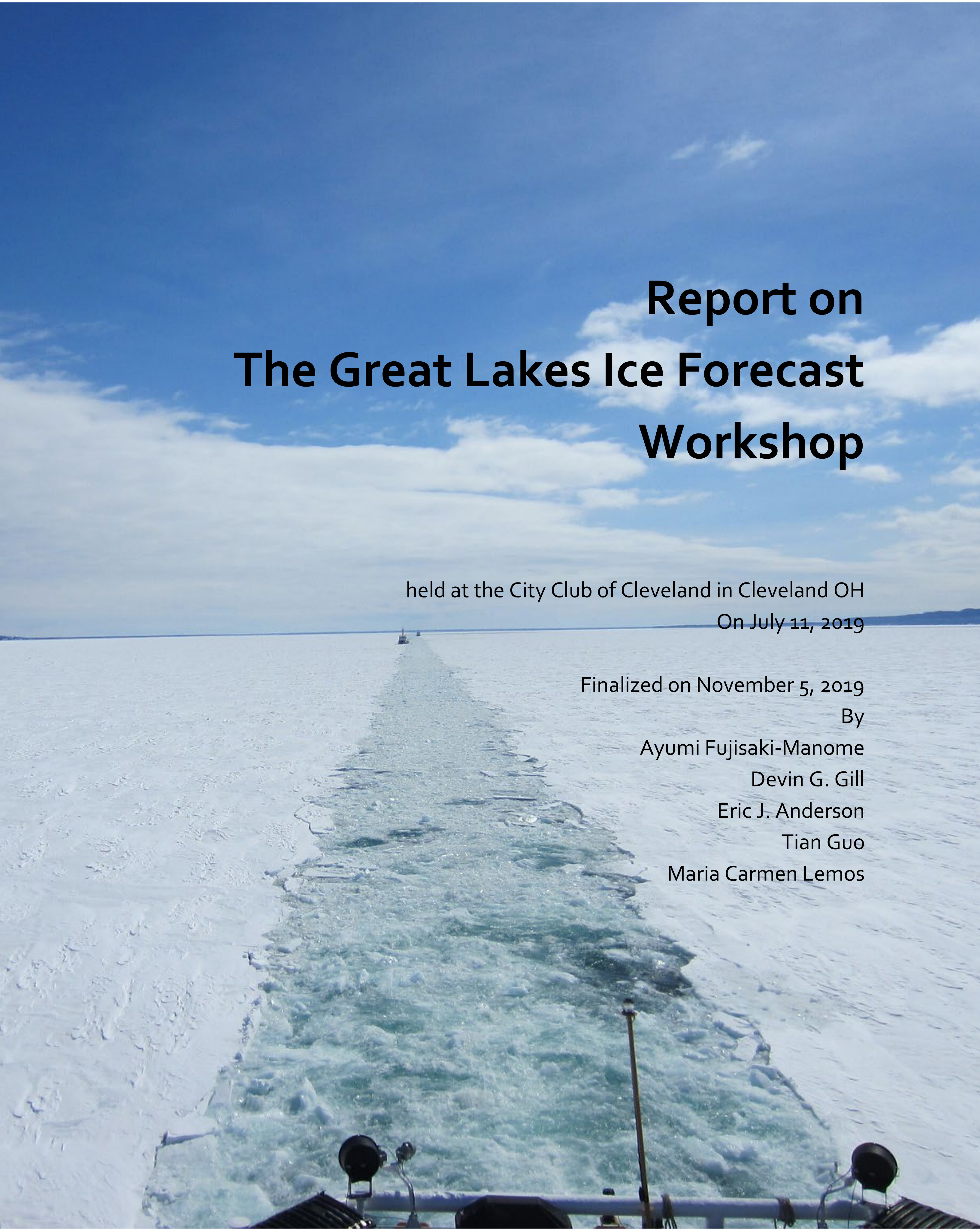

Report on The Great Lakes Ice Forecast Workshop

held at the City Club of Cleveland in Cleveland OH
On July 11, 2019

Finalized on November 5, 2019

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Summary

In the North American Great Lakes, lake ice that forms during winter often poses challenges in navigation safety. 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. However, 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. There are existing satellite- and model-based products that inform vessel operators with Great Lakes ice conditions. However, the current gap in these products is the short-term forecast capability that provides a prediction for the next few hours-days in advance. 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 upcoming product should help improve winter mariners' decision-making, a critical condition for this is that the user interface of the upcoming ice forecast product provide usable information for the mariners.

In this context, the project team conducted a stakeholder engagement study as part of the GLOFS research-to-operations (R2O) process, with the main activities of hosting a needs assessment workshop with two targeted user groups, members of the Lake Carriers' Association and U.S. Coast Guard (USCG) 9th District, as well as a need-assessment survey. During the workshop, a total of 27 invited participants from the shipping industry, USCG 9th District, NOAA, and the University of Michigan, engaged in a facilitated discussion, science presentation, and world cafe activity. A needs assessment survey was also conducted for a broader number of vessel operators from the shipping community and USCG 9th District. Transcripts of the workshop and survey were analyzed systematically to generate actionable recommendations to develop the user interface of the upcoming short-term ice forecast product from GLOFS, as well as recommendations for the longer-term model development. Key findings include that stakeholders use ice information for shipping planning for safety, ice breaking, emergency response, rescue missions, law enforcement operations, and buoy retrieval, that stakeholders desire near-real time information at a sufficient temporal frequency with the capability to focus on important geographic areas, and that coordination with the existing ice information sources (e.g. National Ice Center, Daily Ice Briefs by USCG 9th District) is important. In the longer term, a few research opportunities for the future model development were identified, including messaging forecast uncertainty information, translating certain model variable (e.g. ice pressure) into the severity of ice breaking or navigation, and risk of ice breaking in generating more ice due to immediate refreezing.

By demonstrating a proof-of-concept of knowledge co-production in the Great Lakes ice forecast product, the effort underscores the importance of continuing interactions among the key user groups, the decision makers on the user interface at NOAA, and the model developers at the university and NOAA Great Lakes Environmental Research Laboratory.

Background

As extreme weather events become more frequent with climate change, forecasts should be easy for the public to use. In the North American Great Lakes (hereafter Great Lakes), severe ice cover, which is one of such extreme events, has direct socioeconomic impacts on commercial shipping and navigation safety[1]. As such, accurate forecast information of lake ice conditions should mitigate these impacts, through enabling shipping community to plan their operations effectively to helping U.S. and Canadian Coast Guards with planning and coordinating their ice breaking operations. However, an important condition for achieving this is that the forecast product provides usable interface for user decision-making.

While there are several existing resources of Great Lakes ice information (Table 1), the capability of short-term forecast of Great Lakes ice conditions is missing. To fill this gap, the development of an ice forecast model is underway to be added to the existing NOAA Great Lakes Operational Forecast System (GLOFS[2]), which provides nowcast and forecast guidance of lake conditions including lake surface temperature, currents, and water levels out to 120 hours four times per day (i.e. at 0Z, 6Z, 12Z, and 18Z). The physical model is based on the Finite Volume Community Ocean Model (FVCOM[3,4]) and this model is coupled with the unstructured grid version of the Los Alamos Sea Ice Model (UG-CICE[5]). The effort of research-to-operations (R2O) transition will continue through 2022, and within this timeframe the short-term ice forecast guidance will be implemented into GLOFS. To maximize the usability of the upcoming ice forecast guidance, it is critical to understand *what decisions stakeholders make using ice information, what ice information stakeholders use to support that decision-making, and what the stakeholder usability requirements are for a short-term Great Lakes ice forecast.*

In this context, the project team conducted a stakeholder engagement project as part of the GLOFS R2O process, with the main activity of hosting a needs assessment workshop with two targeted user groups, members of the Lake Carriers' Association (LCA) and U.S. Coast Guard (USCG) 9th District, as well as a needs assessment survey. The overall goal is to formulate recommendations to GLOFS on the design of the user interface of the upcoming ice forecast guidance from GLOFS. This report summarizes the activities taken in this effort, the findings from the workshop and the survey, and recommendations to NOAA on the user interface of the upcoming ice forecast guidance from GLOFS. In section 2, goals and methods for the workshop and the survey are described. In section 3, the results from the workshop evaluation and the survey are reported. In section 4, recommendations to the ice forecast product of GLOFS are provided in terms of two categories: 1) "*actionable items*" to the upcoming user interface, and 2) "*recommendations to the longer-term model development*". In section 5, concluding remarks are provided.

Table 1. Existing Resources of Great Lakes ice information used by the shipping community and USCG.

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 CoastWatch	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 (experimental, based on the previous generation model)	modeled concentration, thickness, movement, water surface temperature, currents	nowcast: four times per day, forecast: two times per day	5 days	
Daily briefs for Operation Taconite	email	daily	-	Vessel Traffic Service Soo, USCG 9th District
Canadian Great Lakes ice products	chart* (concentration, stage of development, departure from normal)	daily	-	Canadian Ice Service
	text	daily	Daily	
	text	biweekly	30 days	
Summary of ice conditions				LCA

*Daily ice charts consist of data both from the National Ice Center and the Canadian Ice Service.

Objectives and Methods

The major goals were to understand the current perception of the Great Lakes shipping community and USCG on Great Lakes ice information, and how the upcoming Great Lakes short-term ice forecast 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. For this, we addressed three primary questions in the workshop and survey.

Q1: What decisions do stakeholders make using ice information?

Q2: What ice information do stakeholders use to support that decision-making?

Q3: What are stakeholder usability requirements for a short-term Great Lakes ice forecast?

The workshop was held at the City Club of Cleveland, Ohio on July 11, 2019 with 27 participants. From the target user groups, 4 representatives from LCA and 5 representatives from USCG 9th District were in attendance. These groups were targeted, because they represent influential actors in the Great Lakes navigation and shipping sectors. Additional participants included representatives from local Weather Forecast Offices, National Ocean Service, National Ice Center, and the Great Lakes Environmental Research Laboratory (see Appendix A for the participant list).

Figure 1. Science presentation on the Great Lakes ice forecast model development during the workshop. (Photo credit: Dr. Tian Guo)

The workshop started at noon with a social lunch, followed by a facilitated panel discussion with target stakeholders, a science presentation on Great Lakes ice forecast model development (Figure 1), and a world cafe data collection activity inviting participation from all workshop attendees (see Appendix B for the workshop agenda). Questions posed to stakeholders during the facilitated discussion and world cafe activity were guided by a semi-structured interview guide. The world cafe activity is a group note-taking exercise wherein participants are assigned to homogeneous groups and asked to rotate to different memo-pad stations located around the room. At each memo pad, the group worked together to write responses to the questions. At the conclusion of the activity, all participants had worked with their group to answer every question posed at each station. Final results were reported out to the group for discussion. This reiterative approach using facilitated discussion and the world cafe activity allowed participants to generate, review, and affirm answers posed to participants during the workshop.

With the informed consent of participants, workshop discussions were recorded, transcribed, and coded using Conventional Content Analysis[6]. NVivo qualitative data analysis software (QSR International Pty Ltd. Version 12, 2018) aided in transcript coding, and the analysis of code frequency and concentration. Memo-writing throughout the research process was used to support the intellectual rigor of data analysis and identification of salient themes and variables[7]. To support quality assurance of workshop results, participants completed workshop evaluations, and key stakeholder advisers from the LCA and USCG reviewed study results. Workshop discussion results are reported in the Results section. The nine stakeholder participants from LCA and USCG 9th District also participated in pre and post evaluation surveys to assess their perceptions of the proposed forecast and the workshop itself. The evaluation survey results are presented in Appendix C.

The need-assessment survey was mainly designed to aid answering the three primary questions with a large number targeted stakeholders. It also included a mock short-term ice forecast and tested users responses and satisfaction with the mock forecast. The survey contents and summary for individual questions can be found in Appendix D. The survey was implemented online using Qualtrics software (Qualtrics, Provo, UT), sent out to the targeted user groups (LCA and 9th District USCG) on July 2, and was closed on September 12th. A total of 67 valid surveys were collected, 35 from LCA and 32 from USCG.

Results

Analysis results from the workshop are presented for each question posed in the Objectives and Method section. In the following subsections, each question is discussed with key themes, supporting quotes taken from the workshop transcript, and survey results.

Question 1: Which decisions do stakeholders make using ice information?

Theme 1: Stakeholders use ice information for a variety of purposes including shipping planning for safety, ice breaking, emergency response, rescue missions, law enforcement operations, and buoy retrieval.

Participants indicated ice information is crucial for them to navigate during ice conditions. Particularly, ice breaking, emergency response, rescue missions, law enforcement operations, and buoy retrieval are activities typically conducted or led by the federal agencies (US and Canadian Coast Guards). Ice breaking, emergency response, and rescue missions are undertaken to support the shipping industry as they continue to operate during icy conditions. Buoy retrieval is conducted at the end of the shipping season to protect aids to navigation and monitoring equipment from becoming entrapped in the ice or otherwise damaged during winter conditions.

- *Shipping*
(24.51% coverage of transcript; 45 codes)
- *Ice Breaking*
(12.39% coverage; 19 codes)
- *Emergency Response*
(0.81% coverage; 4 codes)
- *Buoy retrieval*
(0.77% coverage; 1 code)
- *Rescue Missions*
(0.17% coverage; 2 codes)
- *Law enforcement operations*
(0.06% coverage; 1 code)

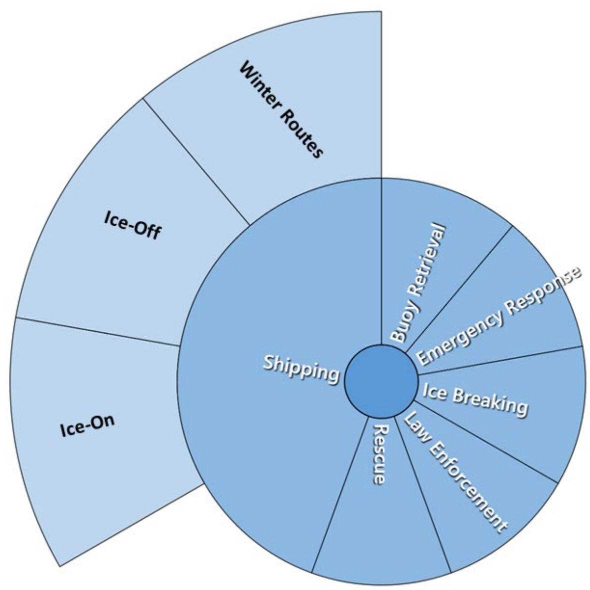

Figure 2. Frequencies of codes from the workshop discussion as purposes for which the users make decisions whether or not it's safe to navigate during ice conditions.

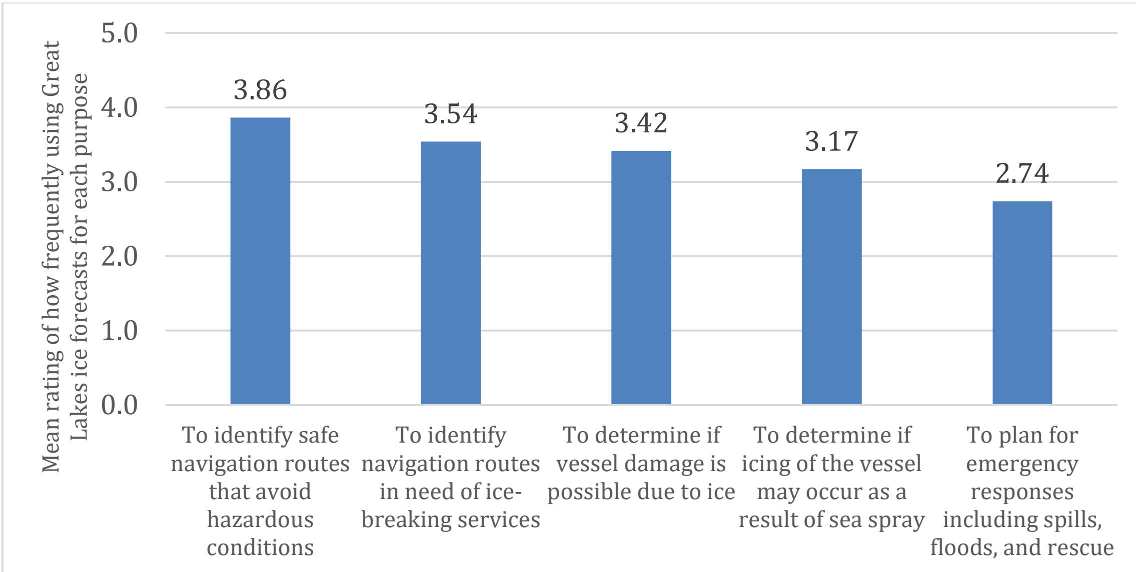

Figure 3. Mean scores of the survey question "during winter, how frequently do you use Great Lakes ice forecast for the following purposes" on a five-point scale with one (1) meaning almost never, 2 meaning several times per season, three (3) meaning several times per month, four (4) meaning daily, and five (5) meaning several times per day.

<u>Theme 2: Navigating during icy conditions for shipping purposes was a predominant concern among participants.</u>

Discussion of the impact of ice on shipping was coded as a predominant variable during the workshop (Figure 2), and this is consistent with the survey results (Figure 3). Other uses for ice information included the USCG 9th District's winter activities. Participants highlighted the importance and values of this support for the shipping industry. Specific decisions related to shipping activities included where and when to deploy ships across the Great Lakes, when to schedule maintenance work or pay employee overtime, and what contractual arrangements can be made with businesses hiring shipping services.

"We're using [ice] information to find out what's going to be the easiest route across a lake. If the ice is moving, it might be favorable to go one direction today, but tomorrow might be different. We've gotta plan for where we're going to be tomorrow. That might influence what we're doing today."
– LCA Member

<u>a. Ice information is especially valuable for shipping decisions during ice-on and ice-off</u>

Ice-on (also referred to as lay-up for shipping) occurs when ice first begins to form on the Great Lakes; ice-off (also called fit-out) occurs when ice begins to melt at the end of the season. These times typically align the closing (around January 15) and opening (around March 25) of the navigational locks in Sault St. Marie. When ice-on or ice-off occurs, knowing where ice is located becomes challenging. Large plates of ice can break away from shore and drift into open water. Movement of these large ice plates can run a ship aground or "pinch one of the boats [between ice plates] preventing it from moving."

“There are two times of year when we’re really looking at ice forecasting, the lay-up time of the year in December and the fit-out time. The lay-up time, we’re looking to see how fast it’s developing, and where it is or isn’t developing.” - LCA Member

Question 2: Which ice information do stakeholders use to support that decision-making?

Theme: Participants use the following ice information to support decision-making: timing of changes to ice, ice movement, ice pressure, measures of information uncertainty, ice thickness, location-specific information, ice type, and whether ice is fixed to shore.

- *Timing of Changes* (12.39%; 23 codes)
- *Movement (12.36%; 22 codes)*
- *Pressure (7.20%11 codes)*
- *Uncertainty (6.06%; 11 codes)*
- *Thickness (6.23%; 10 codes)*
- *Specific Locations (4.13%; 9 codes)*
- *Type (2.24%; 7 codes)*
- *Fixed to Shore (1.27%; 3 codes)*

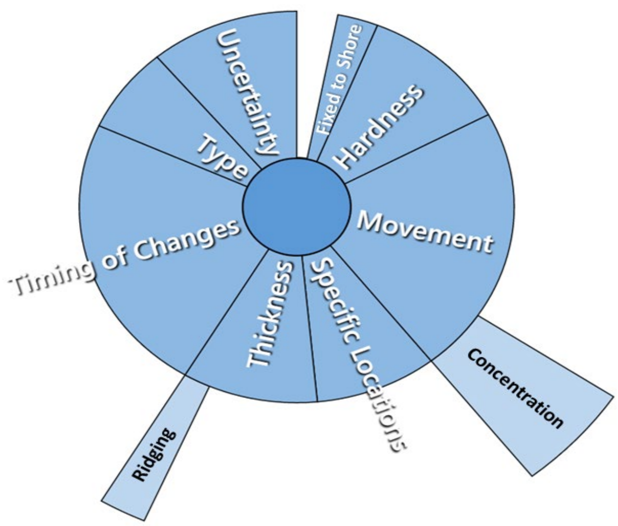

Figure 4. Frequencies of codes as ice-related parameters needed to inform whether or not it’s safe to navigate during ice conditions.

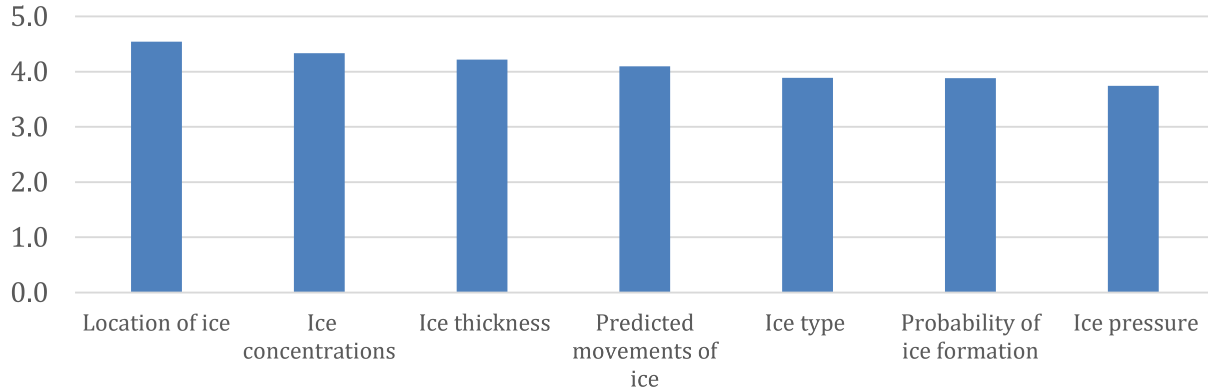

Figure 5. Mean scores of survey questions "How useful are the following types of Great Lakes ice information" on a five-point scale with one (1) meaning not useful at all, two (2) meaning slightly useful, three (3) meaning moderately useful, four (4) meaning very useful, five (5) meaning extremely useful.

Descriptions of ice information used by stakeholders to support decision-making is found in the sub-sections below.

a. <u>Timing of changes in ice conditions and ice movement were the predominant parameters.</u>
   To make informed navigation decisions, ship operators need to know where ice is located at a given location within a specific period of time. Unexpected ice movement can result in a ship running aground in nearshore areas or becoming trapped in ice. Depending on weather conditions, routes maintained by icebreakers may shift over the course of a few hours. Knowing if these routes have shifted and where the ice have moved is essential to ensuring vessel and personnel safety. In Figure 4, the movement and timing of changes in ice conditions were highlighted as critical data parameters during the workshop (Timing of Changes: 12.39% coverage, 29 codes; Movement: 12.36% coverage, 22 codes).

"[Ice forecasts] are really helpful for us, especially if we're traveling across open water on Lake Superior. But when we're coming into Whitefish Bay...to be able to identify the exact spot where we can enter the ice especially if the track is moving, that's valuable information." - LCA Member

b. <u>Participants reported information gaps in the following areas: movement of ice, ice type, ice pressure, and whether it is fixed to shore.</u>
   Although changes in ice conditions and predicted ice movement were identified as two of the most critical ice parameters for decision-making, this information is not readily available. They identified predicted ice movement, ice type, ice pressure, and whether ice is fixed to shore as information gaps that they hope researchers will work to fill. Ice type plays a role in terms of the amount of damage that a vessel may incur. Older ice or blue ice is noted for being particularly hard, and pressure riding as a result of wind creates thickened ice that create obstacles to

navigation. On the other hand, in the survey results, ice type, predicted movements of ice, and ice pressure were rated relatively low (Figure 5). This may be partly because within the larger shipping community, not everyone is yet familiar with how to interpret these types of information, as described in the following section (3.B.a).

"You know there are different kinds of ice. It can be harder. Coast Guard reported off of White Fish point back in '14 or '13 that there was 9 feet of blue ice that they saw, and you're not going to want to go through that. When you have wind rows [ridging], they're built up 10, 12 feet and you are trying to go around those. That could be an instance where you can't move. You've got to have somewhere for those sterns to swing." - LCA Member

c. <u>Participants are interested in ice pressure, but do not understand how to interpret this data.</u>
The type of ice and its pressure or hardness can affect the amount of damage a ship may incur while navigating through ice. However, this information isn't readily available or easy for stakeholders to interpret in terms of risk to vessels. Measures of ice thickness are frequently available and often correlate with pressure, but ice type and pressure may provide greater insight into the risk of hull damage. Occurrences of ridging is related to ice pressure, and is also of great interest to stakeholders.

d. <u>Ice information requirements change throughout the season.</u>
   i. <u>During ice-on and ice-off, at the prime information needs are for specific locations. During mid-season, information needs are expanded to offshore areas in the lakes.</u>
   ii. <u>Long-term forecasts are useful for pre- and post-winter lay-up and fit-out planning. Short-term forecasts are needed mid-season when ships are navigating through ice.</u>

During the colder months of the shipping season, stakeholders seek lake-wide forecast information to support navigation during lengthy trips spanning the lakes. This geographic focus shifts during ice-on and ice-off as risks to navigation increase in specific nearshore areas including bays and connecting waterways. Ships are at greater risk in these areas of being run aground or "pinched" between shifting ice plates. During ice-on and ice-off, historic trends in ice conditions have aided their decision-making in when to retrieve and deploy ships, as well as how long they could use for winter maintenance. Accurate, longer-term forecasts can help the US and Canadian Coast Guards and shipping companies prepare for the anticipated start and close of the shipping season.

"In January, February, and March; we're looking at longer range forecasts to determine when to start sailing our fleet...Are we going to start them up on March 25th when the Soo Locks open, or do we start them up in April because the ice is going to be thicker longer? So, we plan our operational winter maintenance and when we should deploy our ships in the spring based on longer range forecasts."
- LCA Member

e. The USCG 9th District and vessel operators desire metrics for information uncertainty given the high levels of risk involved with their decision-making while navigating the Great Lakes.
There is a high level of uncertainty and risk in decision-making relating to safety and financial issues while navigating through icy conditions. High risk of vessel damage in unsafe ice conditions threaten major financial losses for shipping companies if vessel repairs are necessary and shipping operations are waylaid[1]. If the ice forecast can reduce operator uncertainty about ice conditions, it would be highly valuable to stakeholders. Participants suggested that adding measurements of uncertainty to ice forecast data would help users to better interpret the forecast and more effectively use it to inform decision-making.

"We're a risk adverse company, so we're looking at [ice forecasts] to figure when we're deploying our fleet….It affects our customers business if we lay-up sooner than we expect…You've only got from point A to point B to buy time to make as many trips as you can."
- LCA Member

Question 3: What are stakeholder usability requirements for a short-term Great Lakes ice forecast?

Effective ***(25.4%; 69 codes)***
- Contextual Information *(7.11%; 19 codes)*
- Geographic scale *(6.75%; 16 codes)*
- Frequency *(8.09%; 15 codes)*
- Time Scale *(4.63%; 13 codes)*
- Accurate *(1.81%; 4 codes)*
- Reliable *(0.90%; 2 codes)*

Satisfactory ***(12.4%; 37 codes)***
- User Confidence *(6.15%; 17 codes)*
- Visual Design *(2.34%; 10 codes)*
- Attitudes *(4.76%; 7 codes)*

Efficient ***(7.56%; 15 codes)***
- Accessible *(3.32%; 8 codes)*
- Navigable *(2.18%; 4 codes)*
- Understandable *(2.06%; 3 codes)*

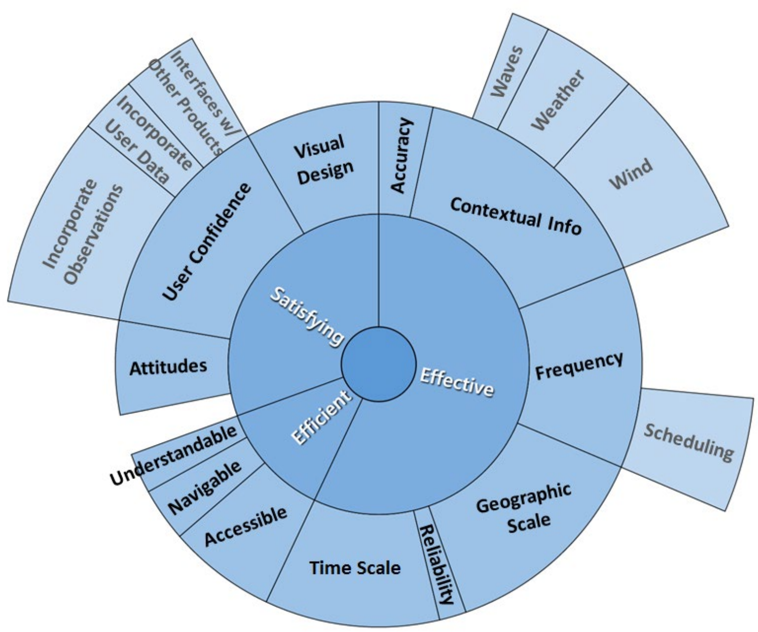

Figure 6. Frequencies of codes as usability requirements for a short-term Great Lakes ice forecast.

Theme1: To be effective, forecasts must provide information at the right geographic scale, time scale, and frequency, and be reliable, accurate, and contain contextual information.

Descriptions of ice forecast usability requirements for effectiveness are found in the sub-sections below (a - d).

a. Mismatch in geographic and time scales between forecasts and user needs presented predominant challenges to using ice forecasts effectively.
For vessel operators, communication with the USCG and fellow ships is critical to effective decision-making. The USCG is a primary conduit of ice information and navigation tips. Currently, stakeholders rely on access to Daily Ice Briefs delivered by the U.S. and Canadian Coast Guards (Table 1). Yet, observations in these reports delivered every morning are often from the day before, and don't satisfy stakeholder need for near-real time information. These stakeholders require a greater frequency of reported ice conditions (e.g. what is the ice condition right now and where ice will move in the next few hours), because conditions can change rapidly. Nearshore areas, connecting waterways, and harbors can be the most difficult to navigate during icy conditions, but available forecasts do not provide highly accurate or reliable information at this geographic scale.

"Those connecting waterways are among the most challenging...you need those daily or more than once a day reports on what actually is happening. You get several different types of ice moving through these connecting waterways, and you can see it all in one day." - LCA Member

"Looking at existing products from the National Ice Center and Canadian Ice Service, it seems like ice thickness and concentration is provided at a macro level. They're pretty well modeled. The micro level gets tougher when you want to look at specific areas." - U.S. Coast Guard 9th District

b. Near real-time frequency is desired for ice information during winter navigation.
Ice conditions can change rapidly in the Great Lakes, requiring timely responses from vessel operators. However, the ice information products that stakeholders currently rely on are updated daily. To better support stakeholder decision-making, ice information products should alert stakeholders to changes at greater frequency.

"[The USCG 9th District] are constantly talking about what they've got coming up an hour in front of them….And it changes by the hour, by the minute sometimes." - LCA Member

c. Participants lacked confidence in the accuracy and reliability of existing seasonal and 30-day ice forecasts
Workshop participants were open to working with researcher to develop ice forecast products, while also acknowledging past frustrations with forecast inaccuracies. As one participant said,

“...And how often is the [ice] forecast for December to February accurate? It’s maybe 50/50?” Another participant remarked that Great Lakes satellite imagery that informs ice forecasts is “really helpful, but you’ve gotta have a clear day. (as accuracies in satellite imagery are limited by cloud cover)” Despite these challenges, participants reported continued use of these seasonal and 30-day ice forecast products as they search out all information available to them to inform decision-making.

d. Ice forecasts should include contextual wind, wave, and weather information.
In the absence of near real-time ice forecasts at the required spatial resolution, vessel captains have relied upon wind, wave, and weather information to form their own predictions for ice movement. This contextual information aide users in their understanding of ice information and predictions.

“When we have strong easterly winds coming from Lake Huron...I’m going to go and hug the Canadian shore, because I know all of the ice is going to be on the Michigan side.” - LCA Member

“If you get the right wind direction, sometimes [ice-breaking tracks] will hold...In other cases, light wind days, it could hold for 48 or 72 hours. We’ll go through there once per day to keep it wet….Other days you need constant attention to it all day long.” - U.S. Coast Guard 9th District

Theme 2: Participant satisfaction with the ice forecast product was determined by their attitude toward forecast developers, their confidence in the forecast, and their perceptions of forecast visual design.

Descriptions of ice forecast usability requirements for satisfaction are found in the sub-sections below (a - c).

a. Participants had favorable attitudes toward forecast developers and promoted opportunities to collaborate.

Overall, participants welcomed increased communication and collaboration with researchers. Some participants expressed interest in learning from researchers how to incorporate new types of data (e.g. ice pressure) into their decision-making. Ohers thanked the researchers for existing seasonal ice forecasts that are already available. As one participant said, “I think we’re still learning how to use your data, and how to help you back. This is still a growing area.”

b. Participants may lack confidence in the ice forecast, because it does not incorporate observations or provide a mechanism for data contributions by users.

For some participants, the proposed short-term Great Lakes ice forecast lost credibility when they understood that monitoring data (or observations) is not incorporated into model predictions. This sentiment was echoed by multiple participants with varying degrees of conviction. As one captain said, , “The model is a model of models...and not actual observation data! I thought it was all incorporated, and it’s not….It’s just a forecast using other forecasts without actual eyes on to say, yeah that forecast was right!” Visual confirmation of ice conditions is communicated between vessel captains, and this strongly informs decision-making. A USCG captain countered that recorded observations have their own limitations regarding reliability and standardization of data collection: “...One thing that we’ve come across is that observations can be wildly different from one person to the next...When you’re doing fine calculations, it muddies your math….I can see the benefits of hindcasting and actual observations. You just have to be careful.”

c. Participants are more confident in ice information products that crossover with other products, specifically those included in daily briefs from the USCG.

The Canadian and US Coast Guards present a daily ice brief during the winter season that includes weather nowcast/forecast, daily ice charts from NIC, radar satellite imagery, and photos of ice conditions from vessels over the water. Participants expressed that they would like this short-term ice forecast product to be included within these daily briefs.

Theme 3: Forecast efficiency is determined by whether it’s accessible, navigable, and understandable.
Descriptions of ice forecast usability requirements for efficiency are found in the sub-sections below (a - c).

a. The predominant technical concern for forecast accessibility is the ship’s limited bandwidth capacity for accessing online forecast tools.

When forecasts are viewed while the ship is underway, mobile phone access and interface is required. However, in many regions of the Great Lakes, access to the internet is extremely limited. As one USCG captain stated, “*We would like to see the lowest bandwidth possible to be able to read the forecast….It takes 10 minutes to get emails at times….We’ve got a lot of products with high bandwidth, and they’re just not used at all.”*

b. To be navigable, the visual design of the short-term ice forecast should be intuitive and interactive.
Participants expressed a need for a range of information at different scales, but explained the importance of limiting “clicks” to access information. They suggested using visual animations, layering of data onto interactive maps, point-and-click functioning for additional data, and “zoom” capabilities to adjust spatial scale.

c. Most ice information is understandable, except for ice pressure.

By virtue of experience and close communication with USCG, participants expressed a strong understanding of how to interpret most ice information. However, ice pressure was highlighted as a parameter that stakeholders need help understanding.

Recommendations to Great Lakes short-term ice forecasts

Recommendations to Great Lakes short-term ice forecasts were formulated based on the coding analyses from the workshop and the survey results. With aid from the model developers, these recommendations were classified into two categories, *actionable recommendations* and *recommendations to long-term model development*.

Actionable recommendations

Actionable recommendations include items that may be addressed with the existing ice model (FVCOM+UGCICE), without any additional development on the model. Actual feasibility should rely on the resource where the ice forecast guidance from GLOFS will be hosted at NOAA.

Variables

- Key ice variables that are directly diagnosed by the existing model, such as concentration, movement, and thickness, should be included.
- Concurrent weather information, such as wind, air temperature, and waves should be also provided as they are helpful in providing a context of ice conditions.

How

- The information on the timing of changes in ice and weather conditions is critical. This could be achieved by various ways, including written warning, timeseries of static forecast graphics, and animated forecast graphic. The capability to communicate sub-daily changes at sufficient frequencies (e.g. hourly) is important.
- The capability of providing location-specific information in key geographic is critical. It should be noted that such requirements to location-specific information change during an ice season, from waterways, bays and other nearshore areas during ice-on and ice-off, to offshore during mid-season. This can be achieved by subsets of graphics focused on key locations

The information at spatial scale of ~10^3 m is important. Given the model's spatial resolution of 200m-300m nearshore, this is possible for the nearshore areas.

- The capability of interactive forecast graphics is important. This include displaying selected variables (e.g. wind field over ice concentration, ice thickness over ice extent), as well as zooming in specific locations.
- Near-real time capability is critical. The existing GLOFS (currently no ice forecast guidance yet) provides nowcast/120-hour forecast four times a day. The upcoming ice forecast guidance should align with this cycle to meet the user needs.
- Acknowledgement of uncertainties in the nowcast and forecast in some capacity is desired.

Coordination

- The upcoming product of ice forecast guidance from GLOFS should be unified with the existing data products at NOAA, such as daily ice analysis from the National Ice Center, allowing to be a new layer within a unified product. Simple interfacing or linking to the existing project may not result in aligning these data products.

● Given that USCG 9th District is the main conduit for the vessel operators on the Great Lakes ice information during winter, the coordination with USCG 9th District's daily ice briefs is critical.

● For real-time verification of the model nowcast/forecast of ice conditions, coordination with the vessel operators is desired, for example by aligning with the Vessel Ice Observations for Ice Condition Scale requested by USCG 9th District. Given the sparseness of observations of ice conditions, such reports from vessels greatly benefit real-time model verification.

● Coordination with the existing observational analysis (i.e. the ice charts from the National Ice Center) is desired to proper messaging of uncertainties in observations and model forecast, as both may deviate from a 'true' state. For example, satellite observations are limited during sustaining cloudy days and the forecast has its own model errors.

● Limited bandwidth for the connection on the lakes should be noted. Users out on the lakes are often unable to access a sophisticated web forecast due to the poor connection. Coordination with the existing channels for over-water users, in particular with USCG 9th District is critical to address the gap in connection.

Recommendations for long term development

These recommendations address the current gaps in the model and other resources in order to guide the future development of the ice forecast guidance from GLOFS. These involve changes to the model, verification of the changes in the model, as well as launching new coordination with other entities. As such, accomplishing these recommendations would take a longer time and would not be done immediately.

Variables

● Ice pressure/hardness, ice types, measures of information uncertainty are major gaps in the existing forecast variables. Some of these variables can be directly tied with the existing model variables but requires rigorous verification (e.g. ice pressure) while others require in-depth post-processing (e.g. ice types, uncertainty).

● Given the difficulty in interpreting ice pressure/hardness, an important translation of the information may be relating ice pressure/hardness to ice severity. Coordination with the existing effort on the ICECON product[8] by USCG, the University of Alaska, and Great Lakes Environmental Research Laboratory (GLERL) would be important (see *Coordination* section).

● Risk of ice breaking in increasing ice 'hardness' could potentially help decision making in ice breaking operations by USCG. An ice breaking activity creates leads (open water) and smaller ice pieces, which re-freeze quickly in sufficiently cold situations. This results in thicker and harder consolidated ice, which makes navigation even more difficult.

How

- A data assimilative approach should be explored in parallel with the ongoing modeling research, for example, by utilizing an observational analysis from the National Ice Center as the model's initial ice field and starting model forecast from there. Care should be taken in incorporating observations as an observational analysis has its own errors (e.g. satellite observations with a visible sensor are limited by cloud cover). In such cases, the model may produce results closer to the 'truth'.
- Advanced presentation of forecast uncertainties is desired. There are a few possible levels in presenting forecast uncertainties including verbal acknowledgement of uncertainty, displaying uncertainty information based on the hindcast skill and known bias, and uncertainty information based on ensemble forecast.
- Improved accuracy in longer-term (e.g. seasonal) forecast on ice-on and ice-off dates is desired. While GLOFS provides forecasts only up to 5-days out, an alternative new product or improving existing seasonal forecast products (e.g. NOAA's Climate Forecast System[9,10]) to meet this need should be considered.

Coordination

- Coordination with the ongoing ICECON[8] effort by USCG, the University of Alaska, and GLERL in developing the ice severity product (related to ice pressure and hardness).
- Possible mitigation for the limited bandwidth on the lakes would be the SMS service. Coordination with the Great Lakes Observing System (GLOS), which operates the SMS service for the Great Lakes buoys, would be a helpful way to address the poor connection on the lakes.

Concluding remarks

In summary, this project is part of the 'knowledge co-production'[11] process and demonstrated the use of social science methods in informing the Great Lakes short-term ice forecast product development. The findings from the workshop activities and the survey provided in-depth information on needs for the upcoming Great Lakes ice forecast guidance from the next generation GLOFS, which inform the design of the user interface of ice forecast guidance from GLOFS, as well as the direction of the future development of the ice model in GLOFS. While the feasibility of 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, as well as for the model developers at GLERL and Cooperative Institute for Great Lakes Research (CIGLR) to navigate their future engineering. In turn, the improved ice forecast product will help improve the users' decision-making.

The findings from this project underscores the importance of active interactions among the model developers at GLERL and CIGLR, the key user groups, and the decision makers on the forecast user interface at NOAA, in designing and advancing Great Lakes ice forecast product. This reconfirms the increasing recognition of the importance of knowledge co-production in weather enterprise in general[12,13]. Engaging key user groups in an early stage of the product development is critical, especially because R2O processes in typical weather, ocean, and lake forecast products at NOAA take several years (>5 years for GLOFS) and it is difficult to make major changes in the model configurations and the user interface once these are transitioned to the operational environment. Continuing interactions among these entities is essential for a usable Great Lakes ice forecast product, and therefore better decision-making.

Acknowledgements

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References

1. Lake Carriers' Association, Iced Out: Study Reveals Loss of More Than $1 Billion Due to Inadequate Icebreaking Capabilities on the Great Lakes. (2019). Available at: http://www.lcaships.com/2019/08/01/iced-out-study-reveals-loss-of-more-than-1-billion-due-to-inadequate-icebreaking-capabilities-on-the-great-lakes/. (Accessed: 21st September 2019)
2. Anderson, E. J. *et al.* Ice Forecasting in the Next-Generation Great Lakes Operational Forecast System (GLOFS). *J. Mar. Sci. Eng.* **6**, 17 pages (2018).
3. Chen, C., Beardsley, R. C. & Cowles, G. An Unstructured Grid, Finite-Volume Coastal Ocean Model FVCOM User Manual. *Oceanography* **19**, 78–89 (2006).
4. Chen, C. *et al.* An unstructured grid, Finite-Volume Coastal Ocean Model FVCOM -- User Manual. *Tech. Rep., SMAST/UMASSD-13-0701, Sch. Mar. Sci. Technol., Univ. Mass. Dartmouth, New Bedford.* 416 pp (2013).
5. Gao, G., Chen, C., Qi, J. & Beardsley, R. C. An unstructured-grid, finite-volume sea ice model: Development, validation, and application. *J. Geophys. Res. Ocean.* **116**, 1–15 (2011).
6. Hsieh, H. F. & Shannon, S. E. Three approaches to qualitative content analysis. *Qual. Health Res.* **15**, 1277–1288 (2005).
7. Charmaz, K. Teaching theory construction with initial grounded theory tools: A reflection on lessons and learning. *Qual. Health Res.* **25**, 1610–1622 (2015).
8. Leshkevich, G. A. ICECON Ice Type Classification. *NOAA Great Lakes Environmental Research Laboratory* (2017). Available at: https://coastwatch.glerl.noaa.gov/sar.html. (Accessed: 21st September 2019)
9. Saha, S. *et al.* The NCEP climate forecast system version 2. *J. Clim.* **27**, 2185–2208 (2014).
10. Saha, S. *et al.* The NCEP climate forecast system reanalysis. *Bull. Am. Meteorol. Soc.* **91**, 1015–1057 (2010).
11. Lemos, M. C. & Morehouse, B. J. The co-production of science and policy in integrated climate assessments. *Glob. Environ. Chang.* **15**, 57–68 (2005).
12. Kruk, M. C. *et al.* Engaging with users of climate information and the coproduction of knowledge. *Weather. Clim. Soc.* **9**, 839–849 (2017).
13. Aguilar-Barajas, I., Sisto, N. P., Ramirez, A. I. & Magaña-Rueda, V. Building urban resilience and knowledge co-production in the face of weather hazards: flash floods in the Monterrey Metropolitan Area (Mexico). *Environ. Sci. Policy* **99**, 37–47 (2019).

Appendices

Appendix A: List of participants in the workshop

Paul Christensen	Interlake Steamship Co.
Ken Gerasimos	Great Lakes Fleet
Tom Rayburn	Lake Carriers' Association
Brian Peterson	American Steamship Company
CIV Jerome A Popiel	USCG[1] Ninth District
LT Jason Radcliffe	USCG Ninth District
LCDR Benjamin P Morgan	USCG Ninth District
LTJG Blake E. Bonifas	USCG Ninth District
LCDR Norma Smihal	USCG Ninth District
Ron Williams	NWS[2], Duluth, Minnesota
Dallas J McKinney	NWS, Cleveland, Ohio
Robert LaPlante	NWS, Cleveland, Ohio
Greg Mann	NWS, Detroit, Michigan
Kirk Lombardy	NWS, Cleveland, Ohio
Brian Hirsch	NWS, Central Region Headquarters
Philip Chu	Great Lakes Environmental Research Laboratory
George Leshkevich	Great Lakes Environmental Research Laboratory
James Kessler	Great Lakes Environmental Research Laboratory
Jonathan EdwardsOpperman	National Ice Center
John G. W. Kelley	NOS[3], Coast Survey Development Laboratory
Mojgan Rostaminia	NOS, Center for Operational Oceanographic Products and Services
Ayumi Fujisaki-Manome	University of Michigan CIGLR
Devin Gill Brant	University of Michigan CIGLR
Tian Guo	University of Michigan CIGLR
Kimberly Channell	University of Michigan GLISA
Karlie Wells	University of Michigan GLISA
Erin Maher	University of Michigan GLISA

[1]United States Coast Guard
[2]National Weather Service
[3]National Ocean Service

Appendix B: Workshop Agenda

Workshop Agenda

The City Club of Cleveland
850 Euclid Ave 2nd Floor, Cleveland, OH 44114
Mandel Room

Registration, Pre-Survey, & Lunch (Noon-1 pm)

Introduction, *Devin Gill and Dr. Fujisaki-Manome* (1-1:10 pm)

Facilitated Discussion: Great Lakes Ice Information Needs, *Devin Gill* (1:10-1:50 pm)

Break (1:50-2 pm)

Presentation: Ice Forecast Model Development, *Dr. Fujisaki-Manome* (2-2:20 pm)

World Cafe Activity: Ice Forecast Usability, *Devin Gill* (2:20-3 pm)

- 5 groups in 6 minute rounds, Separate NOAA and stakeholder note sheets

Break (3-3:10 pm)

Presentation: Ice Forecast User Survey, *Dr. Guo* (3:10-3:15 pm)

Discussion: General Q & A, *Devin Gill* (3:15-3:20 pm)

Post-Survey (3:20-3:25 pm)

Wrap-up (3:30 pm)

Appendix C Evaluation Survey Results

Great Lakes Short-Term Ice Forecast Workshop
Evaluation Survey Results
July 11, 2019

Nine target stakeholders participated in the Great Lakes short-term ice forecast workshop on July 11th in Cleveland, OH, including U.S. Coast Guard employees and members of the Lake Carriers' Association. These nine participants were asked to participate in pre and post evaluation surveys to assess their perceptions of the proposed forecast and the workshop itself. Survey results are presented below.

Q1: In your own words, what is the purpose or goal of this workshop?

Prior to participation in the workshop, seven participants expressed that the goal of the workshop was to improve ice forecasts. Two participants mentioned learning about forecasts as a goal, and three participants mentioned elements of knowledge co-production, whereby participants collaborate with researchers to generate new knowledge together. Answering the same question in the post-survey, eight participants referenced improving the forecast, one participant mentioned learning more about ice forecasts, and four participants referenced aspects of knowledge-coproduction. In the future, researchers should emphasize the role of co-production in our approach to ice forecast development.

Q1 Pre-Survey Responses	
1.	Improve ice forecasting tools used by Great Lakes commercial shipping operators
2.	Identifying through facilitated discussion and open dialogue parameters & potential products to assist mariners w/ ice forecasting
3.	Gain knowledge on how they develop the forecast and possible changes to the forecast
4.	To formulate ideas, concepts using data and experience to better understand how forecasting ice conditions on the Great Lakes
5.	To explore options of and requirements for Great Lakes ice forecasting
6.	Provide Coast Guard insight for researchers
7.	To learn more about Great lakes ice forecasting products, to improve products, to meet/interact with product users
8.	To facilitate future ice forecasting, taking advantage of subject matter experts and researchers abilities and skills
9.	To discuss the CG's use and application of ice forecast models, and how we use it to make decisions
Q1 Post-Survey Responses	
1.	Improve ice model
2.	Refining detail, augmenting survey, defining expectations
3.	Gain knowledge of ice forecasting
4.	Create a better model of ice forecasting
5.	Collaborate to brainstorm ice forecast requirements/needs
6.	Collaborate to find aspects to improve forecast models of Great Lakes
7.	Evaluate operational ice forecasting needs; provide feedback on ice forecast model
8.	Help shape the future of GL ice forecasting based on all our input
9.	To discuss the CG's use and application of ice forecast models, and how we use it to make decisions

Q2: <u>Please indicate how strongly you agree with the following statements about this workshop:</u>

a): I feel knowledgeable about ice information products available to support Great Lakes navigation.

b): I understand my role in this research study.

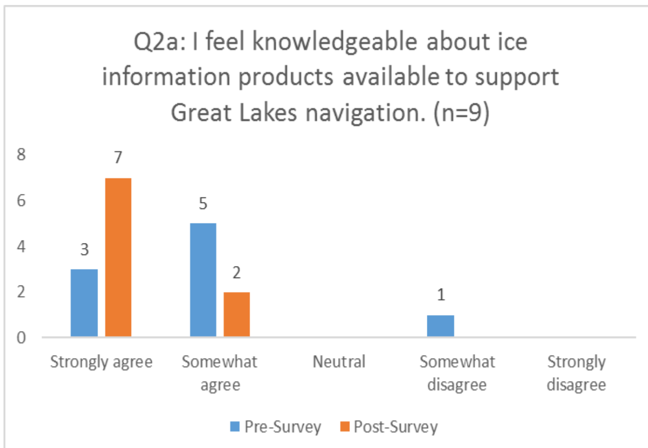
c): I understand the goals of this research study.

d): If a forecast can provide five days advance notice of ice conditions on the Great Lakes, I would use this information for trip planning.

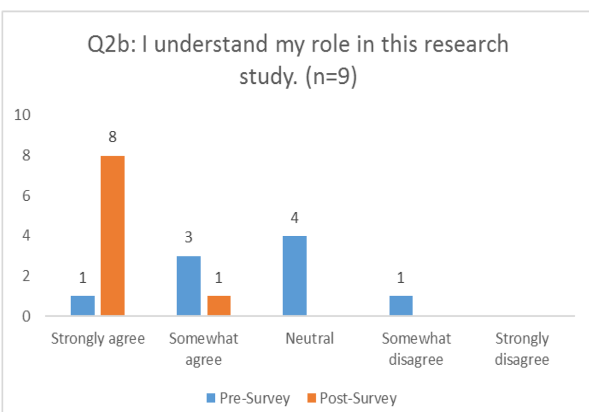
e): The development of a short-term Great Lakes ice forecast would be useful for my industry.

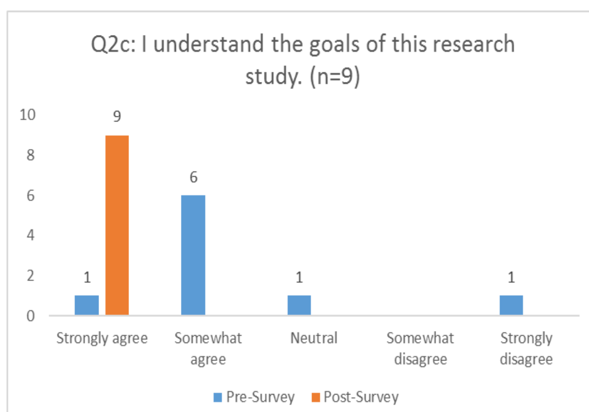
f): I will/did benefit from my participation in this workshop.

As a result of participating in the workshop, participants reported feeling more knowledgeable about ice information products available to support Great Lakes navigation.



Overall, participant understanding of the goals and their role in our ice forecast research increased after participating in the workshop. Post-workshop, all but one participant reported that they have a strong understanding of their research role.



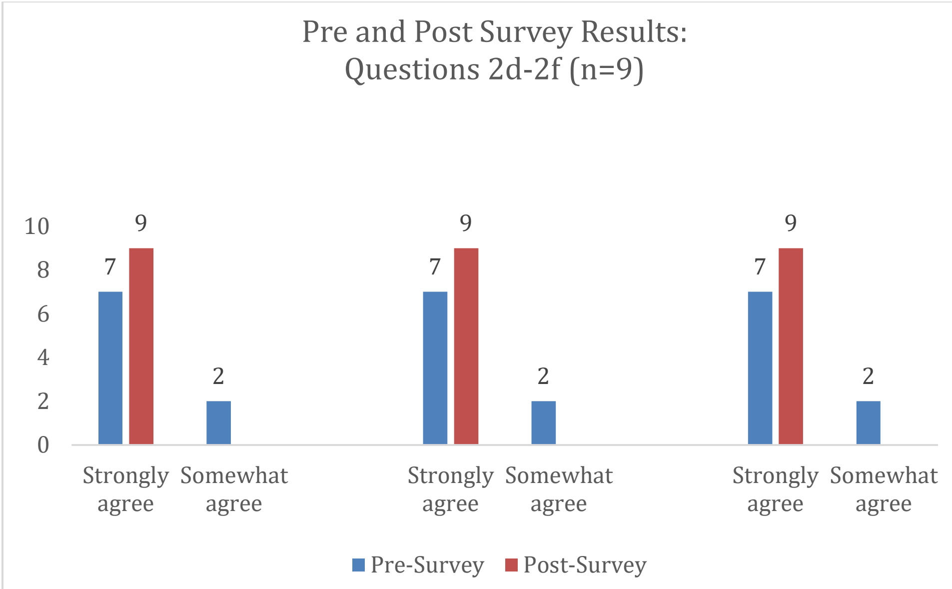


Before and after the workshop, participants reported a strong willingness to the use forecast, because they thought that it would be useful. All participants reported that the workshop was beneficial.

Willing to use the forecast

Forecast is useful

Workshop is beneficial



Q3: Would you like to provide any further explanations for your survey responses?

In the pre-survey, three participants provided additional detail about the perspectives that they represent as workshop participants. In the post-survey, one participant suggested specific information platforms that the ice forecast could integrate with and emphasized their interest in incorporating artificial intelligence into ice products.

Q3 Pre-Survey Responses	
2.	I'm not a vessel operator, but represent our members on issues of mutual concern and interest. My input will probably be at the 30,000 foot level.
4.	No.
6.	No.
7.	I served on CGC Mackinaw (2006-2008) and am returning to coordinate ice breaking ops on the Great Lakes after being away for over 10 years. I remember using GLERL products many years ago on MACK.
8.	In my work with the Coast Guard, I deal with several mission areas/disciplines, i.e. ice rescue, oil spill, response in ice, ice breaking, etc. Attempting to represent all these areas.
9.	N/A.

Q3 Post-Survey Responses	
2.	Great workshop with great agency representation
5.	There are platforms that could be used for ice model/apps. Find out more about ATAK/ITAK (DHS W & T technology). Use AI and other emerging technologies.
6.	no
7.	I understand how the USCG can help improve ice forecast model; I understand how we use ice products; I met other ice product users. Thank you!
8.	Great to see what is being worked on!

Q4: What benefits or outcomes do you think you will/have gained by attending this workshop?

In the pre-survey, participants reported that they hoped their participation in the workshop will result in improvements to forecast products, increased knowledge, and relationship-building with other stakeholders and researchers. In the post-survey, participants confirmed that these outcomes were achieved.

Q4 Pre-Survey Responses	
1.	Improve websites
2.	Better understanding of potential products.
4.	LEARN!! Not sure what--but learn.
5.	Listen and learn
7.	To learn more about available products and network with ice forecasters and industry users.
8.	Interchange of ideas, info, seeing the realm of the possible
9.	Learn more about the process of the development of the short term ice forecast models.
Q4 Post-Survey Responses	
4.	Better understanding of what is accomplished
5.	Greater knowledge of ice forecasting, Great partnership with private industry, regulators, and scientists
6.	Really distilled ideas to focused improvement objectives
7.	I understand how the USCG can help improve ice forecast model; I understand how we use ice products; I met other ice product users. Thank you!
8.	Great to see what is being worked on!

Appendix D Survey Summary

2019 Great Lakes Ice Forecast User Survey

Dear ice information users,

As someone who works in the Great Lakes navigation/transportation sector, you are being asked to participate in this survey to assess information needs relating to Great Lakes ice conditions. We want to understand your information needs to develop Great Lakes ice forecast products.

You must be 18 or order to participate. Your response will be kept anonymous and confidential. By submitting this survey, you are voluntarily agreeing to participate.

We sincerely thank you for your time and effort!

---

1. How frequently do you refer to the following websites or email bulletins for Great Lakes ice information during the winter?

1 = Almost never 2 = Several times per season 3 = Several times per month 4 = Daily 5 = Several times per day

	Percentage					Mean	n
	1	2	3	4	5		
National Ice Center webpage	*26*	*6*	*26*	*28*	*14*	*2.97*	*65*
Coast watch webpage (link)	*22*	*9*	*22*	*34*	*13*	*3.06*	*64*
NOAA GLERL Great Lakes Coastal Forecasting System webpage	*16*	*5*	*19*	*39*	*22*	*3.47*	*64*
National Weather Service, Cleveland Station webpage	*25*	*9*	*17*	*30*	*19*	*3.08*	*64*
Daily Ice Briefs from the U.S. and Canadian Coast Guards	*16*	*3*	*13*	*52*	*17*	*3.52*	*64*
Lake Carriers' Association Summaries of ice conditions	*35*	*19*	*15*	*25*	*6*	*2.48*	*65*
Other. Please specify here________________________________							

Note. No responses specified other ice information sources.

2. How useful are the following types of Great Lakes ice information?

1 = Not useful at all 3 = Neither 5 = Very useful n.f.= I'm not familiar with this type of ice information

	Percentage					n of n.f.	Mean	n
	1	2	3	4	5			
Ice thickness	*6*	*3*	*11*	*21*	*59*	*1*	*4.22*	*63*
Ice concentrations	*3*	*0*	*13*	*29*	*56*	*1*	*4.33*	*63*
Location of ice	*5*	*0*	*6*	*14*	*75*	*0*	*4.55*	*64*
Predicted movements of ice	*5*	*7*	*12*	*28*	*49*	*3*	*4.10*	*61*
Ice type (new, brash, plate, etc.)	*8*	*5*	*15*	*36*	*37*	*3*	*3.89*	*62*
Ice pressure	*10*	*10*	*14*	*27*	*39*	*5*	*3.75*	*59*
Probability of ice formation (how likely will ice form)	*3*	*8*	*25*	*25*	*39*	*3*	*3.89*	*61*
Other. Please specify here ____								

Other:

- *"Flooding as a result of the ice conditions"*
- *"ice conditions that prohibit commercial shipping for periods longer than 3 days"*

3. During winter, how frequently do you use Great Lakes ice forecasts for the following purposes?

1 = Almost never 2 = Several times per season 3 = Several times per month 4 = Daily 5 = Several times per day

	Percentage					Mean	n
	1	2	3	4	5		
To identify safe navigation routes that avoid hazardous conditions	*17*	*3*	*8*	*22*	*51*	*3.86*	*65*
To identify navigation routes or bridges in need of ice-breaking services	*23*	*3*	*9*	*26*	*39*	*3.54*	*65*
To determine if vessel damage is possible due to ice	*23*	*11*	*9*	*15*	*42*	*3.42*	*65*
To determine if icing of the vessel may occur as a result of sea spray	*32*	*9*	*3*	*20*	*35*	*3.17*	*65*
To plan for emergency responses including spills, floods, and rescue	*32*	*20*	*8*	*22*	*19*	*2.74*	*65*
Other. Please specify here ________________________							

Other:

- *To see impact of icing on shipping industry*
- *To develop recovery COAs for commercial shipping when icing causes Maritime Disruptions lasting longer than 72 hours*
- *To determine whether I need to order tugs to break up the ice when entering a port.*
- *To determine how long we have ice rescue crews ready to go*
- *Pollution response strategies due to ice*
- *Ice Rescue*

Ice information can be presented at different and spatial scales. The following questions help us understand your time scale preferences.

4. Among the following list of time scales, which ones have you used in the past? (Select all that apply)

□ Current ice conditions (nowcast) *85%, n=57*

□ Ice conditions over the **next** few days (short-term forecast) *70%, n=47*

□ Projected ice conditions for the upcoming season (seasonal) *48%, n=32*

□ Ice conditions during previous seasons (seasonal hindcasts) *31%, n=21*

5. Please rank the usefulness of ice forecasts at different time scales (1-most useful, 4-least useful)

_____ Current ice condition (nowcast) *median =1*

_____ 3 day forecast *median =2*

_____ 5 day forecast *median =3*

_____ 10 day forecast *median =4*

6. How many days in advance would you prefer to receive the ice forecast?

______days

1 day (1, ASAP, daily on the ice call) 14% n=6
2 days 14%, n=6
3 days (3, 1-3days, 2-3) 34%, n=15
4 days 5%, n=2
5 days 16%, n=7
7 days 14%, n=6
10 days 2%, n=1
30 days 2% n=1

We are also interested in learning your needs for location specific ice information.

7. In addition to lakewide ice information, how interested are you in ice information for specific locations in Great Lakes? *Mean=2.05 n=62*

1	2	3	4	5
61%	*8%*	*7%*	*13%*	*11%*
Not interested at all		Moderately interested		Extremely interested

8. Please rank ice information for different locations in order of usefulness (1-most useful, 6-least useful).

____ Navigation locks *Median = 2*

____ Entrance to major ports (i.e. Duluth, Marquette, Cleveland) *Median = 1*

____ Straits of Mackinac *Median = 3*

____ Whitefish Bay *Median = 4*

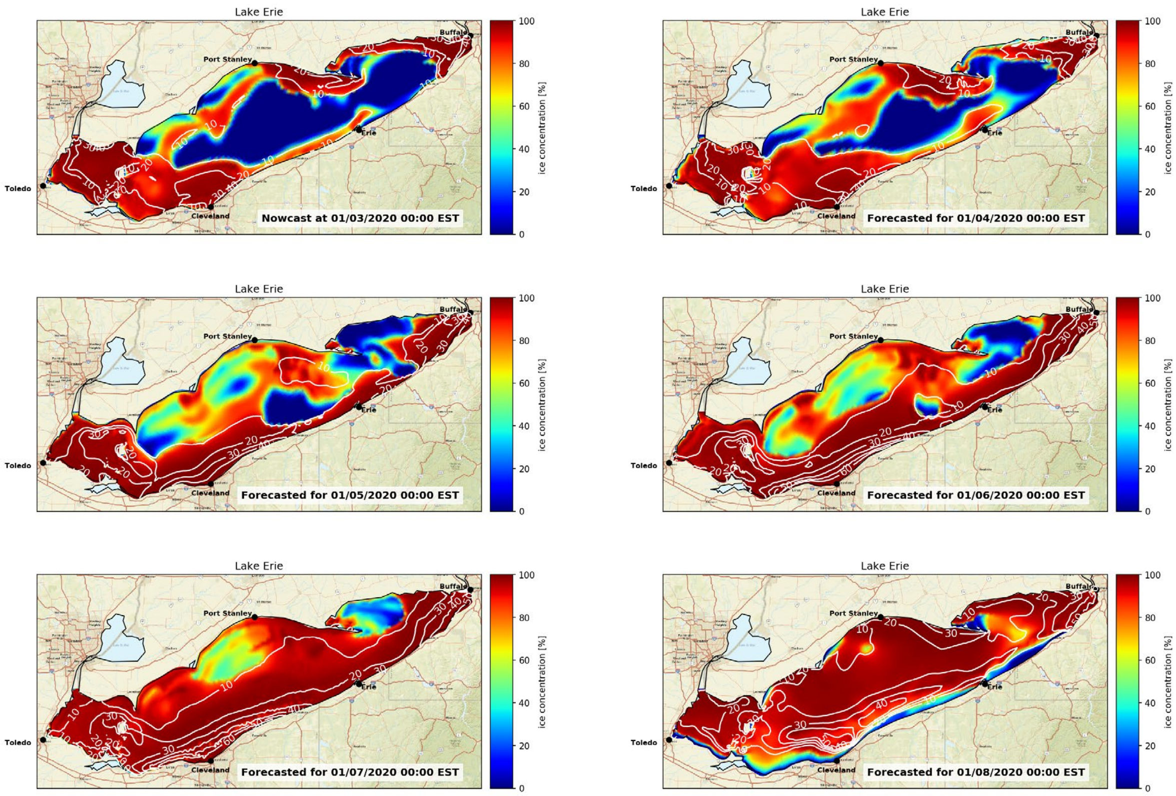
____ Thousand Islands *Median = 5*

____ Other. Please specify here ______________________________

Other:

- *All ports*
- *Connecting waterways that support commercial shipping during the ice season: St Mary's, St Clair, Detroit Rivers*
- *Entrance to major ports, Straits, and Whitefish Bay*
- *Green Bay, Saginaw Bay, Georgian Bay*
- *Green Bay, WI., Saginaw Bay, MI.*
- *High activity recreational areas: W. Lake Erie, Saginaw Bay, Green Bay, Lake St. Clair*
- *Pelee Pass/Western Lake Erie*
- *St Marys River/Georgian Bay*
- *St. Mary's River, Detroit River, St. Clair River*
- *Whitefish Bay, Straights of Mackinac, West End of Lake Erie, West End Lake Superior, Keweenaw Peninsula*

CIGLR and the NOAA Great Lakes Environmental Research Laboratory (GLERL) are developing a short-term ice forecast to help lake vessels prepare for and prevent rescue scenarios during changing ice conditions. To help us improve the forecast products, please review the mock forecast below showing ice concentrations and thickness in Lake Erie on January 2020 and answer the following questions.



The color represents ice concentration in percent, the contour line represents ice thickness in centimeters.

Please imagine that you are preparing to navigate across Lake Erie from Cleveland, Ohio to Buffalo, New York in early January, 2020. You received the above ice forecast information.

9. Based on the ice conditions described in the forecast, what percentage **ice concentration** is predicted to occur near **Buffalo, NY on January 6, 2020**? *n=37*

☐ Less than 20% *0*
☐ 21% to 40% *0*
☐ 41% to 60% *8% n=3*
☐ 61% to 80% *0*
☐ 81% to 100% *92% n=34*

10. How **thick** is the ice predicted to be near **Buffalo, NY on January 6, 2020**? *n=36*

☐ Less than 10cm *6% n=2*

☐ 11-20cm *3% n=1*

☐ 21-30cm *8% n=3*

☐ 31-40cm *14% n=5*

☐ 41-50cm *53% n=19*

☐ 51 to 60 cm *17% n=6*

11. In the forecast, at which speed are **the overall ice conditions** changing over the entire lake? *n=36*

☐ Very slowly *0*

☐ Slowly *3% n=1*

☐ Moderate speed *25% n=9*

☐ Fast *47% n=17*

☐ Very fast *25% n=9*

12. Particularly, at which speed is **ice concentration** changing? *n=36*

☐ Very slowly *0*

☐ Slowly *3% n=1*

☐ Moderate speed *22% n=8*

☐ Fast *50% n=18*

☐ Very fast *25% n=9*

13. At which speed is **ice thickness** changing? *n=36*

☐ Very slowly *0*

☐ Slowly *8% n=3*

☐ Moderate speed *47% n=17*

☐ Fast *22% n=8*

☐ Very fast *22% n=8*

14. How much risk of vessel damage do you think the forecast ice conditions pose for your ship? *Mean=3.33 n=36*

1	2	3	4	5
6%	*17%*	*33%*	*28%*	*17%*
No risk at all		Moderate risk		Extremely high risk

15. How likely are you to stay in port waiting for ice conditions to improve? *Mean=2.89 n=35*

1	2	3	4	5
20%	*29%*	*17%*	*11%*	*23%*
Not likely at all		About as likely as not		Very likely

16. How likely are you to adjust your route in response to the forecast ice conditions?
Mean=3.50 n=36

1	2	3	4	5
11%	*14%*	*14%*	*36%*	*25%*
Not likely at all		About as likely as not		Very likely

17. Overall, how do you rate the mock ice forecast?

Mean	n	The Ice Forecast I saw						
			Percentage					
			5	4	3	2	1	
3.90	*39*	Easy to interpret	*31*	*36*	*28*	*3*	*3*	Confusing
3.74	*39*	Comfortable to use	*23*	*44*	*23*	*5*	*5*	Frustrating to use
4.03	*39*	Has the right amount of information	*31*	*46*	*21*	*0*	*3*	Has too much information
3.98	*40*	Very useful	*35*	*40*	*18*	*3*	*5*	Not useful

18. How much additional information does this ice forecast add to the resources you have used in the past (e.g., National Ice Center webpage, National Weather Service, Cleveland Station webpage)? *Mean=3.06 n=36*

1	2	3	4	5
8%	*22%*	*33%*	*28%*	*8%*
Not much				A great deal

19. If the proposed ice forecast is easily accessible, how likely are you to use it? *Mean=4.33 n=39*

1	2	3	4	5
3%	*13%*	*0*	*31%*	*54%*
Not likely at all				Very likely

20. Please indicate how likely you would be to use the proposed ice forecast if it is delivered using the methods listed below.

1= Not likely at all 3= Neutral 5= Very likely

	Percentage					Mean	n
	1	2	3	4	5		
Bulletin emailed to you	*6*	*8*	*11*	*25*	*50*	*4.06*	*36*
Information presented on a website	*5*	*0*	*5*	*32*	*58*	*4.37*	*38*
Receive text message alerts	*22*	*8*	*24*	*22*	*24*	*3.19*	*37*
Incorporated into an existing ice conditions report. Please specify the report___________ • *GLERL Ice Concentration Forecast* • *Lake Carrier* • *OPS Brief* • *Paired with USCG Ice Reports of Actual Ice Con*	*5*	*14*	*14*	*29*	*38*	*3.81*	*21*
Other_______________							

Other: NWS briefing from Cleveland and Buffalo

21. Is there anything you like about how the ice forecast is displayed?

- *Add normal LCA Routes, and designed ICE Routes to maps, along with forecasted wind conditions.*
- *Clear concise color scale is helpful. Contour lines are helpful as well.*
- *I am wondering if this forecast will be generated for Whitefish Bay and the Straits. Otherwise looks great!*
- *I could not view as I am working off a sat phone and items would not load, sorry*
- *I could not view it*
- *I was unable to play any of the videos.*
- *Liked the time period the forecast advanced each frame.*
- *lots of good information, relatively easy to use and understand*
- *On my Coast Guard government computer this video did not play, so you may want to leave my answers out.*
- *The color contrast was very easy to understand.*
- *The colors seemed opposite of what I would have expected. Red indicates 'warm' to me so I would suggest that ice be represented by blue 'cold color' (darkest/navy blue for highest concentrations) and red represent unfrozen water (warm).*

- *The National Ice Center and Canadian Ice Service slides are pretty good and I feel comfortable using them. Your initiative looks promising, but perhaps a few tweaks to make them easier to understand quickly.*
- *The thickness contours.*
- *Wasn't able to access on military computer*

22. Is there anything you do not like about how the ice forecast is displayed?

- *Change the unit of measure to inches. Would like the ability to change what information is displayed as a color and what is displayed as a contour line.*
- *cm vs inches for ice thickness.*
- *From the perspective of a Coast Guard air station, I utilize the information provided to help determine what type of case we're dealing with, so ice coverage, thickness, and ice type are the most relevant pieces of information in our world of work.*
- *Having the ability to scale the forecast in critical waterways (channels) would help for trip planning.*
- *I do not like the use of centimeters. It must be in inches.*
- *I like it.*
- *It works over your website, much better than youtube (mock forecast). Since I am [personal identifiable information was taken out], I use your forecasts daily. Our MIL systems have a tough time with heavy webpages/youtube.*
- *limited internet access means graphic intensive videos are sometimes not available for use onboard the vessel*
- *make it work for sat communication*
- *Too many to look at... best to get the info from as few slides as possible?*
- *Wasn't able to access on military computer*

23. In addition to the ice information products you have used and the one we are testing here, what is you biggest unmet ice information needs?

- *As an icebreaker captain, I am constantly looking for the effects of wind on ice coverage and where the ice is shifting to. If there is a way to predict where ice is moving, that would help. This is especially relevant in Western Lake Erie.*
- *For search and rescue purposes, the probability or likelihood that floes will break loose (and possibly trap ice fishermen, snowmobiles, etc.). Also, the possibility of ice-caused flooding.*
- *Ice concentration and thickness as well as its movement are important. But what is really valuable for our operational planning is ice PRESSURE. 24" of ice under moderate pressure versus 24" of ice under heavy pressure are very different and knowing where those locations are would be very helpful to our agency. Thanks for all the great work!*
- *None. Here at …[personal identifiable information was taken out] we are able to brief and understand the current and forecasted ice conditions without any issues. The only issue is the satellite feeds of the ice coverage that are obscured by cloud cover, but that is a minor thing.*
- *Solid sat images, paired with a decent ice forecast, enables us to conduct escorts and standard DOMICE ops. We always run into issues with clouds for the sat images, to best see where/how the ice is moving. Is there anything you want more of from the USCG side to pair in with your forecasts?*

Lastly, please help us understand who responded to our survey by answering the following questions:

24. Which category best describes your profession? *n=49*

□ Coast Guard employee *49% n=24*

□ Other federal employee. *4% n=2*

□ Personal vessel operator *n=0*

□ Commercial vessel operator *43% n=21*

□ Non-governmental organization employee. *2% n=1*

□ Other. Please specify:_*n=1 captain on a great lakes frighter*

25. How many years have you worked in this profession? *n=47*
Mean = 19.06 Standard Deviation = 10.76 Min = 2 Max=42

26. In which country are your vessels flagged? *n=40*

□ Canada □ United States *n=39 98%* □ Other nationality *n=1 2%*

27. Is there anything else you would like us to know?

[A response(s) that contained Personally Identifiable Information (PII) is removed]

- *I look at a lot of weather sites during the spring and fall. what we really need are weather stations/buoys that don't get pulled Nov 1. this is the time we need that information not in the Summer months. Even most land stations will not be working by Jan 15. This has been a problem for many years.*
- *Sailed 4 winters on the Great Lakes, the 70 year winter in 2013-2014 and several others. Maritime commerce and changes with the USCG policy has made DOMICE ops much more streamlined and better to operate since that winter of 2014. I applaud the ice prediction tool you all put out, and I have used it paired with sat images/ice concentration maps you produce several times a day for DOMICE ops. Keep up the great work, it makes a BIG difference on how we plan our escorts and do our preventative ice breaking/track establishment.*
- *Thank you.*