Scaling-up Stakeholder Engagement Efforts to Inform Better Communication & Uptake of NOAA Great Lakes Ice Forecast Information

Final Report

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Executive Summary

Great Lakes ice cover is integral to human activities in coastal communities and the region overall, from being an obstacle to vessel navigation in the transportation sector to providing an opportunity for winter recreation. Timely, accurate, and usable ice information for a broad and diverse range of users is critical to these activities. Existing satellite and model-based products provide information regarding Great Lakes ice conditions. However, existing products are limited in their spatial and temporal extent, resulting in information gaps for decision-support.To fill this gap, the development of a short-term Great Lakes ice forecast model is underway to be added to the next generation of National Oceanic and Atmospheric Administration's (NOAA's) Great Lakes Operational Forecast System (GLOFS). While this new product is designed specifically to support winter mariners' decision-making, a critical condition for this is the development of a user interface that supports information usability.

In 2019, the project team was awarded a seed grant from the Graham Sustainability Institute at the University of Michigan to conduct a stakeholder engagement needs assessment workshop with 27 participants from the shipping industry, U.S. Coast Guard 9th District, NOAA, and the University of Michigan. This initial effort allowed the team to identify the Great Lakes ice information needs of end-users, and to form high-level recommendations for the user interface of the upcoming ice forecast guidance from NOAA. However, the limited funds did not permit more in-depth stakeholder engagement, submission of formal recommendations to NOAA, or exploration of co-production variables of interest such as uncertainty, information interplay, and credibility. NOAA's Climate Program Office provided additional support to the project team to gather further stakeholder input to inform future updates to the model, provide recommendations for development of the front-end user interface, and better characterize specific user information needs that NOAA may be able to address through the development of ice information products.

In the follow-on project, the project team designed a series of interviews with key informants from organizations that were critical to the flow of information within this network (U.S. and Canadian Coast Guards, U.S. and Canadian Shipping Companies, and the U.S. Army Corps of Engineers). Based on the interview study results, we developed an experimental user interface for a short-term ice forecast prototype, which was presented to stakeholders for their evaluation during two focus groups in 2021. The focus groups consisted of a guided evaluation of the forecast prototype, and a scenario-based exercise to explore how the forecast might be used in a real-world navigation scenario. The results were collectively analyzed to formulate actionable recommendations to the user interface of the upcoming ice forecast guidance from GLOFS. Furthermore, the results provided recommendations for potential future forecast model development, including extending the model coverage to key river corridors and determining acceptable thresholds of forecast accuracy and uncertainty. Overall, the participants expressed satisfaction with the co-production process and are eager to stay invested with further development of the product to ensure it is validated, deployed, and adopted by others in the field. This research approach is applicable to other forecast model products in the research-to-operation transition at NOAA, and is expected to mutually benefit developers and users.

Introduction

Lake ice impacts the Great Lakes community

In the Laurentian Great Lakes (hereafter the Great Lakes), ice cover is integral to human activities in coastal communities and the region overall. For example, severe ice cover is an obstacle to vessel navigation in the transportation sector; ice jamming at rivers and resulting flooding are threats to the communities living in coastal areas; frazil ice buildup on intake structures can slow waterflow at water intakes; and ice blockage may reduce flow to intakes of hydro power plants. On the other hand, ice cover provides opportunities for winter recreation, such as ice fishing and tours to ice caves while creating temporary landbridges for island communities.

The capability of short-term ice forecasting will greatly benefit decision making around these activities. For example, the shipping season is largely restricted to the ice-free period in the lakes (April–December) or when aid can be provided by federal and private icebreaking services. For the vessels that continue to operate during ice-covered periods, accurate information on ice extent, concentration, and thickness is crucial to ensure safe navigation (Figure 1). As another example, there have been reported incidents where ice fishermen became stranded on an ice flow requiring U.S. Coast Guard rescue operations (Figure 2). If ice fishermen had been forewarned of dangerous ice conditions, informed trip planning might have prevented a rescue scenario. Timely, accurate, and usable ice information (i.e., current conditions and forecasts) for a broad and diverse range of users is critical to these activities. When Great Lakes ice information is actionable, it has great potential to reduce safety risks for mariners and their vessels, among other stakeholders.

Great Lakes ice information

Results from the Workshop in 2019

GLERL, CIGLR, and the Great Lakes Integrated Sciences and Assessments (GLISA) began collaborating in 2018 to improve ice forecast guidance in the Great Lakes region. Specifically, this team received a small grant from the Graham Sustainability Institute at the University of Michigan to improve the usability of GLOFS by including stakeholders in the design of an ice forecast user interface. The limited funds supported one stakeholder workshop (held in July 2019 with 10 stakeholders) and pre-workshop surveys with the 9th District U.S. Coast Guard and the Lake Carriers Association. The workshop allowed scientists and decision makers to jointly identify barriers, opportunities, and recommendations to improve GLOFS usability (Fujisaki-Manome et al., 2019a,b). However, the limited funds did not permit more in-depth stakeholder engagement, submission of formal recommendations to NOAA, or exploration of co-production variables of interest such as uncertainty, information interplay, and credibility. NOAA's Climate Program Office provided additional support to the project team to gather further stakeholder input to inform future updates to the ice forecast model, develop recommendations for development of the front-end user interface, and better characterize specific user information needs that NOAA may be able to address through the development of ice information products. Initial workshop results informed the development of the following stakeholder engagement study, and allowed us to characterize currently available ice information and existing information gaps needed to support user decision-making.

Significant results from the 2019 workshop included a preliminary description of the Great Lakes navigation industry network and the actors included therein, a cursory description of the risks and context that shape navigator decision-making, and initial feedback on an early version of the short-term ice forecast prototype. The network, risks, and decision-making context were further elucidated through iterative engagement with stakeholders described in the Methodology section of this report. In 2019, the initial forecast prototype projected only ice concentration information. During our initial workshop, stakeholders explained that it was essential to overlay ice thickness with ice concentration data to get a sense of risk for vessel damage during navigation. Observing one or the other parameter in isolation was not sufficient for interpreting navigable conditions. In subsequent years of project development, stakeholders and researchers collectively identified additional parameters to include within the forecast product that would aid in interpreting navigation risk based on ice concentration, thickness, and predicted velocity. It also became clear after the initial workshop that a web-based, interactive forecast product was preferable to the static images traditionally provided within the Daily Ice Briefs. Since ice-briefs were a preferred information type for many industry stakeholders, our initial forecast included static images as key outputs - however stakeholders reported over the course of this study that for this information, a more interactive tool would

Figure 1. Freighter Manitowoc in Whitefish Bay, Lake Superior, March 22, 2013. (Photo Credit: NOAA, cited from the NOAA CoastWatch website)

Figure 2. Stranded anglers awaited rescue after an ice floe broke away from the Lake Superior shoreline near Duluth on February 9, 2021. (Photo Credit: Darren Tilbury, cited from the Chicago Tribune)

be most appropriate and accessible. Further, stakeholders also identify critical geographic regions, or key "problem" areas where ice forecasts are particularly relevant including connecting waterways and harbors. These recommendations were refined and expanded upon through iterative engagement with stakeholders, and informed the results and recommendations of this report.

Currently available information

Table 1 summarizes currently available lake ice information for the Great Lakes. They are based on satellite observations (e.g., Great Lakes CoastWatch), model simulations (e.g., Great Lakes Coastal Forecasting System, or GLCFS), or a collection of multiple types of information such as satellite observations and weather forecasts (e.g., Daily Ice Briefs). The U.S. National Ice Center (NIC) has been the nation's primary source of current and forecast ice information for the Great Lakes, which are used in many data sources in Table 1. The NIC is a fully integrated multi-agency organization composed of contributions from the U.S. Navy (USN), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Coast Guard (USCG). Its NOAA contribution is housed under NOAA National Weather Service's National Centers for Environmental Prediction/Ocean Prediction Center (OPC) in College Park, MD. The primary product for the Great Lakes is a daily Great Lakes ice analysis, which is created in cooperation with NIC and Canadian Ice Service under the North American Ice Service (NAIS). Great Lakes ice analysis updates are provided primarily by the operational forecasters at National Weather Service (NWS) Weather Forecast Offices (WFOs) who assist users (such as seasoned ship captains, ship scheduling managers, and officers at the U.S. and Canadian Coast Guards) with reading and interpreting this data.

Short-term ice forecasting: Addressing a spatiotemporal information gap

The daily Great Lakes ice analyses provide an estimate of ice concentration and distribution based on remotely sensed data from satellites or flyovers, which could be hours or days old. Due to the dynamic nature of ice in the Great Lakes, the ice field can vary dramatically over several hours or a few days due to wind conditions or changes in air temperature (Hawley et al., 2018). Therefore, observed conditions may not be sufficient to provide decision makers with the information necessary to operate safely or effectively. Seasonal outlooks and forecast products from NIC, which have a 30-day lead time, have a gap in the short-term (i.e. next several days) range, which could be critical to enhance decision-making support. Scientists at CIGLR and the NOAA Great Lakes Environmental Research Lab (GLERL) have recently developed a coupled lake hydrodynamic-ice system [the Great Lakes Operational Forecast System (GLOFS), Anderson et al. 2018] to provide improved short-term forecasts of winter conditions (e.g. ice extent, ice thickness). A new version of GLOFS with the coupled hydrodynamic-ice models is presently in transition from research to operations at NOAA NOS and NIC to provide the first-ever, short-term (i.e., 5 days) ice forecast guidance.

Needs for co-production

Needs for scaling up user engagement

While the ongoing transition of the new version of GLOFS to operations is needed to better serve the navigation and transportation industries, engagement of potential user groups in this process has been limited, mostly to those with the operational forecasters at NWS WFOs (e.g., Science and Operations Officers or SOOs). This is reasonable given the formal role that operational forecasters play communicating the forecast guidance to users (e.g., OSTI, 2021). However, given that Great Lakes ice information is frequently accessed by professionals beyond NOAA including those in the shipping industry and U.S. and Canadian Coast Guards, further engagement with these potential user groups in the initial development of information products is necessary to understand the usability of existing ice data products, user information needs, and preferences for user interface with data products.

Co-production approach

In this project, we adopted a collaborative research approach, known as knowledge co-production. By adopting a knowledge co-production approach, researchers sought to ensure the forecast is designed in a way that best fits the needs of the target users. Knowledge co-production has been defined as "the process of producing usable, or actionable, science through collaboration between scientists and those who use science to make policy and management decisions" (Meadow et al., 2015). It has been increasingly adopted in development of climate information (e.g., Hirons et al., 2021; Vincent et al., 2018; Bremer and Meisch, 2017).

By involving target users in the design and implementation of our work from initial product design to prototype evaluation, we sought to ensure that the users' information needs and preferences were captured by GLOFS, graphical products, and the web interface. Therefore, our research process included close collaboration with user groups from the United States and Canada including the Coast Guards, Army Corps of Engineers, and private shipping industry.

Table 1. Existing Resources of Great Lakes ice information used by the shipping community and USCG. (Updated from Table 1 in Fujisaki-Manome et al. 2019)

Name	Type	Frequency	Forecast Period	Provider
Daily Ice Briefs	conference call with presentation	daily (or as needed) during the winter	-	U.S. and Canadian Coast Guards
Great Lakes Ice Analysis Products	chart* (concentration) with egg code	daily	-	National Ice Center
	text	biweekly	30 days	
	text	yearly	issued in December, provides outlook through February	
	chart* (concentration, thickness estimate, combined)	daily	-	National Ice Center and U.S. Coast Guard 9th District
Great Lakes Coast Watch	satellite images (RADARSAT, SENTINEL)	A few times per day, limited spatial coverage	-	NOAA Great Lakes Environmental Research Laboratory
	ice type classification (ICECON)	A few times per day, limited spatial coverage	-	
Great Lakes Coastal Forecasting System (GLCFS, experimental, based on teh previous generation model)	modeled concentration, thickness, movement, water surface temperature, currents	nowcast: four times per day, forecast: two times per day	5 days	
Statistical seasonal forecast	Ice coverage percent values	biweekly	annual (predict maximum ice cover)	
Daily briefs for Operation Taconite	email	daily	-	Vessel Traffic Service Soo, USCG 9th District
Canadian Great Lakes ice products	chart* (concentratio, stage of development, departure from normal)	daily	-	Canadian Ice Service
	text	daily	daily	
	text	biweekly	30 days	
Great Lakes Ice Outlook (CLEICELIO)	text	issued Monday, Wednesday, Friday (when ice cover is present)		NWS Weather Forecast Office in Cleveland *The website also lists the Canadian Daily Ice Forecast (text) and the 30-day outlook by the Canadian Ice Service and the National Ice Center Listed Abover
Summary of ice conditions				LCA

Objectives

The major goals were to understand the current perception of the Great Lakes shipping community and US and Canadian Coast Guards regarding Great Lakes ice information, and how NOAA's upcoming Great Lakes short-term ice forecast guidance would provide the most useful information for stakeholders' decision making. As the project output, all findings were used to formulate recommendations for the user interface of the upcoming Great Lakes ice forecast guidance. In addition, the collected user data will inform future direction of the hydrodynamic-ice model development. The specific goals are as follows:

Goal 1: Conduct a needs assessment with target user groups of the short-term Great Lakes ice forecast guidance through interviews with key informants and focus groups with the Great Lakes shipping community

Goal 2: Form actionable recommendations on the user interface of the ice forecast guidance from NOAA's Great Lakes Operational Forecast System

Goal 3: Inform the future direction of the forecast model development for the Great Lakes, which would addresses the gap in the current forecast model and requires longer-term investment

Goal 4: Advance our understanding of knowledge co-production by exploring how users perceive and interpret ice information credibility and uncertainty

Methodology

Our iterative approach to engaging end-users in our research began with an exploratory workshop to support development of a series of semi-structured interviews. Based on the results of these interviews, we developed an improved forecast display prototype from that presented during the 2019 workshop and the interviews. The improved forecast display prototype was evaluated by two focus groups.

In 2019, the preliminary workshop was held for 9 representatives of the U.S. Coast Guard 9th district Coast Guard and the Lake Carriers Association (representing the interests of U.S. flag ships in the Great Lakes) to better understand the decision-making, risks, and information required for Great Lakes winter navigation. As a result of this workshop, we identified the key decisions that the Coast Guards and commercial shipping companies make that are affected by ice, the information types or variables necessary to support decision-making when navigating through the ice, and user preferences for providing more usable ice information (Fujisaki-Manome et al., 2019) . Based on the results of this workshop, we developed a list of 11 key-informant interview participants from organizations that were critical to the flow of information within this network (U.S. and Canadian Coast Guards, U.S. and Canadian Shipping Companies, and the U.S. Army Corps of Engineers), and who were perceived by their peers as being exceptionally knowledgeable about Great Lakes ice navigation. Interviews were conducted using a virtual teleconferencing software, and transcribed for analysis using Conventional Content Analysis (Hsieh, 2005) and NVivo qualitative data analysis software (QSR International Pty Ltd. Version 12, released 2020).

Over the course of the study, the prototype graphic of forecast guidance evolved iteratively as the team responds to feedback from the stakeholders. The initial prototype graphic presented at the workshop in 2019 included the information of ice concentration only, and did not provide region specific view (Figure 3). Based on the feedback received during the workshop and the interviews, the team developed the design of a short-term ice forecast guidance display prototype (https://ciglr.seas.umich.edu/experimental-ice-forecast-graphic/, Figure 4), which was presented to stakeholders for their evaluation during two focus groups in 2021. The prototype provides a display of not only ice concentration, but also ice thickness, as well as the overlay of wind speeds or ice speeds. It also provides zoomed graphics over several geographical areas whose ice conditions were identified to be most critical for the stakeholders (e.g., Straits of Mackinac, bays). A focus group for U.S. and Canadian shipping industry members was held on June 17th, 2021, while the other focus group for U.S. and Canadian Coast Guards and US Army Corps of Engineers was held on June 25th, 2021. For the June 17th focus group, 7 participants represented the interests of U.S. shipping companies, 2 represented Canadian companies, and 1 individual represented an industry association serving companies in both Canada and the United States. On June 25th, 4 representatives from the US Coast Guard, 2 from the Canadian Coast Guard and 1 individual from the US Army Corps of Engineers participated in the focus group. The focus groups consisted of a guided evaluation of the forecast display prototype, and a scenario-based exercise to explore how the forecast might be used in a real-world navigation scenario (see the appendix for the interview guide). Focus groups were conducted with virtual teleconference software and transcribed for qualitative analysis using the same methods adopted for the interview study. As each phase of the project built upon the findings of the previous phase, the following results from the focus group study represent a culmination and synthesis of findings from the entire project.

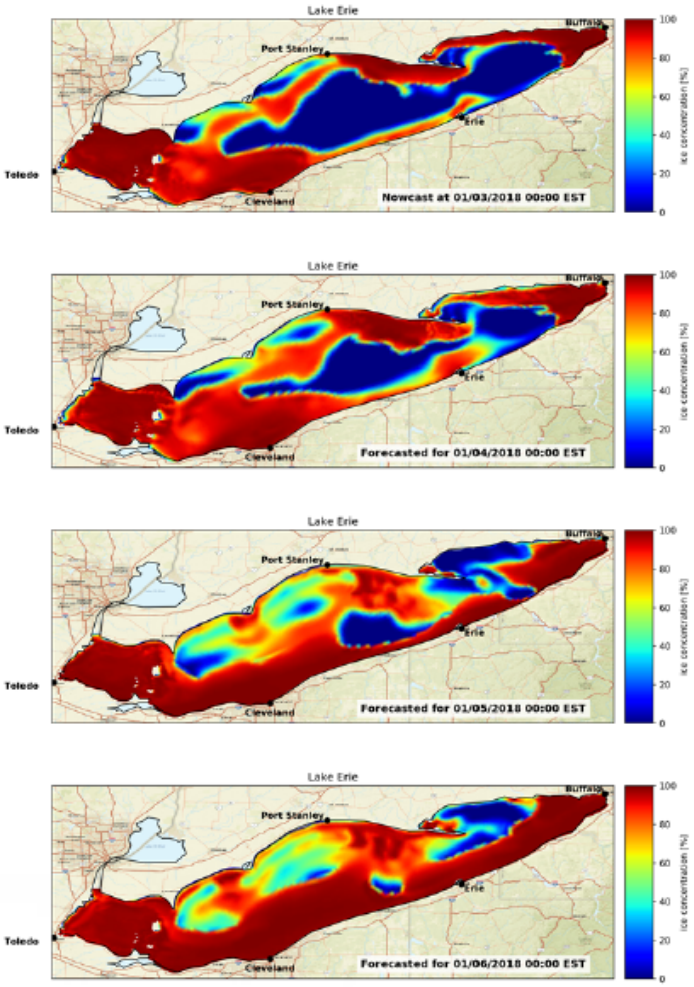
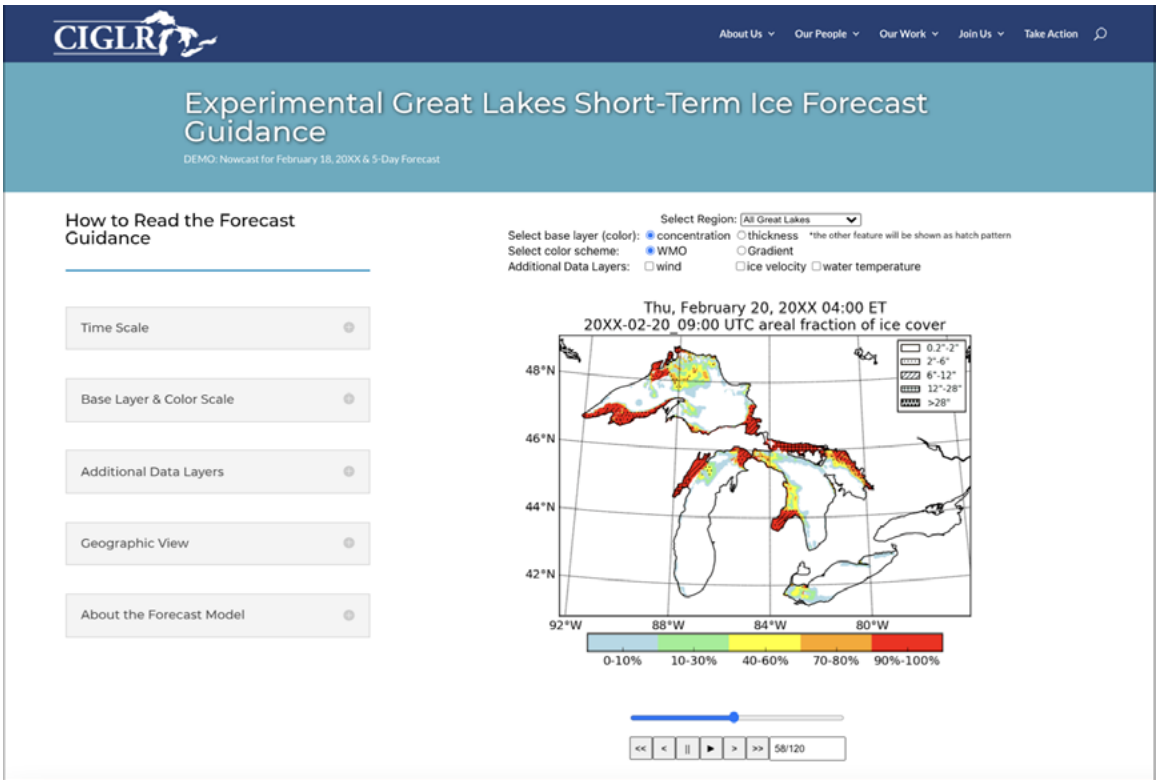


Figure 3. (Left) The initial prototype of Great Lakes short-term ice forecast guidance presented to the initial workshop in 2019. Over the course of study, the prototype graphic was developed iteratively as the study team responded to feedback from the stakeholders.

Figure 4. Excerpt of a graphic from the short-term ice forecast display prototype (https://ciglr.seas.umich.edu/experimental-ice-forecast-graphic/).]



Results

Questions posed in focus groups aimed to explore the decision-making context of our target users to help us interpret their information needs. Users described factors that influenced their decision making process, including how uncertainty and trustworthiness influenced their interpretation of primary data sources. Users also shared both positive and constructive responses to the draft ice forecast including thoughts on navigability, familiarity, accessibility, utility, and willingness to adopt the tool. Figure 5 depicts the occurrence of topics discussed in focus groups which were delineated using a qualitative coding software, NVivo. Both elements, decision making factors and response to forecast guidance, are critical to informing recommendations for improvement in the user interface and future modeling, which strongly consider not just useful data, but also the context in which the forecast guidance will be used in the field.

What we learned about forecast guidance users

We begin by highlighting aspects of decision-making that influence navigation in icy conditions on the Great Lakes. Users consider a range of information, both concrete and abstract, when making decisions and have a unique approach to considering these factors in their decision making process.

Decision Making Factors: What information is valuable to the decision making process for our users?

Multiple variables are valuable and necessary to user decision making, ultimately informing how to safely navigate the lakes in icy conditions. First, users indicated the weather and ice conditions as a main source of information including the following:

- **Wind** - Direction, speed, and duration of wind was an important variable that informs where loose ice will move.
- **Ice Coverage and Thickness** - Ice parameters determine if ice will move and create hazardous and unpredictable conditions. If the ice is thick with wide coverage, it is likely to stay put, but if ice becomes thinner and less concentrated, it is more likely to mobilize and become less predictable.
- **Water Temperature** - (Surface) Water temperature determines if ice will form, thaw, or remain stable. When temperatures begin to warm or fluctuate, ice conditions become more hazardous as ice begins to thaw and move.
- **Pressure Ridges** - Based on the above variables, users consider if pressure ridges may form. Pressure ridges are dangerous because they can pinch ships and trap them in the ice.

Quotes from Focus Groups:

"*Wind - to be able to watch the velocity and the direction change over the course, that's what's beautiful about this model is that the five days allows you to see that transition where before we're looking at 12-hour increments.*" - Agency User, Focus Group on June 25, 2021

"*The things I'd talk about is checking the weather information, seeing which way the wind is gonna go, what the temperatures are gonna be, and thinking about how that's gonna impact the movement of the ice, whether there's any pressure zones or it's gonna push any ice flows into our intended route.*" - Agency User, Focus Group on June 25, 2021

"...the beauty of the forecast model is that you get to see it all develop right there, you can see the thickness has changed, you can see the percentage of coverage change, you can also see the wind direction change." - Agency User, Focus Group on June 25, 2021

While weather and ice conditions played a major role in decision making, they were only a part of the decision making process. In addition to specific data parameters, users looked for other types of information to further interpret these factors and understand field context that may alter their ultimate decision. These parameters include:

- **Support** - Industry users frequently communicate with the Coast Guards to understand the availability of ice breaking resources to support their navigation. Without icebreaking support, a vessel may not be able to make its voyage.
- **Visibility** - Users considered visibility risks related to both daylight limitations and visibility inhibited by poor weather conditions (e.g., snow squalls). Conditions can change rapidly and without proper visibility ships may charge into dangerous conditions.
- **Timing** - Users consider estimated total transit duration and destination times and how these time frames might intersect with unfavorable predicted conditions. If they cannot complete the voyage before conditions change, they may opt to delay

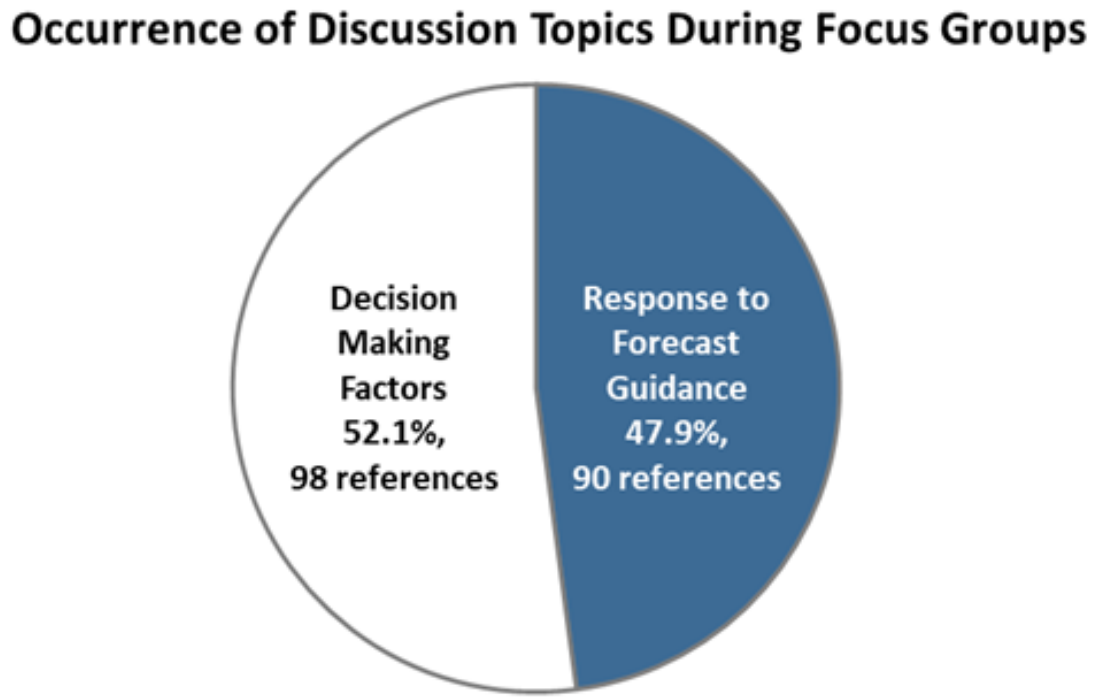


Figure 5. Occurrence of major themes discussed by focus group participants including decision making factors and response to the draft forecast

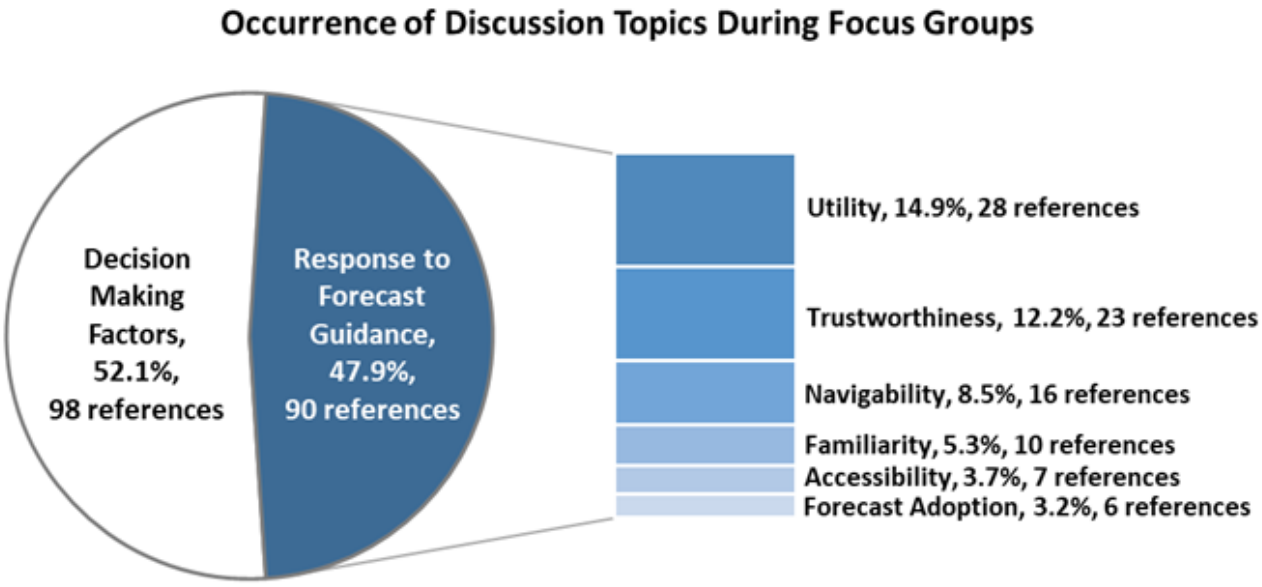


Figure 6. Breakdown of subtopics mentioned in user response to forecast.

their departure.

- **Ships** - Age and ability of the ship making the trip was referenced less frequently, but was nonetheless a factor influencing final decision making. For example, if a ship is old, the operators may feel less confident pushing the limits of the navigation route.

Quotes from Focus Groups:

"*...we have a mental sort of model of what you're presenting us today, about what we know of the ice regime, with the Coast Guard providing us with our own ground truthing is, and understanding that there's not too many vessels operating that time of year, so you gotta look at, "Okay, what's RADARSAT telling us?" 'cause that's the key, because that's real time, it's probably no more than a day old now with greater coverage...*" - Agency User, Focus Group on June 25, 2021

"*Regardless of industry's desire to go, we're gonna evaluate it from a safety and a readiness of our icebreaking resources before we accept to provide that escort. And those decisions are made on a daily basis.*" - Agency User, Focus Group on June 25, 2021

Decision Making Process: How do users analyze and integrate multiple sources of information to make decisions when information sources are fragmented and often uncertain?

Forecast guidance users work in an environment with high uncertainty, and while they have access to a range of information, there are still limitations related to timeliness, reliability, and geographic scale. To make up for these gaps, users have adapted a mental process for integrating multiple sources of information to enhance the decision making process. The following topics describe in greater detail the process and variables that help users make final decisions of whether or not to navigate the lakes (i.e., "go-no-go"), including understanding field risk and data uncertainty and validation:

- **Risk Reduction** - Great Lakes navigation is an inherently risky operation, especially in conditions where ice is mobilized without a clear track. Gaps in data sources present added risk as they are not able to provide a completely accurate and up-to-date picture of what conditions are in real-time. Users are required to make informed decisions within a risky and uncertain environment, where missteps could result in costly and life threatening consequences. These conditions have led users to develop mental forecasts out of necessity, pairing hard data with lived experience to reduce risk and fill data gaps.

Quotes from Focus Groups:

"*...it's a risk assessment tool as we decide and carry out a safe voyage in some pretty dicey risky conditions. Either at the end of the season or at the beginning. It makes it more efficient and safe.*" - Industry User, Focus Group on June 17, 2021

- **Field Experience and Data Integration** - Leveraging years of experience, users are able to interpret static information and predict dynamic ice conditions based on prior knowledge of seasonal trends and temperament in certain geographic areas. Users integrate multiple sources of information to predict ice behavior in the field, similar to the way a traditional model would digest information. This mental integration allows users to pair data and external factors in a productive way that ultimately allows them to decide the safest plan for navigation. It became clear that prior knowledge and experience in the field was essential to interpreting these data in a productive manner to produce reliable decisions. In contrast to risk mitigation, better decision making abilities can also allow users to make positive gains. For example, if conditions are forecasting better than anticipated, operators may be able to proceed with a route and avoid losing money from a delayed shipment of a highly valuable product.

Quotes:

"*We run a mental model of what you're developing for us about how you think the ice is now and how it's gonna move based on the environmental factors from right now to two, or three days down the road.*" - Industry User, Focus Group on June 17, 2021

"...there's hundreds...might be thousands of years of experience on ice between the masters, deck officers and the folks on these calls, that sort of can ground truth that if you're forecasting a certain condition and... say...we remember all these previous winters and it didn't happen that way...so I guess you have the benefit of an experienced and knowledgeable resident workforce here that knows how ice grows and moves on the Great Lakes..." - Industry User, Focus Group on June 17, 2021

- **Uncertainty and Validation** - As seasoned professionals, users have become accustomed to working in uncertain conditions and are therefore willing to accept a degree of uncertainty. Users understand that the lakes can be inherently unpredictable, however they are interested in knowing what data gaps or inaccuracies exist and how they may be able to overcome them. When possible, users examine available sources to validate conditions. Operators remain in open communication with ship captains to verify real-time conditions and try to validate or clarify predicted conditions. However, this may not always be feasible if visibility from the ships becomes an issue.

Similarly, satellite imagery can be used as a real-life snapshot of ice conditions, however cloud cover can inhibit ability to see the lakes in these images. Validation is an important part of decision making, but limitations remain in the ability to utilize these sources at all times.

Quotes from Focus Groups:

"It's gonna be difficult to forecast it.... The stuff that we see now mostly is what exists today, but I think it would be great if you could do that, but I think we all understand that at least if you get us in the ballpark of what we're gonna be expecting, we all understand that there is gonna be certain amount of localized anomalies we're gonna have to deal with, and our captains are gonna have that just through experience." - Industry User, Focus Group on June 17, 2021

User Response to Short-Term Ice Forecast Guidance Prototype

In addition to learning about user decision making factors and processes, we gained feedback on user response to using the new ice forecast guidance and how it may be useful in the context of their work. Users shared thoughts related to ease of navigability, familiarity of
features, how they may access the tool, their trustworthiness of the tool, and ultimate utility of the new forecast guidance (Figure 6).

Navigability: How easy was it for users to begin using the forecast guidance for the first time?

- Ease of Use - Overall, users felt that the visualization of forecast guidance was intuitive and required minimal effort to start using. Having all variables on one screen visualized as a dynamic sequence of future conditions was beneficial for comprehension. Current resources require users to assess multiple sources of static information on separate pages leading to greater potential for misinterpretation (i.e., daily ice brief in PDF format). Users also responded positively to the ability to zoom in on specific regions and found it easy to find the drop-down menus if they needed assistance in understanding a component of the product.
- Familiarity - Many users referenced familiarity as a factor in their ability to easily use the forecast guidance without coaching. The forecast guidance reminded users of similar NOAA, NWS, and NIC products used in the field including visual elements (i.e., color scheme and hatch pattern overlays) and data updates which occur every six hours.

Quotes from Focus Groups:

"It's quick, it's easy, you can pick it up and start using it without spending any time reading through any of the how-to guides or anything like that. It's very, very user-friendly." - Industry User, Focus Group on June 17, 2021

"Everything is very familiar and easy to interpret, so you can pretty much just start using it right away." - Industry User, Focus Group on June 17, 2021

"And you've incorporated a lot of the tools that we are already using on other sites or stuff that we've been used to... And that's beneficial." - Industry User, Focus Group on June 17, 2021

Accessibility: How did users anticipate accessing the forecast guidance? And, what were potential barriers in doing so?

During focus groups we asked users to describe the platforms they anticipated using to access the forecast guidance. These included which devices would be commonly used by different user groups, as well as potential bandwidth issues on the ships.

- **Forms of Access** - Users on land anticipate accessing the forecast guidance via computer or tablet whereas users on vessels are more likely to access the forecast guidance via smartphone. The user interface of forecast guidance must be developed in a way that can be equally visible and comprehensible through either platform.
- **Bandwidth** - Accessing the forecast guidance while on the water can provide bandwidth challenges that could prohibit the use of the forecast guidance by a key stakeholder group. Users offered multiple suggestions to overcome this issue. For example, one user described other tools that allow for the ability to turn off high-resolution images so the page will load faster in areas with low connection. Another user suggested having the ability to download a snapshot of the forecast guidance to a local device for direct access while on the water, with the ability to redownload the data (e.g., daily) once they've returned to stronger signals. Considering risk on the water, ship captains cannot wait for data to load if they are to rely on the source as a driver for decision making. (i.e., internet connection cannot dictate the ability for ships to use the product or not).

Quotes from Focus Groups:

"I know from the ice-breaking platforms, bandwidth is a concern, so the ability to turn on or off high resolution things that are gonna demand a lot of bandwidth would probably be a good entering argument." - Agency User, Focus Group on June 25, 2021

Trustworthiness and Credibility: How did users rate their trust in NOAA forecast models in general?

Users described a general trust in NOAA forecast models and mentioned the National Ice Center (NIC) as another credible, go-to source of information in the field. In considering trustworthiness of forecast guidance in general, users reported that trust in any new product takes time to develop and encouraged opportunities to validate the ice forecast guidance early so it could become a trusted product more quickly. Again, validation was a major player in clarifying data uncertainties which ties in the ultimate trust of the forecast guidance. Users also appreciated the built-in updates (i.e., every six hours) featured in the forecast guidance and felt that they were accessing the most up-to-date information in a frequently changing environment.

Quotes from Focus Groups:

"I think that trust is gonna take just some user experience and validating the information, working through a winter using the tool and seeing how the information on the forecast lines up to real world conditions. It's gonna take time. That's where it would be nice to start using this right away, if that's an option, even if it's like an experimental type product, just being able to start using it and playing around with it and seeing how close the data is to actual conditions." - Industry User, Focus Group on June 17, 2021

Utility: How will the forecast guidance be useful to our users?

Users shared insights into the usefulness of the forecast guidance including the ways in which the forecast guidance improves upon existing resources while filling gaps as a complement to other resources.

- **Game Changing** - Users viewed the forecast guidance as a major improvement upon existing resources and tools used in decision making. The dynamic, all-in-one nature of the forecast guidance enhances the ability of users to run mental forecasts and mitigate risks. Users were eager to transition away from traditional, outdated resources that, while previously beneficial, no longer provide the highest level of comprehension and detail available (i.e., egg ice charts).
- **Another Tool for the Toolbox** - When adopted, the forecast guidance will not be the only source of information beneficial to users. Users see the forecast guidance as another tool amidst other resources that, when paired, will allow them to maximize their ability to plan safe and effective routes. Users also frequently communicate and share information with others in the field and envision the forecast guidance as another consistent piece of reliable information that can be shared across the industry.

Quotes from Focus Groups:

"From the initial development that Ayumi and the rest of the team has done is nothing short of spectacular. This is gonna be a game changer for us in the mission management, and so kudos to you for what you've done." - Agency User, Focus Group on June 25, 2021

"I think this is brilliant and we're moving in the right direction. There's bound to be tweaks, but I think this is certainly... This is a game-changing tool." - Agency User, Focus Group on June 25, 2021

"...we'll take every little input of information to make the right decision at this time of the year." - Industry User, Focus Group on June 17, 2021

Recommendations to the user interface of forecast guidance

Specific Recommendations to the user interface

Learning about what motivates decision making in our user group, and understanding how users responded to initial prototypes of the short-term ice forecast guidance allows us to present a number of recommendations to improve the user interface of forecast guidance before it is officially deployed.

Moving Forward

Engaging with forecast users was a beneficial and productive approach to our research which allowed users to feel positive about their interactions with our team and feel more prepared to adopt the forecast.

- **Forecast Adoption:** Users were eager to start using the forecast guidance displayed in the experimental user interface. While there were multiple suggestions for improvements, users felt the product will be ready for use in some capacity after these minor adjustments are made. Users also expressed interest in trialing the product as a way to begin validating forecast predictions and thus build early trust in the model before official deployment. Additionally, understanding that users have a strong capacity to integrate multiple sources of information to make complex decisions, it is clear that users will be well equipped to adopt the forecast which will have inherent levels of uncertainty.

Quotes from Focus Groups:

"You know I think the forecast page is great. You know I mean if it was rolled out today in this format, I know we've discussed a lot of different

changes and improvements, but it's definitely very usable today, so for taking all the information we've provided over the last couple of years and compiling it together and creating this website, I think it's fantastic the way it is today....It's a really great product the way it is today." - Industry User, Focus Group on June 17, 2021

"Here you have a one-stop, a five-day model that gives us the future of what's to come, and that's the number one thing. As someone who has to plan 12 [hours], 24 [hours], three days out in advance, that's what makes this tool so special." - Agency User, Focus Group on June 25, 2021

"The raw materials we move are integral to the North American supply chain and in many cases no other modes of transportation exist to move the materials Great Lakes ships move. By supporting Great Lakes transportation, the work that you are doing benefits everyone in our country. This includes people who purchase new appliances such as washing machines, dishwashers, refrigerators. It includes people who drive automobiles and use other modes of transportation. The materials moved even go into roads, bridges, buildings, toothpaste, animal feed, windows, and so much more! I think it's fascinating that the work we are doing is all interconnected in many ways and there are so many other ways its connected that is not even apparent." - Follow-up feedback from focus group participant, June 19, 2021

- **Determining Acceptable Thresholds of Forecast Accuracy and Uncertainty:** Future directions for research includes exploring thresholds of accuracy and uncertainty for decision-making. Although we found that the Great Lakes navigation community accepts a degree of information uncertainty (due to their high risk decision-making environment and fragmented information sources, which has resulted in the development of robust decision-making processes), we did not explore numeric thresholds for accuracy and uncertainty. We found it difficult to approach this question hypothetically. With the operationalization of the short-term ice forecast guidance, end-users may actively use the forecast in their decision-making while in the field. This may allow for future quantification of forecast results compared with field observations. Researchers can work toward identifying a threshold for acceptable forecast accuracy and uncertainty by first determining which parameters of the forecast are most important for decision making, then measuring their accuracy (perceptions of forecast accuracy based on navigator experience and through formal hindcast skill assessment).
- **Co-Production Process:** Users responded well to the co-production process which allowed the product to be designed with users in mind. Users felt the process was both organized, and professional while providing the added benefit of clarifying product outcomes. The process also gives users a chance to interact with the product before it is launched, providing them with an early look at the tool while having a chance to share feedback for improvements. This positive response should encourage a continued research approach that engages end users.

Quotes from Focus Groups:

"I think it's exceptional... If an architect designs something a carpenter can't build, then you have a problem. So, I think that the fact that you engaged us early and you engaged us constantly is key, and we're more than happy to continue with that kind of process, no matter what it is, but continual engagement between us, industry, the Coast Guards, so we're all using the same tool, we're validating the same tool is critical going forward." - Industry User, Focus Group on June 17, 2021

"You can reach out to us any time, because I think it's a great way of you getting information and getting us to think of what we need and communicating that to you." - Industry User, Focus Group on June 17, 2021

"I have really enjoyed participating in the focus group sessions and look forward to the next time we get together. You are very organized, the meetings are engaging, and it is fun to be a participant. The communications leading up to the meetings are very informative and help me better prepare for the focus group. I hope you are able to continue your work for a long time and look forward to working together in the future. The ice forecasting tool is fantastic and it is exciting to be part of the work you are doing." - Follow-up feedback from focus group participant on June 19, 2021

Table 2. Table of recommended updates to the short-term Great Lakes ice forecast guidance based on direct response and feedback from intended users.

Feature	Issue	User Recommendation
Geographic Scale	Users need to be able to view all details present in the map	• Focus on enhancing zoomed-in maps that provide necessary detail for decision making • Make the map graphic larger in proportion to the rest of the web platform
Geographic View Selection	View selection was sufficient, however more options would be useful	• Place highest priority on adding river corridors (i.e., St. Clair River / Lake St. Clair, Detroit River, St. Mary's River, Saginaw River) • Expand lakeviews (i.e., expand Straits of Mackinac further west to include Lansing Shoal, add Southern Lake Huron and Lake St. Clair) • Other interesting additions, but less critical included certain lake views (i.e., Lake Michigan, Lake Erie) and ports or harbors (i.e., Duluth, Superior, Thunder Bay, Whitefish Bay, Green Bay)
Ice Concentration and Thickness	While color gradient with a hatch overlay was familiar and intuitive to some, others took more time to comprehend	• Provide the option to turn off simultaneous view of ice concentration and thickness so as to simplify the view if desired • Concentration and thickness determine if ice will move or not, therefore it is not necessary to view concentration once it reaches a steady 100%
Ice Concentration and Thickness	Legends were inconsistent and contributed to comprehension issues	• Display both legends for concentration and thickness in a similar format • Inset legends were more eye catching, but would benefit from including a title instead of relying solely on metric to indicate variable
Wind / Ice Velocity	Arrow symbols are not consistent with maritime standards	• Update arrows depicting wind and ice velocity to be visualized as barbs which are more consistent with other resources in the field • Barbs make it easier for users to interpret speed and direction simultaneously for two variables that predict where ice will move
Water Temperature (surface)	Temperature readings were difficult to see in certain views (both zoomed in and zoomed out)	• Provide options to turn off other layers so as not to overshadow temperature data • Because water temperature informs whether ices will form, thaw and thus move, some users will focus in solely on the variable as an important KPI for activating certain operations
Water Temperature (Surface)	Water temperature readings need to be tailored to international audience	• Include options to view water temperature readings in Celsius in addition to Fahrenheit
Time Scale	Users wanted to know more about the freshness of the data displayed in the forecast	• Incorporate a time stamp to indicate when the data was last updated and when it will be updated next • Alternatively, include a schedule of when data is refreshed on a regular basis
Navigability	Data display became cluttered when too many variables were displayed	• Provide the ability for users to turn on and off each variable to tailor the device to their distinct needs, which may change throughout the season
Accessibility	Bandwidth on the ships could seriously impact the ability of users to access the forecast	• Provide the ability for users to turn off high resolution graphics for quicker loading capacity • Provide the ability for users to download the forecast to a local device for access away from network connectivity

Conclusion

Our research aimed to engage forecast users as a way to identify information needs while understanding the context in which users make decisions. Our process allowed us to identify key information gaps that are directly addressed through the ice-forecast guidance and tailored to our user groups. While the forecast guidance was well received by users, it will be critical to implement the recommendations we received from focus group participants in order to fill the identified gaps and directly respond to user needs. While the feasibility of implementing the recommendations from this effort depends on actual resources at the operational environment at NOAA, the new insights on stakeholder needs is critical for the decision makers at NOAA to determine priorities in designing the user interface. This report provides a summary of actionable recommendations (Table 2) for NOAA to refer to when developing the actual user interface of ice forecast guidance from GLOFS. Furthermore, the identified gaps during this project can inform future development of the forecast model. For example, many participants noted that the Huron-Erie river corridor needed to be covered by the forecast model. This naturally guides the modeling research to be extended to cover navigational river corridors in the Great Lakes.

Moving forward, users shared overwhelming support of operationalizing the forecast and based on their high level of knowledge and experience, we feel that users are well prepared to begin validating the ice forecast as early as this winter through a potential trial period. Focus group participants were also highly satisfied with our co-production approach and are eager to support further development of the product to ensure it is validated, deployed, and adopted by others in the field. We are encouraged by the results of our research approach that engaged stakeholders and social scientists and we recommend extending this user feedback model across other research at NOAA.

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Appendix

Focus Group Guide
Short-term Great Lakes Ice Forecast Guidance

Notice that meeting is being recorded

1. Introduction - 10 minutes

Personal introductions

Review of project goals and work to date

- Project to design a 5-day Great Lakes ice forecast for thickness and concentration with input from intended users, the Great Lakes shipping industry
  - Forecast will be transitioned to operations at the National Ice Center; we are gathering final recommendations before we hand over the forecast to NIC.
  - Forecast is still a prototype. We hope to continue to improve crispness of visuals. Because it is a demonstration, it is not real-time and a year has not been specified for the predicted conditions.
- 1 workshop, 11 interviews. Both Coast Guards, American and Canadian Shipping Companies, USACE.

Informed Consent

- Ask if all have had an opportunity to view the informed consent document emailed with their invitation
- Expectations for participating in a focus group
- Have each person state name and job title for verbal consent

Meeting Agenda:

- Forecast Evaluation, Break, Forecast Exercise
- Ask attendees to pull up the forecast web page on their browsers

2. **Forecast Usability Evaluation** - 60 min

First, we're going to discuss specific aspects of the ice forecast to evaluate them. This next set of questions will include open discussions and group polling. We will be using a polling platform called Mentimeter. You can participate via your computer or phone by either clicking the direct link we just put in the chat, or by following the instructions shown here. Go to www.menti.com and enter the code [**insert updated survey code here**]. You will see the current question on your screen, and your responses will populate on my shared screen as they are submitted, so we can talk through them together.

Mentimeter

1. Did you have the opportunity to view the demo forecast prior to this focus group? [Yes, No, Unsure]

Open Questions on Slide

2. What is the first thing that comes to your attention when viewing this product? What catches your eye?
Optional prompt:
- What are your initial impressions of the usefulness of this forecast?

<u>Base Layer & Color Scale</u>

Mentimeter

3. How easy is it to interpret both ice thickness and concentration in this forecast? [Very easy Somewhat easy Neutral Somewhat difficult Very difficult]]

Open Questions on Slide

4. Is it clear that whichever data type you don't choose as the base layer will become the hatch pattern? Do you think this is a helpful way to display concentration and thickness simultaneously?

5. Do you have any suggestions for improving the display of ice concentration and thickness?
Optional prompts:
- Are the two color scale choices (WMO color scheme, gradient color scheme) useful?

<u>Additional Data Layers</u>

Mentimeter

6. How easy is it to interpret additional data layers to the map (predicted ice movement, wind speed and direction, and water temperature)? [Very easy Somewhat easy Neutral

Somewhat difficult Very difficult]

Open Questions on Slide

7. Do you have any suggestions for improving the display of additional data layers?

8. Are there any data types that you would add? Remove?

Optional prompts:

- Is it easy to add additional data layers?
- How useful is it to view these data layers on top of the base layers?

Geographic Scales

Mentimeter

9. The region map options represent the most important geographic areas for ice navigation. [Yes, No, Unsure]

Open Questions on Slide

10. Should we have highlighted different geographic areas?

Do you have any suggestions for improving the display of geographic views?

Optional prompts:

- Would you like river corridors to be included? How important is that to you? Ask for a raise of hands or comments in chat.
- Would labeling ports be helpful? Is the map scale okay; would you like a zoom option?

Availability

Mentimeter

12. How do you anticipate accessing this forecast? [Smartphone, Computer, Other] - select all that apply

Open Question on Slide

13. Do you have recommendations on how we can make the forecast easily accessible to you?

Optional prompts:

- *I regularly have the bandwidth to access this forecast when I need it*

Understanding the Forecast

Mentimeter

14. How far out does the forecast predict ice conditions? Every...

- **5 days**
- 6 hrs
- 3 days
- 24 hrs

15. How frequently does the website update the forecast with the latest weather information? Every...

- 1hour
- **6 hours**
- 12 hours
- 24 hours

16. How frequently does the model capture lake conditions? Every...

- 1 second
- **1 minute**
- 1hour
- 6 hours

Open Questions on Slide

17. How easy is it to interpret the ice forecast as explained in the infographic?

18. Is there anything that might be confusing?

Optional prompts:

- Is it clear how to use the drop-down tabs to interpret the forecast graphic?
- Is it easy to find your time zone?
- Is it clear how to use the animation bar?
- Is the language used on the web page easy to understand, and consistent with the language that you use professionally?

(Transition back to open interview questions)

19. What do you think is most useful about the ice forecast? Is there anything that isn't particularly useful that we might eliminate?

20. Is there additional information that you would like to see included in the ice forecast? If so, what?

- **BREAK** - 10 min

3. **Forecast Exercise** - 60 min

Break-up into smaller groups based on user-type (20 min)

For this exercise we'd like to pretend that you received the Coast Guard Daily Ice Brief while preparing to navigate through the Mackinac Straits. This will help us understand how you might use ice information in real-time while at work.

- To begin this exercise, we will give you five minutes to review the information in the Ice Brief on your own.

- Now that you've had some time to look over the brief, here is your task: 1. As a group, come-up with a specific decision or work scenario that you might face on February 18th that would require you to navigate across the Mackinac Straits. Examples: preparing for an ice breaking mission, planning a trip, etc. Feel free to develop the scenario in any way you think necessary. Feel free to fill in the details of your story with hypotheticals. You will describe this scenario to us at the end of the activity. (facilitator note: Reminder not to get bogged down in the details)
- Once you have identified your scenario for navigating across the Straits, use all of the information in the Brief including the new forecast to identify your preferred navigation route. It's ok if you all do not agree on the final route - we're more interested in your thought processes and how you use this information than in the final outcome. You will describe this route to us at the end of the activity.
- Lastly, we would like you to share with us the different types of information you used to determine your preferred route or ice breaking mission. Let us know what information was most important to your decision-making and why.

Report back template:

- Why is your team seeking to navigate across the Straits?
- What is your navigation route and why?
- What specific information from the daily ice brief and/or the forecast was most critical for this decision?

Optional Prompts

- Did the ice forecast help you make a 'different' decision than otherwise?
- What information was still missing and could have made your decision much more robust i.e. room for improvements?
- As a group, you can determine what kind of vessel you are navigating.

Report Out on Break-out Groups - (15 min)

20. After participating in this activity, how well do you think the forecast complements the ice information already available to you in the Daily Ice Brief? Does the forecast fill any information gaps?

21. Will you use this forecast? Why or why not?

Optional Prompt:

- What might affect your willingness to use the forecast?
  - Newness of product? Ex: I need to try using the forecast for a full season to get a sense of its accuracy
- What barriers might exist? Technical?
- Is NOAA/NIC a credible information source?
- What would increase the trustworthiness of the forecast? (e.g. verified by observations by vessel reports, satellite imagery, etc.

Conclusion - 10 min

1. How satisfied are you with the outcomes of this project including the forecast itself? How satisfied are you with your overall participation in this project and your interactions with our team?

Optional Prompts:

- How could we have improved our project interactions with you to generate valuable outcomes?
- Think about either your interactions during this focus group, or throughout the course of the project. Whichever best applies to you.
- Would you like to have had more opportunities to provide feedback at different stages of the project?

2. Did the outcomes of this project meet your expectations? Were the outcomes different from what you expected?

3. Do you have any other final recommendations for our project team to improve the forecast or our engagement efforts with intended product users?