple expansion of the product to Alaska due to different data availability (different NWS data and products, and also different nonmeteorological data types/sources from those available for the CONUS), the potential development of an Alaska-specific WSSI raised the need to consider the creation of different and additional components for the WSSI compared to the CONUS version. While some of the framework and visualizations of the CONUS WSSI could be adapted into the WSSI Alaska framework, user feedback was needed to inform the direction of product modifications and develop a prototype for the Alaska region. Further, learning how the WSSI can be adapted to different regions was hypothesized to provide insight about how impact-based forecasting tools can be scaled/modified nationally to adapt to different audiences and geographies which might be valuable to, and considered for, other areas.

Specifically, this research used focus groups and surveys to assess how the WSSI components reflect the needs of Alaska region stakeholders, to determine how the product's impact definitions and categorization align with stakeholder expectations surrounding severity levels, and to provide recommendations to the WPC that could be considered and operationalized while they develop the WSSI Alaska product. Additionally, lessons learned from this process of adapting a national product to specific needs and data availability may inform the refinement of other NWS products.

2. Methodology

Working toward achieving these research outcomes and objectives, the Nurture Nature Center (NNC), WPC, and Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado, Boulder, met with Alaska Weather Forecast Office (WFO) representatives from Fairbanks, Juneau, and Anchorage, along with other project partners to develop focus group scenarios specific to each of six regions: West Coast, Southwest/Bristol Bay, Southcentral/Anchorage, North Slope, Juneau, and Fairbanks. Scenarios were developed around severe weather events, and the WFOs contributed briefings and other NWS products to build out the timelines of a storm progression. The research team (NNC) then created mocked-up versions of WSSI for Alaska (which did not exist outside the CONUS) for inclusion in the scenarios (Fig. 1). The research team held six virtual focus groups in June 2022, recruiting stakeholders from each region with contacts provided by the WFO partners. Stakeholders included representatives from emergency management, transportation, aviation, schools, and other professions. Professional stakeholders, rather than laypersons, were chosen for this early phase of development of the WSSI Alaska product due to their understanding of the complex winter impacts and forecast needs of their communities, and as such, study results reflect this population rather than the full range and scale of the Alaska population.

Focus group participants completed pre- and postsession surveys and participated in a facilitated 2-h discussion. Presession survey questions were related to familiarity with the WSSI, winter weather impacts in their area, their experience with winter weather events, how they use NWS information, and what actions they take when a winter storm is forecasted. Postsession survey questions asked about barriers they face in responding/preparing for winter storm events, forecast product display preferences, usefulness of the products shown in the focus group scenario, usefulness of the various elements included in the WSSI mock-up product, suggestions for legend definitions or categories, what impacts/components should be included, and if the product would be useful for decision-making. The focus group scenario discussion included questions related to preparedness, actions, understanding, needs, and challenges around the forecasted weather and presented products. For example, "how would you use this product in your decision-making at this time?"; "what other information would you be looking for with this impending storm?"; "would you share this information with anyone?"; and "how helpful is this kind of information?" The Alaska WSSI product and legend detail were a particular focus of discussion. The intent was to understand the needs for winter weather forecasting products and what impacts matter the most to each of the regions. Focus groups formats were the same for all locations with only the scenario shown being different (tailored to that location), and the same focus group facilitator led discussions in all the sessions.

The focus group discussions were recorded, transcribed, and analyzed for content themes using NVivo software. The analysis involved both a deductive and inductive coding system, with key terms, such as products, and intent to share, identified before coding, and others emerging from trends in the focus group transcripts. Terms included components (wind/wind direction, temperature, precipitation/rain on snow, snow load, and flash freeze), impact areas (infrastructure, flights/air travel, erosion, flooding, visibility, avalanche/landslide/mudslide, and sea ice/jams), products (special weather statement, warnings/watches/advisories, and briefings), storm progression (trajectory, timing, and transition), communication (partners, share/public, and social media), and confidence/uncertainty/probabilities. Survey data were analyzed using Excel. Underlying data and specific survey instruments are provided open access at the Harvard Dataverse (https://doi.org/10.7910/DVN/H7N7G4).

3. Results

a. Surveys

There was a total of 27 participants (ranging in ages from 20s to 60s) across the six focus groups with 30% from Juneau, 17% from Fairbanks, 17% from Anchorage, and the rest from rural communities (Anchorage $N = 5$; Fairbanks $N = 4$; Juneau $N = 8$; North Slope $N = 6$; Bristol Bay $N = 2$; and West Coast $N = 1$). Due to comparatively lower participant numbers, those in the rural communities (North Slope, West Coast, and Bristol Bay) are grouped together in the analysis. Stakeholders ranged from operations to management with the highest number (22%) of participants in the emergency management field and 19% of participants in the risk management field.

In the pre- and postsession surveys, participants were asked how they use and access NWS information, and many reported using NWS (accessed through website, email, or calling NWS) for planning and response, especially related to staffing and resource preparation. Noted winter weather impacts included school closures, road closures (often by winds creating flooding), blizzard conditions, power outages (windstorms), rain on snow, and avalanches/landslides. Importantly, many participants (especially in rural communities) reported they are always prepared and ready for winter weather as a way of life (generators, food supplies, and heating). Others readied for winter weather by preparing cars and homes, increasing staffing/resources, and notifying others about impending weather. Further, accuracy of forecasts and lack of resources (big state, low population) created barriers to using and acting on winter storm forecast information.

Survey participants' specific reactions to the products shown during each focus group scenario are presented in Fig. 2—participants rated how useful each product was to their decision-making. Each focus group had a different range of products shown in their scenario from winter storm warnings to winds, snow, and special weather statements, but all included the WSSI (comparison across sites is shown in Fig. 3).

WSSI was seen as extremely and very useful by the majority of participants for all but Juneau (where 63% felt the WSSI was slightly useful). Overall, 35% of participants felt WSSI was extremely useful and 42% felt it was very useful. The majority of participants further felt that WSSI was useful in decision-making with 77% responding yes (Fig. 3, right). Elaborating on its usefulness to decision-making, participants stated it would make it "easier to access more information in one location" and it is a "good tool to use to help me determine the possibility of adverse weather impacts." Others stated they would use it for preparedness and situational awareness and would share it with the public, stating it would be useful in telling the winter weather story to officials. Additionally, it would be used for determining staffing levels, educating others and relaying hazards, and for anticipating and planning outdoor-related work, hunting, or travel. Importantly, participants saw value in WSSI for helping them to ask appropriate questions about preparedness and for providing "great information to build up for a response and to communicate risk."

Participants also rated the usefulness of specific product elements (Fig. 4) with the six WSSI components, interactivity, map overlays, and forecaster's note having the highest percentage of participants reporting a rating of extremely and very useful.

Wind speed and direction (48% of all participants) and precipitation amount (33%) were the top requests when asked what was missing from the impact product. A range of other impacts and winter-related phenomena was reported with some being specific to an area (see Fig. 5 for which location listed each missing component).

Most participants did not find anything confusing or unclear in the mocked up WSSI product, but some desired quantities

FIG. 2. Percentage of participants rating usefulness of the products shown in each focus group scenario (Anchorage $N = 5$; Fairbanks $N = 4$; Juneau $N = 8$; North Slope $N = 6$; Bristol Bay $N = 2$; West Coast $N = 1$).

related to snow, rain, and wind, and others suggested more detailed descriptions of impacts. A specific question about suggested changes to the legend reiterated the desire for more details on impacts for each category, including what aspects of daily life are most likely to be disrupted and the specific locations to be affected. Further, specifics on what triggers a moderate versus major impact and what parameters defined the moderate category were requested. Other suggestions included having total amounts of snow/rain/ice and aligning with the Department of Transportation (DOT) public road condition reporting system, as well as including visibility and wind gusts for the area.

Most participants preferred a combination of static and interactive products and a combination of graphics and text in products for understanding their winter weather risk. In the postsession survey, a majority (50% or more) of participants in each location reported they were very likely to share what they learned with others, to seek NWS information about severe winter weather risks, to use the WSSI in decision-making when available, and to recommend the WSSI to others.

Some additional information brought up by participants related to the usefulness of having access to archived information, having information on storm trajectories, as well as information on the frequency of storms so that compounding

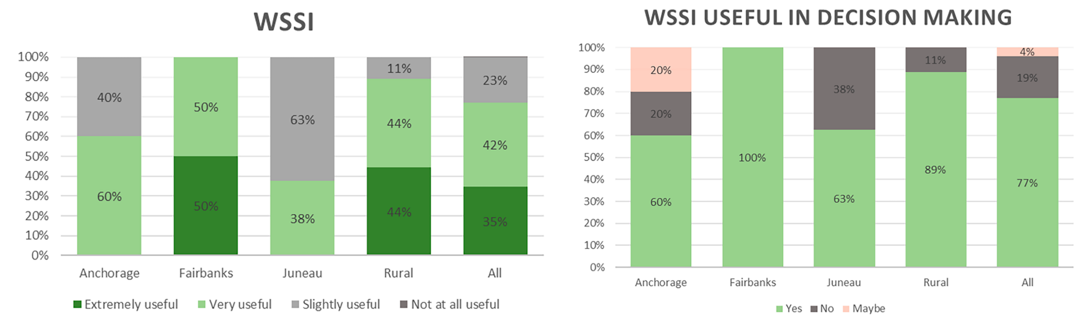

FIG. 3. (left) Usefulness ratings of the WSSI across all areas; (right) WSSI's usefulness in decision-making.

storm impacts could be considered in decisions they have to make. Participants noted that Alaska suffers from a lack of ground-based observations (e.g., need for more weather stations) and that flights are crucial to the ability to transport everything and everyone, thus requiring wind and visibility data.

b. *Focus groups*

As mentioned previously, focus group discussions were recorded, transcribed, and analyzed using NVivo software for several thematic terms. The more frequently discussed topics largely reflected the findings from the surveys. Overall, information about storm transitions (such as the change in precipitation type and storm trajectories), interactivity, and wind forecasts (strength, direction, and effect on visibility) were prominent topics. The findings are summarized into two sections: components and impacts and product presentation.

1) COMPONENTS AND IMPACTS

Participants emphasized that the storm transition between precipitation types was a critical time for impacts, and understanding the timing was important to preparedness: "One of the things we experienced a lot this last winter, especially towards the end of last calendar year, was a lot of freeze-thaw and then precipitation on top of the freeze. And so, I guess, yeah, transitional type information like that would be helpful, especially for transportation and driving conditions" (Anchorage participant).

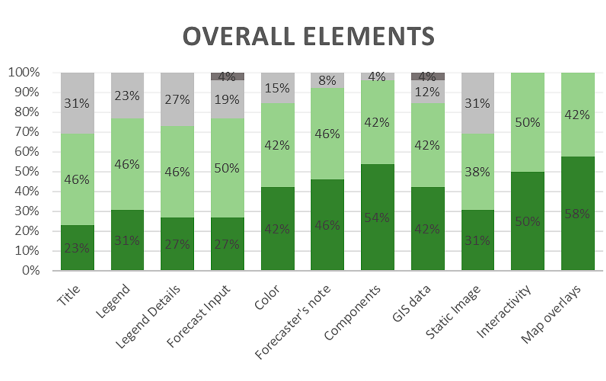

FIG. 4. Percentage of participants rating the different elements of the WSSI product from extremely useful to not useful.

Also important was the direction and duration of the storm; as such, storm trajectory information helped with planning resources and staff effectively. The path of the storm also gave insights into the type of storm and what kinds of impacts to expect, as explained by a West Coast participant: "So just knowing the kind of where, what direction the storms are coming from can give us a better idea of how much snow might involve versus how much wind is going to be involved. Because the northern storms have had a lot of wind … where the southern storms tend to have more moisture, so we get more snow."

Wind was by far the most talked about as a winter weather impact and as a missing component that is needed in the Alaska WSSI. Information on both strength and direction was seen as necessary for understanding impacts that ranged from flooding, tides, power outages, transportation disruptions, to visibility concerns (blowing snow/ground blizzards). For instance, on the West Coast "knowing how fast the wind is projected or predicted to be … gives us an indication of potential structural and power line damage" and "knowing the direction of the wind is a huge factor in how the snowfall is going to affect" them. It is important to note that high winds in areas of Alaska have a greater threshold than many other areas—for instance, 70-mph winds in Juneau are not exceptional. In addition to speed and direction, wind chill is an important impact to include due to many people traveling by snowmachines.

Precipitation was another component cited as missing and important for the Alaska WSSI. One Juneau participant reflected that "precipitation would be valuable because … I think if I could toggle between snow amount and precip amount, those two are going to give me a snapshot of like how heavy, how light, like what's the snow density?" A participant from Fairbanks noted that "the snowfall amount and then the rainfall amount is usually what we ask for when we call direct [the local NWS Weather Forecast Office]. And then the timing of transition times is when we're really looking for when is the snow going to turn to rain or vice versa."

In addition to wind and precipitation, flooding (through precipitation), erosion (through wind and water), tides, snow depth, and temperature were brought up as helpful components for the Alaska WSSI, while snow load and flash freeze were seen as less helpful. In Bristol Bay, a participant reflected, "I don't know how helpful snow load and flash freeze

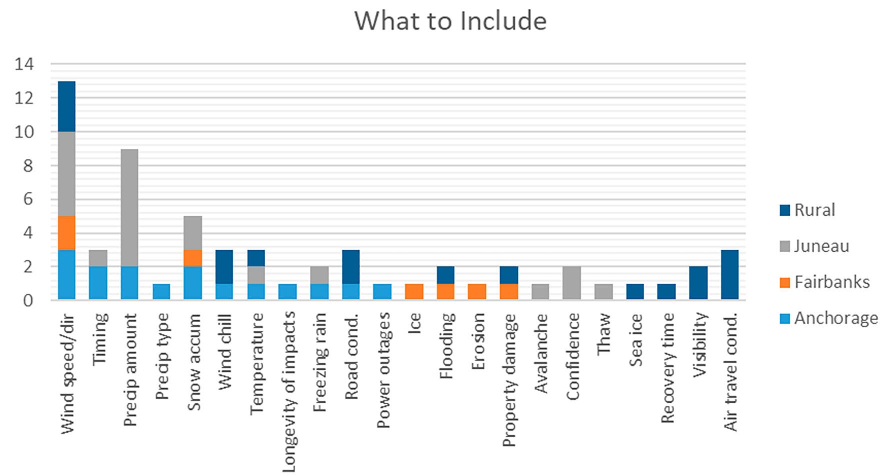

FIG. 5. Missing components that should be included in the Alaska WSSI by location and number of participants.

would be in our area. We're more concerned about visibility and wind gusts and extreme temperatures that could happen." While in Juneau, flooding was identified as a missing but necessary element, "I don't really see in these index categories anything on flooding. And I feel like that would be maybe a good way to capture that daily precip concept, because a lot of times that's like one of the major impacts that we get when there's already snow on the ground, and it rains a lot. We'll have local flooding. So, yeah, that just seems to be one of the major winter storm factors that's not really represented in this yet." In Juneau, the proximity to sea level made the tidal chart and wind information very valuable.

In Fairbanks, expected temperatures were noted as helpful for determining if the precipitation would be snow or rain. For transportation officials, ice was described as the most difficult element to deal with and the progression of temperatures during a storm event is crucial for understanding how to manage impacts: "The ice is huge for us, and the large snow amounts add to the difficulty and then the winds just top it off. The one thing I would like to see is with something this close to an event is a 3-day lookout after the event stopped. So, we're going to see how long we've got to clean this up before it's going to be totally, we're going to get shut down by cold or it's going to be totally stuck to the road for the rest of the winter" (Fairbanks participant).

2) PRODUCT PRESENTATION

Participants also provided feedback on the proposed legend details, pointing out that the meanings of moderate and the phrase "disruption to daily life" are vague and not helpful. One Anchorage participant questioned, "Disruption to daily life, what does that mean? You know, do you stay home or is it just you slow down, or you know, what?" and in Juneau, a participant commented "For the moderate one, it just seems kind of vague. Expect hazards, travel conditions, possible closures, and disruption of daily life. So. And moderate, that would be vague, you know." Participants said that property damage and roof collapses mentioned in the legend rarely happen but blowing trash and debris from wind create real damage on a more routine basis, and they suggested including those impacts, as well as wind impacts (especially related to sea wave height), in the impact forecast details.

Many participants highlighted the usefulness of interactivity, seeking ways to customize the product, layer components or elevation, search by zip code, and easily flip between maps/data: "If there's any way to be able for the user to be able to customize it for what it is that they want to see, that would be fantastic" (Juneau participant). This desire to customize may reflect the varying needs of the various stakeholders and regions in Alaska, though it is important to note that most of the comments were from urban areas, and static product options are necessary in the more rural areas where they have less access to technology and have limited ability to make use of the interactivity.

Across the focus group locations, communication approaches varied, ranging from radio to print and fax (especially in rural areas) to social media and email. Many participants saw value in having the WSSI with its different components as a way to obtain more information in one place. In Anchorage, one person commented, "What's nice is it's all at your fingertips. All the information, no matter where you want to go. You can go there from one page instead of having to dig out what you need to know." Participants also echoed this value of having access to relevant information easily in their comments about the forecaster's note (the white bar at the top of the graphic that provides a place for a succinct summary of impacts and links to watches or warnings or other relevant information). In Anchorage, the forecaster's note was seen as "useful to be able to give people access to go find more information for themselves" and in Fairbanks, it was noted that "Any way of getting more information is better."

Beyond the WSSI, Special Weather Statements and Winter Storm Warnings were additional information products that were highly valued. One Bristol Bay participant noted that for the Special Weather Statements, "I think people take these a little bit more seriously than they do the precipitation map, and things like that tend to be off. So, these statements are a little more helpful." Further to this idea of having more information, several participants wanted information about past storms, how impacts were characterized, and to be able to see how storm impacts were changing over time. Understanding if storms are increasing in severity helps with planning staff, resources, and budgets, as one Fairbanks participant commented "If we're seeing an increase in weather events or types, that historical information is really important in that." A summary of the event was also requested in order to understand how the storm rated and to see how the index performed (ground-truthing in order to provide confidence).

4. Discussion

Alaskan stakeholders in this study underscored the diversity in user experiences, winter weather hazards, and, importantly, raised the issue that thresholds differ significantly depending on one's location and climate (see, e.g., the results related to wind speed tolerances). This finding is supported by several other studies that conclude there is a variety of weather forecast needs and risk tolerances that require a range of thresholds to address (Morss et al. 2010; Senkbeil et al. 2013; Novak et al. 2023). Meléndez-Landaverde and Sempere-Torres (2024) also note that different vulnerabilities may require different thresholds for categorizing impacts. Novak et al. (2023) suggest that user impact thresholds should be aligned with probabilistic hazard information so that decision-makers will have quantitative probabilities of impact to support their decisions. This requires creating impact scales that associate specific impacts to the probability categories (Novak et al. 2023), a process advanced by the WSSI.

This study on WSSI Alaska suggests that there is a significant need for on-the-ground data observations throughout Alaska, as there is a paucity of data points compared to the CONUS. It also suggests the need to consider factors that may be outside the usual winter impacts for the CONUS, especially related to travel as road travel is less of an issue in many Alaskan communities due to fewer roads and small aircraft and snowmachine (i.e., snowmobile) travel are more common. Further, the feedback gathered in this study revealed that the hazards, thresholds, and triggers for decision-making relevant to Alaskan stakeholders may vary from CONUS. Making an effort to expand collection of data across diverse users and a wide spectrum of winter storm events can shed more light on these differences and support better understanding of forecast needs. This is also supported by Novak et al. (2023) who highlight the importance of understanding how different storm scenarios and their predictabilities affect decision-making and trust in forecasts. Further, they note that partner trust and confidence can be built through a probabilistic threshold approach that calibrates probabilities to thresholds that are a main factor for decision-making as a way to support IDSS (Novak et al. 2023).

This study of WSSI applicability in Alaska did not address probabilities, but given the lack of ground observations and uncertainty in forecast models for the region, probabilities may be a prudent approach for assessing risk and understanding possible impacts. Novak et al. (2023) point to the intersection of winter weather predictability limitations and risk management and decision-making as the space where impact-based probability forecasts would be valuable, but these would need to be created with consideration of the varying climatic, demographic, and geographic characteristics of diverse regions, such as Alaska. Further, more research is needed to understand the risk perceptions and impacts related to wind speed (Agdas et al. 2012), a significant factor noted in this study with Alaskan stakeholders and an element recommended for inclusion in the WSSI Alaska product.

An additional need for impact-based forecasting related to winter weather is to maintain a database of observed impacts for forecast verification. This database must go beyond NOAA Storm Events Database and include information on power outages, road closures and accidents, and air travel delays, among other factors (Novak et al. 2023). Another factor to consider in impact-based forecasting is the role of the changing climate, which is rapidly occurring in Alaska. Many stakeholders noted that it is the deviation from normal winter weather that has the most impact, especially when conditions are warmer than typical and expected. In Kivalina, an Alaskan Inupiaq Inuit community, decreasing sea ice extent and a longer open water season are resulting in increased flooding and erosion as fall storms are more destructive (Fang et al. 2018). These changes and associated impacts must be considered and the WSSI thresholds and impact categories assessed regularly to ensure the ongoing climatic trends are incorporated.

5. Limitations

The research team reached out to partners identified by the local WFOs for participation in focus groups and surveys, and not all participated in the focus groups, leaving self-selected groups in each location. The sessions were initially planned to be in-person but were converted to virtual due to COVID-19 considerations, which may have limited the number of participants. While the participants represented a range of professions relevant to the aims of the project, all relevant professions were not represented in each focus group and numbers were lower in the rural focus groups which led to the research team combining all three into one category for some analysis. Despite these limitations, the results from the focus groups provide critical information to WPC as a WSSI for Alaska is developed.

6. Conclusions

Impact-based winter weather information, such as shown in the WSSI, is valued across many users and geographies (Semmens et al. 2023), but variable winter weather impacts require specific consideration of diverse stakeholders' forecast needs. This study considered how to adapt the WSSI (previously only for CONUS) for Alaska's climate, demographic, data, and geographic environment. Investigating winter weather forecast needs from six regions in Alaska (Anchorage/Southcentral, Juneau, Fairbanks, North Slope, Southwest Bristol Bay/Aleutian Islands, and West Coast) provided insight into the different winter impact concerns. Overall, wind and precipitation information were determined to be key components to include in the Alaska WSSI. Desired wind information included both strength and direction, as well as its effect on visibility (e.g., blowing snow). Air travel was a critical concern requiring wind and visibility information while road travel was less emphasized (in contrast to CONUS needs). While snow load and flash freeze products were less helpful in many locations, flooding (through precipitation), erosion (through wind and water), snow depth, tides, and temperature were all raised as helpful information due to their impacts. Avalanche concerns were specifically raised in Anchorage and Juneau.

Special Weather Statements and Winter Storm Warnings were highly valued in all locations, and the addition of a forecaster's note was valued for providing critical highlights and connection to other relevant information. Storm trajectories and transition information such as precipitation type changes were noted as critical pieces of information for decision-makers. While interactivity was helpful for core partners (especially if the maps could be broken down by regions and/or census areas), static products were needed for briefings and sharing with public audiences who do not always have access to Internet or cell service. Specific recommendations for the WSSI were to provide more details in the legend with impacts relevant to Alaska (i.e., road travel and property damage are less of a concern compared to wind and visibility).

Overall, participants valued having centralized information in one place such as the WSSI, providing clear communication about when and what impacts will occur. Alaska is accustomed to winter and prepared for impacts, but knowing potential areas of concern for an impending storm, its possible progression and transition periods, and being able to understand how the various components (wind, snow, and ice) contribute to the overall impact enhance the ability to respond and mitigate damage efficiently and effectively. The WSSI adapted for Alaska's winter conditions and impacts as well as data availability can help address forecast needs and may become even more useful as the climate changes and typical winter conditions become more variable.

Acknowledgments. This manuscript written by the Nurture Nature Center, Inc., was prepared under Grant Award NA21OAR4590183 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 authors and do not necessarily reflect those of NOAA or of the U.S. Department of Commerce. Dr. Dana Tobin (CIRES) was funded under Grant Award NA21OAR4590188. The authors thank the National Weather Service offices who were partners for this study including University of Alaska: Dr. Richard Thoman, Alaska Climate Specialist; Anchorage, AK Weather Forecast Office: Aviva Braun; Juneau, AK Weather Forecast Office: Ryan Metzgar; and Fairbanks, AK: Jonathan Suk.

Data availability statement. All data created or used during this study are openly available at Harvard Dataverse Semmens, Kathryn, 2023, "Winter Storm Severity for Alaska," https://doi.org/10.7910/DVN/H7N7G4, Harvard Dataverse, V1, UNF:6:OHXAvYIoUkIxKUfo7zxfPA== [fileUNF].

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