

Alaska Sea Ice Forecast Project
Community Workshop Report

St. Lawrence Island (Sivuqaq) & Nome (Sitnasuaq), Alaska

Overview, Discussion Themes, and Recommendations

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Executive Summary

This report presents the discussions and recommendations from three community-based workshops conducted during 2026 as part of a NOAA-funded project led by CIGLR and NOAA GLERL. The project aims to improve short-term sea ice forecasting along Alaska's coasts through higher spatial resolution capturing landfast ice, expanded Alaska ice modeling, and input with Arctic communities. As part of the project, CIGLR contracted with Northwest Planning, LLC (NWP) to co-facilitate engagements and community workshops for learning of end user needs and feedback. The community workshops were hosted in Nome (Sitnasuaq) and on St. Lawrence Island in the villages of Savoonga (Sivunga) and Gambell (Sivuqaq).

Landfast ice—stable sea ice attached to the coast—is central to Arctic ecosystems and supports community subsistence and food security, safe travel, and Inuit cultural continuity. Climate change has significantly altered ice formations and conditions with thinner ice, shorter stability periods, and larger open leads which has resulted in greater risks for accidents and loss of subsistence opportunities. These changes underscore the urgent need for accessible and community-centered ice forecasts with higher resolution.

In the workshop discussions, participants highlighted the importance of incorporating Inuit and Western knowledge to strengthen forecast accuracy, usability, and communications. As forecast efforts and technologies evolve, participants recommended that researchers expand work with communities for blending Inuit and Western science of sea ice, and incorporating real-time and remote monitoring abilities into online forecast systems and tools with higher resolution. The workshop recommendations also included the important value of collaborating with Arctic researchers and integrating Inuit languages for advancing ice forecast inputs/outputs and detailing conditions for safer decision making during landfast ice activities.

Participants also shared the layered communications and social networks within Arctic communities to best distribute ice condition reports and forecasts. They recommended building project communications upon trusted Arctic networks like VHF/CB radio, Facebook, public FM/AM radio, YouTube, and cell phone apps.

Overall, the workshop participants underscored the need for improved sea ice tools and forecasts which are sustained with equally compensated partnerships of Inuit experts in ongoing and future co-development of models and products with researchers, agencies, and forecasters.

Keywords: Sea ice forecasting, Landfast ice, Alaska coastal communities, Inuit sea ice knowledge, Climate change, Ice stability, St. Lawrence Island Yupik terminology, Collaborative Design

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Acronyms

ARP	Arctic Research Program
ACCAP	Alaska Center for Climate Assessment and Preparedness
ARCS	Alaska Rural Communication Service
AOOS	Alaska Ocean Observing Systems
CIGLR	Cooperative Institute for Great Lakes Research
FAA	Federal Aviation Administration
GCAS	GLERL-CIGLR Arctic-sea routes nowcast/forecast System
GINA	Geographic Information Network of Alaska
GOMO	Global Ocean Monitoring and Observing
GLERL	Great Lakes Environmental Research Laboratory
IRaMS	Integrated Radar Monitoring System
IRB	Institutional Review Board
NOAA	National Oceanic and Atmospheric Administration
NWP	Northwest Planning, LLC
NWS	U.S. National Weather Service
PMEL	Pacific Marine Environmental Laboratory
RES	Research Engagement Specialist
SIWO	Sea Ice for Walrus Outlook
UAF	University of Alaska Fairbanks
UIC	Ukpeaġvik Iñupiat Corporation
U.S. ACE	United States Army Corps of Engineers
VHF/CB	Very High Frequency/Citizen Band (two-way radio systems)

Introduction and Background

Researchers at the University of Michigan's Cooperative Institute for Great Lakes Research (CIGLR) with the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Lab (GLERL) are working on a three year project to enhance short-term sea ice forecasting capabilities with higher resolution to capture landfast ice and accuracy along Alaska's coasts. This was made possible with funding from the NOAA Global Ocean Monitoring and Observing (GOMO) Arctic Research Program (ARP). As part of the project, CIGLR contracted with Northwest Planning, LLC (NWP) to collaboratively engage with U.S. Arctic communities for informing stakeholders of this development, involving end users in review of the beta tool, and engaging with community level stakeholders for needs, input, and recommendations including social relevancy of the beta tool.

As background, landfast ice – stable sea ice that attaches to coastal land areas – plays an important role in Arctic ecosystems and seasonal human activities along the coasts of Alaska. Landfast ice is also referred to as shorefast ice, or simply fast ice. In this report, landfast ice will be used as the term to refer to this type of ice.

Over time, there has been great variability of such ice with a warming and changing climate. This has negatively impacted Arctic communities' abilities to safely access localized coastal areas with growing risks and incidents of accidents, injuries, and loss of life among travelers and subsistence providers. These conditions also result in loss of subsistence resources and routes, lower levels of community food security, negative impacts to household income, reduced opportunities for environmental connectivity, and a decline in Inuit cultural practices. This underscores the need for reliable and accessible forecast systems that can accurately predict landfast ice on short-term, regional scales for protecting people, property, and the unique Inuit and Alaskan ways of life.

This project is improving near-term sea ice forecasts and tools which can empower Alaskan communities to safely plan and conduct activities among landfast ice habitats. The project has equal focus on the technological advancement of the state-of-art sea ice modeling for short-term forecasting applications, and engagements with Arctic communities and organizations. The technological goal is to update the GLERL/CIGLR Arctic Sea Routes Nowcast/Forecast System (GCAS), originally developed in 2012, with enhancements in resolution, forecast duration, data inputs, and accessibility to more effectively meet regional user needs. This is co-developed with engagement methods through community workshops to advance integration of Indigenous knowledge while collaboratively understanding end users' local areas and uses of landfast ice, and communication needs for timely forecast information. Overall, this will ensure the tool delivers technically precise forecasts while ensuring usability by Arctic communities for supporting social, economic, and cultural dimensions.

Report and Project Limitations

This report and project have limitations related to scope, resources, and representation. The factors of time, funds, staffing, and travel were significant resource constraints that limited the number of Arctic communities and regions that could be visited and involved as well as the depth of follow-up engagements. Our team worked within the project budget and designed the scope and representation of the workshops to be held with three communities in one region of Alaska.

This project and report also have limits when considering the broader application to Alaska's coast which includes over 90 communities, each with place-based knowledge of nature and sea ice that uniquely informs decision-making. The project forecast tool is intended to serve a much broader audience of the U.S. Arctic; therefore, additional workshops and partnerships with more communities are needed to understand the full scope and range of the U.S. Arctic needs, ice conditions, subsistence practices, languages, and communication preferences.

As part of representation limitations, participants in the workshops were voluntary community and organizational representatives. Most participants were mature community members, whose knowledge is essential, but future work and budgets could include more youth representatives and young hunters, fishers, crabbers, and community technology users to better understand intergenerational perspectives and how sea ice information tools may be used, accessed, and designed with those end users. We also recognize that because the CIGLR research team was not based in Alaska and had not previously worked in these communities, existing relationships, local context, and trust-building were underdevelopment which may have shaped who participated and what information and scope of discussions were shared.

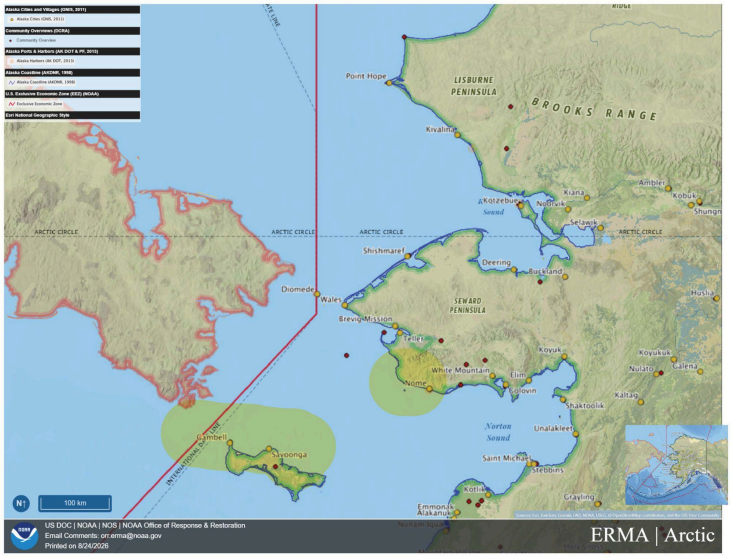


Figure 1. Map of areas of community workshop engagements in Nome and St. Lawrence Island (highlighted in yellow). Source: Arctic ERMA (https://response.restoration.noaa.gov/arctic-erma).

Overview of the Workshops

Workshop Objectives

The workshops were developed according to the project and grant purposes with objectives to promote community level engagement with Arctic residents and partner organizations on the topic of Alaska landfast ice. The following summarizes the objectives for the three workshops.

Objectives: Workshop 1 Savoonga/Sivunga and 2 Gambell/Sivuqaq

- Project and team introductions for building awareness of CIGLR and the project activities while promoting community-level relationship building.
- Explore how St. Lawrence Island communities utilize landfast ice and access sea ice data including Indigenous knowledge.
- Learn which existing online tools are in use at the community level for weather forecasting and ice monitoring by residents and local organizations, and community needs for enhanced sea ice forecasts.
- Discuss how to better co-create tools by including Indigenous knowledge and culture in the project work.
- Discuss how the project could improve the beta design of the online ice forecast tool to help address those needs and be accessible to end users in the community.

Objectives: Workshop 3 Nome/Sitnasuaq

- Project and team introductions for building awareness of CIGLR and the project activities while promoting relationship building at the community-regional and organizational-agencies-universities levels.
- Opportunity for collective and cross-cultural sea ice knowledge sharing.
- Networking with participants to identify collaborative improvements and/or partnership opportunities in landfast ice forecasts and tools serving communities, agencies, and researchers.
- Discuss how to better co-create tools by including Indigenous knowledge and culture in the project work.
- Discuss how the project could improve the beta design of the online ice forecast tool to help address those needs and be accessible to end users in the community.

Project Outreach and Participant Recruitment

Three Alaska communities in the Bering Strait region (also referred to as the Norton Sound region) were selected to work within the available project resources: Savoonga (English) or Sivunga (St. Lawrence Island Yupik); Gambell (English) or Sivuqaq (St. Lawrence Island Yupik); and Nome (English) or Sitnasuaq (Iñupiaq). The three communities were also selected to strategically capitalize on the existing networks and relationships among the project team while considering the unique coastal marine geographies (island and mainland settings), and abilities

to conduct iterative in-person engagements with diverse representation from Inuit communities with longstanding uses of landfast sea ice.

For workshops 1 and 2, participants were recruited with a goal to represent the local community. These included organizational representatives from the village such as the Tribe, city, and Alaska Native village corporation as well as community Elders, emergency responders, and subsistence providers that could help in reviewing the usability and accessibility of sea ice forecast tools. The workshops were open to the community.

For workshop 3, participants were recruited with a goal to represent communities in the U.S. Arctic as well as represent agency and research partners in sea ice forecasting. Partners included community representatives based in the Arctic, Bering Strait regional organizations, state and federal agencies, university Arctic sea ice programs and climate researchers, and NGOs. The workshop was open to the public.

The project outreach and participant recruitment process included pre-workshop engagements with Tribes, Alaska Native village corporations, municipal governments, and regional decision makers like the Alaska Nannut Co-Management Council, Alaska Eskimo Whaling Commission, Kawerak, Inc, City of Nome, and Port of Nome. These engagements involved the project team organizing or joining meetings to start discussions with community leadership and organizational representatives to learn of the project, seek interest in workshop participation, and identify potential workshop dates. For partner organizations, representatives were recruited based upon existing CIGLR team networks and professional relationships in sea ice research and/or Arctic climate tools and forecasts.

As part of the project outreach efforts, the team participated in community media interviews to build public awareness of the project and publicize the upcoming workshops in communities. These were published as news stories with the Nome Nugget Newspaper and KNOM radio station, both of which are regional and accessible to residents of Savoonga, Gambell, and Nome. NWP also shared project information on social media platforms and community flyers to support community awareness of the project and expand outreach to interested Arctic residents.

After these activities for outreach and recruitment, the project team followed up engagements with individual email communications including invitations to participate in the workshops.

Workshop Design and Format

The workshops were co-designed by CIGLR and NWP as informal meetings to allow approachable, thoughtful discussions, and participatory engagement at the community level on the topic of sea ice. There was no minimum or maximum size of participants for the workshops. Each was designed with voluntary participation of community members and organization representatives. There was not an individual participant selection methodology or criteria like age, gender, experience, speciality, and/or organizational association.

In the design, collaborative peer interactions and participatory stakeholder-level discussions were prioritized for each workshop. This promoted sharing of community input, exchanging of Western and Inuit knowledge, formulating creative thoughts and recommendations in project development, and flowing of diverse ideas between participants and facilitators.

The three workshops were formatted to share project information with important time to directly hear from Arctic communities and end users. The agendas were developed with a combination of informational presentations and group discussions including prompts based on a set of preliminary CIGLR research questions that were refined with NWP based upon the workshop audiences.

Each workshop began with introductions of the facilitators (Ukallaysaaq, Ayumi, and John) and was followed by our main facilitator, Ukallaysaaq, reviewing the core workshop values: *safe space, participation, and creativity*. Participants then had the opportunity to share introductions with personal backgrounds with the group. The CIGLR team then overviewed the project for awareness which outlined the primary objectives and the participant informed consent. All participants had the option to skip specific discussions or not answer any questions as they chose. Throughout each workshop, the facilitators encouraged participants to ask questions, share input and knowledge, and offer recommendations.

The workshop agendas can be reviewed in **Appendix A**.

Summary of the Workshops

The information and feedback gathered from these workshops provided very valuable input and progressed the project's purpose to improve the current and future development of landfast ice forecasting and the beta tool. The workshops also helped to inform both the project and partners' forecast and program efforts for better collaborating with Arctic communities and promoting engagements with Inuit organizations and research partners.

Workshop 1: Savoonga/Sivunga, February 24, 2026

Due to weather and travel complications the CIGLR and NWP team were unable to fly into Savoonga and co-facilitated this workshop by Zoom from Nome, Alaska. Community participants met at the planned in-person gathering space at the Native Village of Savoonga. The workshop food and handouts were sent to the village. Workshop handouts included the agenda, two page project fact sheet, IRB informational sheet, and the meeting guide with the fifteen discussion questions. This workshop was facilitated primarily by NWP and lasted an hour and 30 minutes.

After the workshop opening and introductions, the CIGLR team shared summary descriptions with short demonstrations of four online sea ice forecast and monitoring tools as applicable to the project and helped participants consider existing ice forecast tools and models. These included the: NWS Alaska Sea Ice Program, Sea Ice for Walrus Outlook (SIWO), UAF Gambell Sea Ice Radar, and the U.S. ACE IRaMS Sensor in Savoonga. The CIGLR team then presented

their beta ice forecast tool for participant information, and provided a walkthrough of the real time website for orientation to the features under development.

Ukallaysaaq then facilitated discussions via fifteen workshop questions that were organized into three areas to encourage participant feedback and input. These were presented as follows:

(a) Sea Ice Forecasting Tools and Models

1. What are existing sea ice forecast tools community members and organizations use? E.g., radio, online, web-based, Indigenous knowledge, etc.
2. What do you like best about those tools?
3. What do you wish could be improved in those tools?
4. What are the preferred methods the community would like to access the forecast information from this project in the future? E.g., web pages, phone message recording, cell phone text message or push notification, daily email, Facebook page, etc.
5. How can the sea ice forecast information be best presented to be easily understood by community members for using it?
6. How do people access sea ice forecast information while in the field (e.g., hunting, fishing, camping, traveling, etc.)?
7. How could people in the field easily share sea ice condition updates with the project for improving forecasts?

(b) Communities' Sea Ice Activities and Uses

8. What community and subsistence activities would best benefit from an improved sea ice forecast?
9. What emergency response activities would best benefit from an improved sea ice forecast?
10. What business and planning activities would best benefit from an improved sea ice forecast?
11. What types of sea ice information and characteristics are needed to better support the uses identified in the above discussions: subsistence and community, emergency response, business and planning? E.g., Sea ice thickness, ice speed, ice coverage, etc.

(c) Recommendations to Better Include Indigenous Sea Ice Knowledge

12. What are some ways Indigenous sea ice knowledge could be better included in this project forecasting?
13. Are there specific community terms or words used to describe or communicate information about sea ice?
14. What are considerations that the project should update to include Indigenous sea ice knowledge in their forecasts?

15. How should Indigenous data sovereignty and local contributors be honored, cited, and acknowledged in this project?

The handouts included a meeting guide with a complete listing of the questions with space for participants to write in comments or thoughts which allowed individuals the option for sharing their responses in writing if they preferred not to state them verbally in front of the group. After the workshop questions and discussions there was an open opportunity for participants to share additional comments, input, and/or recommendations. At the conclusion of the workshop, participants were compensated with door prizes, which were mailed after the workshop.

Workshop 2: Gambell/Sivuqaq, February 25, 2026

The CIGLR team was able to travel to Gambell for hosting the workshop in-person the following day with a hybrid option. NWP supported the facilitation and notetaking online from Nome through Zoom. Coffee and snacks were available at the in-person site at the Native Village of Gambell including the workshop handouts. Workshop handouts included the agenda, two page project fact sheet, IRB informational sheet, and the meeting guide with the fifteen discussion questions. The workshop lasted 2 hours.

After the workshop opening and introductions, the CIGLR team shared summary descriptions and short demonstrations of four online sea ice forecast and monitoring tools as applicable to the project and helped participants consider existing ice forecast tools and models. These included the: NWS Alaska Sea Ice Program, Sea Ice for Walrus Outlook (SIWO), UAF Gambell Sea Ice Radar, and the US ACE IRaMS Sensor in Savoonga. The CIGLR team then presented their beta ice forecast tool for participant information, and provided a walkthrough of the real time website for orientation to the features under development.

Ukallaysaaq then facilitated discussions via fifteen workshop questions (same as above) that were organized into three areas to encourage participant feedback and input: (a) sea ice forecasting tools and models, (b) communities' sea ice activities and uses, and (c) recommendations to better include Indigenous sea ice knowledge. The handouts included a meeting guide with a complete listing of the questions with space for participants to write in comments or thoughts which allowed individuals the option for sharing their responses in writing if they preferred not to state them verbally in front of the group. After the workshop questions and discussions there was an open opportunity for participants to share additional comments, input, and/or recommendations. At the conclusion of the workshop, participants were compensated with door prizes.

Workshop 3: Nome/Sitnasuaq, April 16-17, 2026

Workshop 3 utilized a different format than workshops 1 and 2 with a design to involve and network multiple stakeholders. This workshop was built upon the prior St. Lawrence Island community discussions, and involved a larger audience of Nome and St. Lawrence Island residents, subsistence providers, community representatives from local to regional organizations, state and federal agencies, and university affiliated sea ice research programs.

The Nome workshop was formatted with time for guest speakers to directly share presentations on their current sea ice knowledge, tools, and developments. This allowed agency and university programs to share their forecasting products and research in the U.S. Arctic. This also allowed time for Inuit speakers to share presentations on Indigenous sea ice knowledge, forecasting, and direct field observations.

The workshop was held in-person at the UAF Northwest Campus in Nome, Alaska, and formatted as two half-day sessions on April 16 and 17, 2026. This accommodated travel schedules for in-person attendance based upon flight schedules to/from Nome. There was a Zoom option and multiple participants chose to join online with some located in Nome, highlighting the usefulness of offering a hybrid option for promoting broad engagement. Attendance online was steady for each day, while we did have some fluctuations of in-person attendance based on individual availability throughout the day.

First Day (April 16):
During the first day's session, the workshop focused on Western approaches to understanding and observing sea ice. These helped to build community and cross-agency awareness of efforts and sparked conversations for collaboration, needs, and enhancements. The following speakers shared presentations on their work around Arctic forecasts products and remote monitoring technologies specific to Alaska:

- Greg Seroka, National Ocean Service
- Jonathan Waddell, U.S. Army Corps of Engineers
- Mike Lawson, National Weather Service
- Lisa Sheffield Guy, Alaska Ocean Observing System
- Andy Mahoney, Sea Ice Research Group at UAF Geophysical Institute
- Rick Thoman, Alaska Center for Climate Assessment and Policy (ACCAP)
- Jennifer Delamere, Geographic Information Network of Alaska (GINA)

The CIGLR team then presented their beta ice forecast tool for participant information, and provided a walkthrough of the real time website for orientation to the features under development.

After a short question and answer (Q&A) session with the presenters, the facilitators transitioned participants to a discussion on the tools, research, and project recommendations for enhancing collaboration with this project and among partners and/or communities. The following questions were shared with the group to gather participant input:

- What do you like best about these tools?
- What do you wish could be improved in those tools?
- How can the beta version of the project sea ice forecast be improved?
- What sea ice information gaps do we still see?

- How can we better foster collaboration between communities, agencies, tools and forecast programs to improve overall abilities to present information around Alaska sea ice?

Second Day (April 17):
During the second day's session, the workshop focused on Inuit and Indigenous knowledge including observations of sea ice. The CIGLR team shared a summary of the St. Lawrence Island community workshops for participant information. Then the following speakers shared presentations on Indigenous sea ice and environmental knowledge as follows:

- Gerald Oxereok, Alaska Nannut Co-Management Council Commissioner from Wales
- Edwin Noongwok, Native Village of Savoonga representative
- Orlin Booshu, Sr., Native Village of Gambell representative
- Bivers Gologergen, Subsistence Provider living in Nome

After a short Q&A session with the presenters, the facilitators transitioned participant discussions to project recommendations for improving sea ice forecasts collaboratively with Indigenous communities in the U.S. Arctic. The following questions were discussed with the group to gather participant input:

- What community activities and uses could benefit from improved sea ice forecasts? Such as subsistence, emergency response, business, and community planning.
- How can Inuit sea ice knowledge and real-time observations better supplement agency sea ice forecasts and monitoring tools?
- What are ways forecast systems and models can better and comprehensively include Inuit sea ice knowledge?
- How can we ensure sea ice tools and forecasts actively reflect and honor Inuit cultures?
- What are ways to promote ongoing partnerships with Inuit communities in enhancing sea ice forecasting and improving overall abilities to present information around Alaska sea ice?

The workshop concluded with a luncheon and closing discussion. Ukallaysaaq facilitated an exercise for participants to reflect on the workshop presentations and discussions based upon the following two questions:

(A) What is your most significant take away from this workshop?
(B) How could you help the project improve Alaska sea ice forecasts?

Each participant then shared their answers and comments with the group via post-it notes or Zoom chat.

Participation Summary

The team is grateful to each participant for attending a workshop and sharing their input, comments, and recommendations with the project. Table 1 summarizes the three community workshops and then following are descriptions of participation by workshop.

Table 1. Summary of the three community workshops.

Workshop	Date	Location & Audience	Format	Participation
Workshop 1	2/24/2026	Sivunga / Savoonga Local Residents & Organizations	Virtual	6
Workshop 2	2/25/2026	Sivuqaq / Gambell Local Residents & Organizations	Hybrid	22
Workshop 3	4/16 & 4/17/2026	Sitnasuaq / Nome Local Residents, Local to Regional Organizations, University Research Community, and Partner Agencies	Hybrid	36

Participants in Workshop 1 Savoonga/Sivunga

This workshop was attended by six (6) participants and three (3) project team members. The participants included two (2) representatives of the Native Village of Savoonga, one (1) Arctic Watch Observer and marine mammal advisor, and three (3) Savoonga community members.

Participants in Workshop 2 Gambell/Sivuqaq

This workshop was attended by twenty-two (22) participants and three (3) project team members. The participants included six (6) representatives from the Native Village of Gambell, five (5) representatives from the City of Gambell, eight (8) representatives from Sivuqaq, Inc. (Alaska Native corporation), one (1) representative from the Norton Sound Economic Development Corporation, and two (2) Gambell community members.

Participants in Workshop 3 Nome/Sitnasuaq

This workshop was attended by thirty-six (36) participants and three (3) project team members. The participants included representatives from the following organizations: Native Village of Gambell, Native Village of Savoonga, King Island Native Community, City of Nome, Port of Nome, Alaska Nanut Commission, Kawerak, Inc., Bering Strait Native Corporation, Ukpeaġvik Iñupiat Corporation (UIC), Alaska Ocean Observing System (AOOS), UAF, Alaska Center for Climate Assessment and Policy (ACCAP), UAF Geographic Information System of Alaska (GINA), Sea Ice Research Group at the UAF Geophysical Institute, Alaska Sea Grant, State of Alaska Department of Fish and Game, National Park Service, National Ocean Service (NOS), U.S. Army Corps of Engineers (US ACE), National Weather Service Alaska Sea Ice Program, Pacific Marine Environmental Laboratory (PMEL)/University of Washington, National Snow and Ice Data Center at University of Colorado, and the University of Michigan.

Participants' Insights and Discussion Themes

The following summarizes the participants' insights and synthesizes workshop discussions into three major themes.

- Landfast ice ecosystem, uses and conditions
- Forecast tools, feedback, and improvements
- Community communications and networks for delivering forecast information

These are presented as three distinct themes that emerged from these conversations and discussions on the project during all three workshops. Note these discussions were often intertwined and the themes are not presented in any order. Each major discussion theme is considered related and interdependent on one another. This is represented by the interconnected nature of the ven diagram in Figure 2.

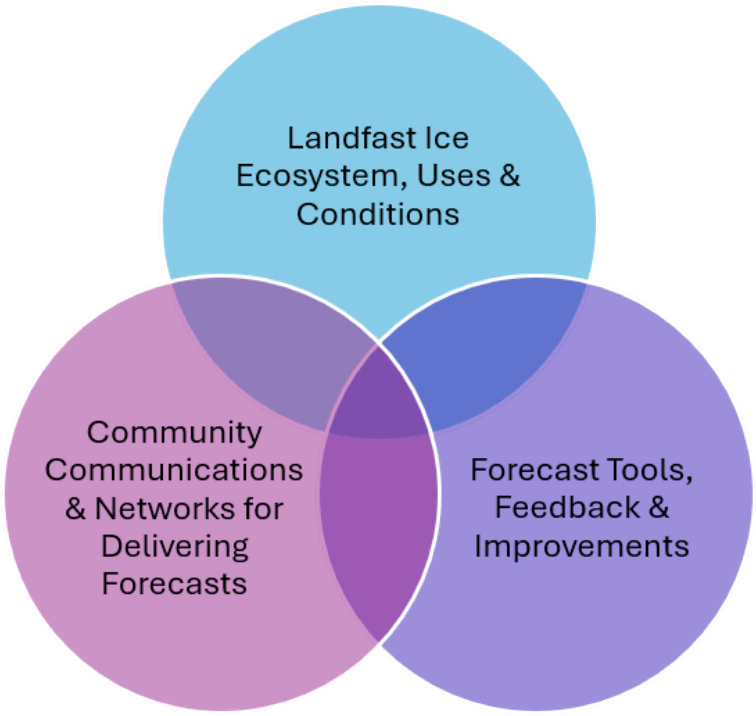


Figure 2. Three major discussion themes from the community workshops.

Landfast Ice Ecosystem, Uses, and Conditions

Landfast Ice Is An Essential Ecosystem for Arctic Communities' Subsistence and Food Security

Workshop discussions highlighted that sea ice, especially landfast ice, is central to Arctic ecosystems, subsistence, and food security in Inuit communities across Alaska. Participants shared landfast ice supports multiple subsistence activities for community food security as a rich habitat for coastal fisheries and marine life. Landfast ice is important for fisheries including, but not limited to, red king crabbing in Nome, gathering of sea peaches in St. Lawrence Island, and fishing for tomcod and blue cod. The ice also supports marine mammal habitats and Inuit harvesting of bowhead and beluga whales, polar bears, walrus, and various seals. The ice also provides areas during subsistence activities to launch and land boats, camp, and/or areas for resting, processing, and/or staging.

The landfast ice ecosystem is a central support for Arctic communities' sustainable subsistence food and economic security, environmental connection, and cultural continuity. Workshop participants expressed that Inuit subsistence is irreplaceable, healthy, and dependent upon sea ice in supporting these activities. Subsistence resources were also noted to be intertwined with and support Inuit arts and tools which had long been important to family and community economic systems as well as cultural identity and expression.

During these discussions, participants shared the growing importance of forecasts among subsistence crews and Arctic communities to plan, coordinate, and harvest more safely by better anticipating conditions of landfast ice, open sea ice, ice movements, and status of travel and access routes involving ice.

- *"We depend upon subsistence which is considered irreplaceable." -Gambell Workshop Participant*

Landfast Ice Supports Seasonal Travel and Marine Access

Workshop participants shared landfast ice supports travel and marine access across established routes with local people commonly crossing several key points to reach the edge of landfast ice or areas like bays, open water, coastal areas, and/or neighboring communities. The landfast ice is used for ground travel by walking, skiing, snowmachine, ATV, and/or dog team for seasonal transportation via winter trails to camps, communities, subsistence harvesting areas, small boat access, areas for small scale commercial fisheries, and/or community events or recreational activities.

During discussions about travel activities, participants shared that seasonal travel via landfast ice also includes individual and community marine access for boat launches/landing areas for subsistence hunting. Workshop discussions on St. Lawrence Island noted community members

often work together to shovel and chop access points to safely reach the edge of the landfast ice to launch boats and pull them back up. Residents may also use these access points to reach areas within a few miles of the community and coast to fish, hunt, gather, and/or crab when conditions allow.

Climate Change is Increasing Ice Safety Issues and Decreasing Subsistence Opportunities

Participants commented on a series of climatic changes over many decades which have significantly altered landfast and sea ice conditions in the U.S. Arctic. Participants have observed that ice formation periods are shorter and result in thinner, softer, less solid ice that is more likely to break apart, wash out, or wear away. Participants also shared observations that both warmer air and water temperatures have degraded ice from the top and bottom.

Workshop participants discussed sea ice is inherently a hazardous environment and Inuit have developed knowledge systems for safety over many generations. Climate changes were noted by participants to cause more hazardous ice environments with critical safety issues. For example in St. Lawrence Island, past sea ice formations had thicker buildup with large icebergs common, compared to today's later-forming ice with fewer and/or smaller icebergs. The landfast ice has become less stable and can quickly degrade due to climate change with thinner layers that can be snow covered – noted by participants to create dangers and travel problems. These modern circumstances often result in unusable landfast ice areas and/or conditions for serious risks of accidents and falling into water among travelers, subsistence providers, and boat crews. Participants also identified larger open leads among ice conditions which can close and quickly trap people in small boats and/or snowmachines while traveling on or among ice.

Due to the less ice and the influences of climatic changes, subsistence providers report lower or missed harvest opportunities, while increasing safety risks to crews by traveling in precarious conditions to reach marine resources. For example, participants in St. Lawrence Island shared subsistence providers must more commonly travel in dangerous open water conditions due to less ice coverage, and transit much further from the village with overnights on the ice or in boats. This exposes crews to greater marine threats such as shifting weather, waves, swells, currents, storms, winds, and new patterns of freeze-up and melt – all which increase life-safety risks to crews and make it harder to know where subsistence resources will be among safe ice or open water. These conditions have increased costs and risks with greater chances of accidents and emergency response situations as crews and families traverse greater distances in very isolated areas.

This has and continues to increase the need for forecasts that cover both landfast ice and open sea ice across expanding travel areas to harvest needed subsistence and cultural resources.

- *"Nowadays, the climate has changed with softer ice, which is dangerous because people could fall right through with snow cover over very thin ice." -Savoonga Resident*

- *"It's hard to predict what's going to happen tomorrow due to climate change and different or more intense weather patterns that come up." -Gambell Resident*

Forecast Tools, Feedback, and Improvements

Indigenous Sea Ice Knowledge is an Essential Forecasting Tool

Discussions among workshop participants highlighted Inuit people have developed scientific knowledge and forecasting of conditions over countless generations in Arctic environments. Participants shared Inuit knowledge, science, and practices of observing environmental indicators as essential methods of understanding ice and weather conditions. These include, but are not limited to, observing ice thickness, cloud ceilings, light reflections, water steam from open leads, wind direction, marine currents, tides, temperatures, and changing weather patterns. This knowledge also encompasses the interrelationships of various related factors like how points on land, sandbars, prevailing currents and waves, and seasonal patterns can affect where ice moves, opens, or builds ridges, as well as recognizing climatic conditions and how those are changing from year to year.

In Arctic communities, Inuit knowledge is vitally important in understanding ice and marine environments over both short- to long-distances, like 10 to 30 miles out. For example on St. Lawrence Island, Inuit watch for bright clouds that indicate abundant ice or large ice structures where subsistence providers can pursue resources, while dark clouds or dense cloud reflections can signal open water, cracks, or areas with little sea ice.

Participants discussed it takes a lifetime to build expert knowledge through identifying and interpreting these indicators by learning both from Elders and field experiences. This represents important cultural and place-based expertise that is essential for navigation, safety, and understanding or anticipating changes in sea ice conditions—before western forecasts based on numerical weather, ocean conditions, and sea ice models became available.

- *"We usually know the change in conditions based on traditional knowledge of the wind and waves before the forecast comes in" -Savoonga Resident*

Importance of Using Both Inuit and Western Knowledge and Tools

When participants were asked which weather and ice forecasting tools they use for information almost all mentioned personal observations and Inuit knowledge blended with radio and TV weather broadcasts, websites, cell phone apps, and/or personal drones. Workshop participants often reference Western data and visuals as complementary with individual and Inuit knowledge sets for anticipating movements and breakups of ice, gauging conditions near launch points and travel routes, and foreseeing blocked routes and/or areas to avoid. These were common examples of using and combining data to assess and determine the environmental conditions and safety before starting, during, and after ice-based or -related activities.

Participants noted the ability to use both Inuit and Western knowledge compiles a much better picture of landfast and sea ice conditions. As climate change makes weather and sea ice conditions more sudden and unusual, Arctic communities are increasingly referencing online satellite imagery and weather apps based upon remote sensing technologies and Western forecasting tools to supplement, but not replace, cultural knowledge for better visualizing and understanding sea ice areas.

Online tools were noted to play an important role in quickly finding and accessing Western information for safely planning travel, subsistence, and community activities. Examples of online tools and data sources already in use among workshop participants included: *NASA World View, GINA Puffin Feeder, Zoom Earth App, Gambell Sea Ice Radar, SIKU, Blue View MXAK, NWS website, and the Windy app*. In discussing these sea ice and weather forecasting tools, workshop participants noted these have become vital to the daily safety of travelers, subsistence providers (hunters, fishers, crabbers, and boat crews), and emergency responders.

- *"Having a tool like the sea ice forecast will give hunters an opportunity to come home safely before sea ice moves and closes in. Give us a chance to see what's going on before it closes in." -Savoonga Resident*
- *"Sea ice forecasts could give us visual information for early detection of the moving ice ahead of us to improve navigation with warnings of potential ice movements and areas where to avoid." -Savoonga Resident*

Opportunities to Integrate Indigenous Knowledge into Forecast Tools and Models

Workshop participants discussed the valuable opportunities to integrate Indigenous knowledge into forecast tools and models. These included the deep environmental knowledge of the Arctic, Indigenous language terms, and placed-based expertise which can advance the understanding of ice behavior, conditions, and interactions like currents, winds, and seasonal patterns. During the workshops, participants shared many examples of Inuit environmental knowledge such as sun dogs, moon rings, and cloud reflections as important weather and/or ice indicators. These were noted not to be recognized or integrated into current Western forecast tools and models.

Within Inuit languages, there are a series of words and terms for ice types, behaviors, and patterns described which simply do not exist in English or Western scientific descriptors. These were discussed as ways that could significantly strengthen both the depth and accessibility of information conveyed by monitoring and forecast tools by using Inuit words. This integration could at the same time promote preservation of Inuit languages within communities for cultural continuity and revitalization.

Review of Forecast Tools for Strengths and Gaps

Workshop participants appreciated the presentation and sharing of weather and forecast tools currently in use and under development. In discussion of strengths, participants noted available tools varied in detail – large scales with hundreds of miles covering large areas but lacking

resolution with local detail (such as NWS), and small scales with high resolution within a few miles of a community area (such ice radar) but lacking large coverage. Workshop participants identified the strengths of the large scale tools for helping to inform broad Arctic ice conditions and patterns. They also shared that ice radar systems in Gambell, Nome, and Utqiaġvik are highly used by communities with high resolution and detailed scale with a range of about 5 miles from the location of radar equipment in the communities. Participants expressed the need to expand radar coverage in additional landfast ice areas as the gap in radar coverage is large in the U.S. Arctic. Additionally, participants noted strengths associated with particular forecast tools or datasets like the date search function in the Zoom Earth App, the true color and night view contrasts on the Geographic Information Network of Alaska (GINA) website, and the ease of use and design of the Windy app for gauging weather conditions and predictions down the road.

During discussion of gaps, workshop participants identified water temperature data, marine and coastal currents directions and speeds, tides, ice thickness, under water ice melt, limited range of ice radar, low resolution of sea ice monitoring systems, limited display of areas that identifies thin ice especially when covered with snow, and limited to very little integration of Inuit knowledge and language. Some participants also discussed missing GPS integration into portable devices to show user locations relative to ice. There was also a gap and need for sea ice forecasts beyond 3-days like 10-14 days in the future.

Community Communications and Networks for Delivering Forecasts

Local Communications and Networks to Consider in Distributing Forecasts

Workshop participants shared that communities utilize and rely on layered communications and social networks to share ice conditions, weather information, and safety updates before, during, and after travel and/or subsistence activities. Participant discussions expressed that today these layered communication networks combine traditional knowledge with public AM/FM radio broadcasts, TV news and weather programs, real-time local and satellite imagery observations, online information from websites and apps, and social interactions via personal exchanges, VHF/CB radios, phone calls/texts and social media. These methods contribute to researching and sharing information on weather and sea ice conditions which are important personal and community considerations in making safe decisions for travel and subsistence activities.

When reviewing communications involving landfast ice, most of the participant discussions focused on networks when boating and marine mammal harvesting. When ice is present, traveling in small boats for subsistence activities is a challenge and climate change has increased those inherent difficulties. Participants in St. Lawrence Island discussed an important network in sea ice communications that includes volunteers and Elders as community observers. They closely watch conditions from their homes or spotting places to monitor ice and environmental conditions, help direct boat crews, and/or provide warnings when changing

weather, winds, and/or ice conditions that could become dangerous to travelers and subsistence activities.

These discussions highlighted the vital importance of ice forecast tools among subsistence boating crews and onshore community observers. For example, workshop participants from St. Lawrence Island shared that there are fewer community observers today, and crews have trended towards a greater dependence on online information and apps, particularly during low visibility periods (such as fog or white out) and nighttime. Participants noted the need for improved ice forecasts that could help in these situations throughout the communication process from planning, transit, and emergency response.

Workshop participants also shared that local boat crews communicate via exchanges (in-person, VHF/CB radio, cell/text) while in the field with other crews to share traditional knowledge and firsthand reports about ice stability, buoyancy, breakage, movement, and changing marine and weather conditions. Participants noted crews often travel and harvest subsistence resources together across large areas, and these communication exchanges are essential for relaying updates to captains, peers, families, and Elders for coordinating decisions, and promoting safety when winds, waves, or shifting ice create dangerous conditions.

Workshop participants also noted the availability of mobile technology in the field with cell phones and portable internet have significantly helped families, hunters, and crews better coordinate, navigate, and support one another in very remote marine and ice environments.

- *“Ways to promote local communication of sea ice conditions with community boat crews. It is critical to see the environmental conditions of the sea ice while boats are pursuing our subsistence marine mammals. Communications are very important to us because when we're helping each other out in very isolated settings. We cooperatively relay information to other people's families because we're harvesting together. The network of community members and hunters is important piece of sea ice forecasts and information.” -Savoonga Resident*
- *“A lot of boats tend to travel together. When they stop, they communicate about the traditional knowledge of the environment including ice conditions or is there any ice that way. Boat crews will communicate about different areas, and they'll tell of the marine environment, or if they get to the ice with reports on the stability, buoyance, ice break, or sporadic conditions of ice depending upon the flow.” -Savoonga Resident*
- *“Community based observers like Elders used to communicate to local boat crews from their homes or gathering spots to help direct hunters, especially when coming home.” -Savoonga Resident*

Changing Technologies Emphasize Digital and Online Social Communications

Discussions during workshops emphasized digital and online communication pathways for receiving up-to-date information on landfast ice particularly via smartphones and web-based platforms. For example, according to St. Lawrence Island workshop participants, VHF/CB radios

were commonly used in the past fifty years and have trended down over time primarily due to costs and availability of community level cell service and high speed Internet. Today, participants noted the community-level growth of online and text communications, web and social media resources, and phone apps.

The increased Alaskan communities' availability, speed, and reliability of Internet infrastructure, with *Starlink* via satellites in particular, has made accessing online sources for weather and ice information very feasible. Participants also noted that the portable *Starlink Mini* is growing in remote use while on the ice, at camps, and/or on boats. Many can now view satellite imagery, check forecasts, and share ice conditions through smartphones and other devices when out in the field while still blending traditional knowledge and real-time firsthand observations to support safe decisions while hunting, fishing, crabbing, and traveling. Because Internet, cell phone coverage, or other digital communication are not always available while crews are far from the village, having accessible visual tools or forecasts in the community to check ice and weather conditions prior to field travel and activities supports safer decision-making on the ice. It was also noted that cell phone coverage remains limited—for example around seven miles near Gambell which can be affected by terrain and/or weather.

Many workshop participants noted the high use of texts and Facebook to communicate. On Facebook there are multiple ways to communicate including village pages and topical groups which support community members in sharing and exchanging updates more broadly.

Workshop participants noted there are Alaskan community inequities in phone and digital communications associated with affordability of the equipment and services. With high poverty rates in rural Alaska communities, many households and individuals have limited or lack reliable broadband Internet, email, and/or phone access.

- *"It's good to have something to look at especially when we don't have much communication. In the past, more of our elders would be observing at home where they would say the weather here, it's coming, the ice is packing up over here, you got to come home. And when we're way out there, we don't have anybody telling us that anymore." -Savoonga Resident*
- *"One needs to recognize access varies among community members like some people don't have access to the Internet, email, or phone services." -Gambell Resident*
- *"Communication is very important to us because when we're helping each other out in very isolated settings. We cooperatively relay information to other people's families because we're harvesting together. The network of community members and hunters is an important piece of sea ice forecasts and information." -Savoonga Resident*

Participant Recommendations

Workshop participants shared important recommendations for enhancing sea ice forecasts and communications across all three workshops. The recommendations can be applied to the CIGLR project as well as broader research and programs with many other entities.

The recommendations are synthesized into three major areas. The first and broadly encompassing recommendation is *Indigenous Knowledge Integration*, followed by *Ice Forecast Model Improvements*, and then *Communications Enhancements with End Users*. These are presented as three distinct recommendations that emerged from these conversations and discussions. Note these recommendations were often intertwined and each major area is considered related and can be built upon the other. This is represented by the stepped nature of the diagram in Figure 3.

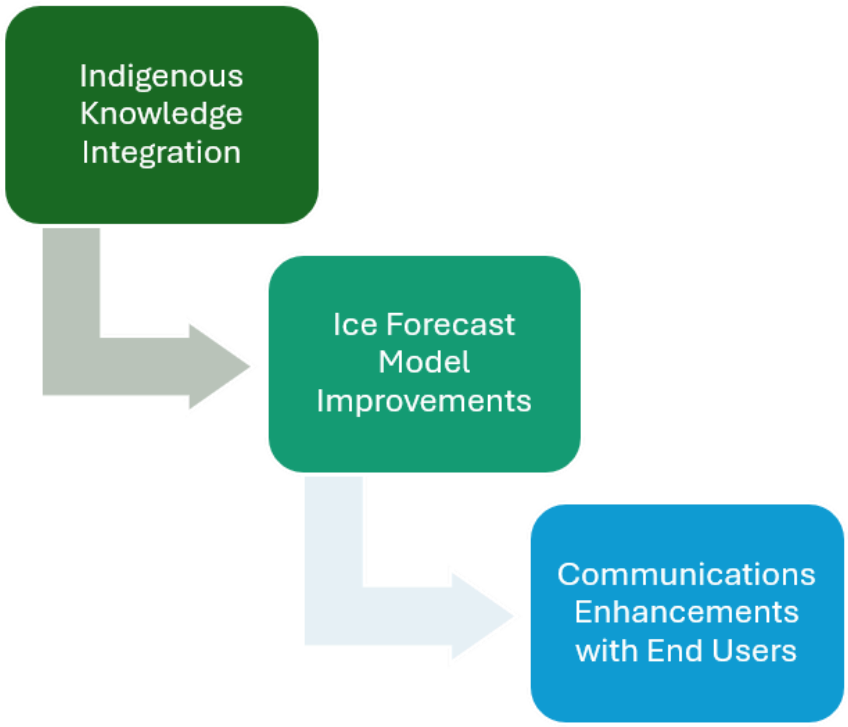


Figure 3. Summary of participant recommendations in three major areas.

Indigenous Knowledge Integration

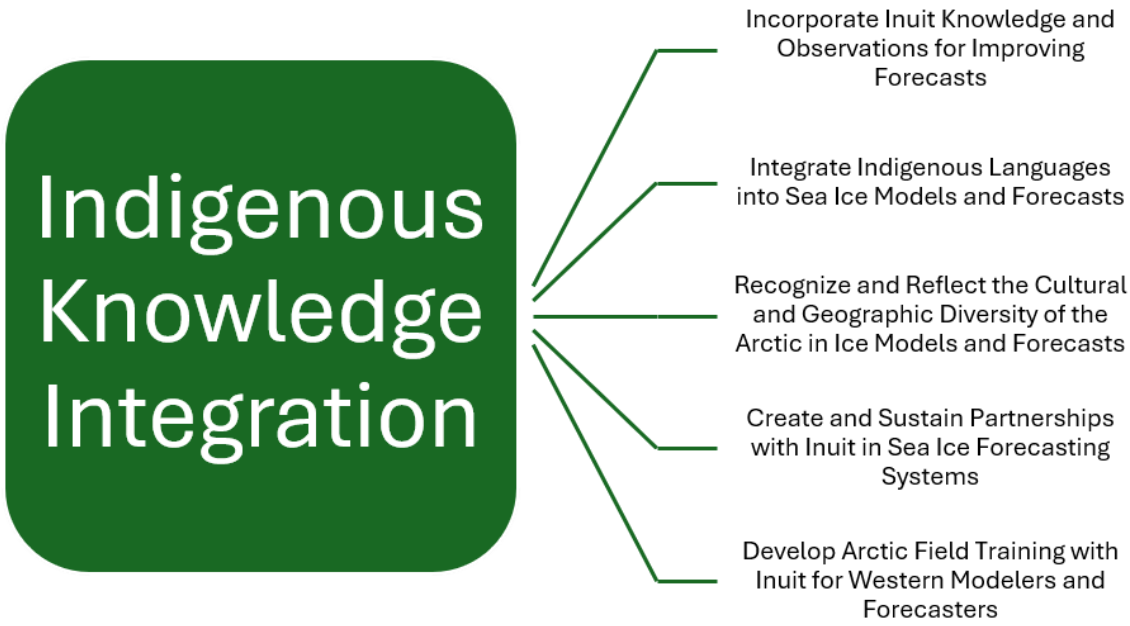


Figure 4. Summary of workshop recommendations related to Indigenous knowledge integration.

Incorporate Inuit Knowledge and Observations for Improving Forecasts

Workshop participants recommended incorporating Inuit knowledge and observations as key inputs to complement and improve sea ice forecast outputs. Both have the potential to significantly strengthen university, state, and federal sea ice forecasts through enhanced data, models, and interpreting of outputs with place-based and deep environmental knowledge of the Arctic that remote sensing and Western science cannot replicate.

Workshop participants discussed that Inuit science of ice is intergenerational and learned from Elders and experienced hunters, fishers, crabbers, and travelers. This knowledge is developed over lifetimes through firsthand field experiences, subsistence activities, and applied knowledge in Arctic environments. This knowledge and data can enrich existing Western data and fill-in gaps to better model, forecast, and categorize multiple ice conditions. It can also expand understanding and/or complement descriptions of complex ice interactions such as but not limited to the influences of winds, swells, currents, ice movements like crashing and piling, and different ice types such as heavy ice, pancake ice, and landfast ice.

Participants noted that Indigenous knowledge includes environmental indicators which are generally not considered in Western models and forecasts. These included observations of the sun, moon, clouds, animal behavior, ice color, and various ice types. Workshop participants also discussed that local knowledge and observations of ice conditions from various Arctic

communities could be gathered over the previous 24–48 hours, as well as ongoing monitoring across the season from freeze-up through early summer to provide important details about ice formation, thickness, thinning, stability, movement, and other local conditions among high use subsistence use areas and travel routes.

- *"How do you facilitate blending of Indigenous and Western sea ice knowledge? Recognize the change in generations and the whole life experience it takes for Indigenous knowledge. The transfer of Indigenous knowledge across generations incorporated especially for those that use the sea ice for hunting, crabbing, fishing, and travel." -Gambell Resident*

Integrate Indigenous Languages into Sea Ice Models and Forecasts

Workshop participants recommended integrating Inuit languages into sea ice models and forecasts for increasing accuracy with terms, words, and descriptors while also supporting improvements in community communications. As background, many Inuit words and terms of various types of ice do not exist in English and provide descriptions for at least 90 conditions and/or status of ice.

This important linguistic and cultural data can directly translate into refinements of scientific categories, presentation of conditions, and enhance forecast communications by describing more detailed characteristics and conditions. Incorporation of Inuit languages, and the embodied cultural knowledge, can greatly expand the vocabulary among scientists and researchers for improving forecast model concepts and products with highly detailed descriptions and terminology of sea ice. This will also help better communicate ice descriptions, predicted conditions, and forecasts with Inuit communities including place names on maps.

The following are a few examples of Iñupiaq words/descriptors from the book *Kiŋmi Sigum Qanuq Ilitaavut - Wales Iñupiaq Sea Ice Dictionary (Arctic Studies Center, Smithsonian Institution, 2007-2008)* by Winton Weyapuk, Jr. and Igor Krupnik (compilers).

- Auksaaniq: hole melted into or through landfast ice or floe ice.
- Ikalitaq: ice floe grounded in shallow water (usually refers to smaller floes).
- Itiġliq: large opening in landfast ice, such as a bay or cover; also refers to the end of a lead with landfast ice on one side on the other. Literally translated into English as "a place you can enter."
- Mituglak: surface of landfast ice or pack ice that has been changed by rain from a smooth surface to a rough surface with ice crystals.

During the workshop discussions, St. Lawrence Island Yupik words were shared to demonstrate the terms of ice types, formations, and reflect Indigenous knowledge of the environment supporting safe boating, hunting, and subsistence access. These included the following by workshop participant Edwin Noongwook:

- Qerngaayaak: when the ice is packed. Any recognizable ice that is packed.
- Iighwilnguq: a large pan of ice. Any type of a large pan of ice; observably, a wide pan of ice.
- Ugla-avet/uglafqaa: scattered ice; when the ice moves apart from each other. The ice scatters apart, this can happen when there are calm winds and ocean. Currents and ocean dynamics can become active, even in calm winds.

Participants stated these and up to 99 other Yupik words and concepts for ice were readily available as documented in the book *Watching Ice and Weather Our Way (Arctic Studies Center, Smithsonian Institution, 2004)* by Conrad Oozeva, Chester Noongwook, George Noongwook, Christina Alowa, and Igor Krupnik.

Workshop participants also noted the recommendation for incorporating Inuit languages will also support intergenerational knowledge transfer and encourage younger generations to continue using Inuit sea ice terminology in today and the future.

- *"Recognize the knowledge of Elders and change in Arctic lifestyles affecting transfer of Indigenous knowledge and need to create ways to share in communities including Native words, taking out to the sea ice environment." -Savoonga Resident*
- *"For example, several years ago, somebody collected about a hundred different names of ice conditions that we observe here in St. Lawrence Island." -Gambell Resident*

Recognize and Reflect the Cultural and Geographic Diversity of the Arctic in Ice Models and Forecasts

Participants recommended ice models and forecasts to reflect and incorporate the diversity of the U.S. Arctic. During the discussions, participants noted the large size of the Alaskan Arctic with miles of coastline, distinct land and sea features, and various landfast ice conditions. Participants also noted the diverse Inuit uses of landfast ice which are influenced by dimensions of unique geographies, local climate, available subsistence resources, and village cultures.

Workshop participants noted the number of villages spread over different regions of Alaska which contribute to the local knowledge and uses of landfast ice based upon the community and land use areas, coastal environmental conditions, micro-climates, cultures, and/or range or availability of subsistence resources. For example during the workshop discussions participants noted some of the differences in bowhead whaling from Utqiaġvik to St. Lawrence Island which is influenced by specific climates, locations, timing of the harvests, stability of landfast ice, and community cultures. This diversity informs broader Inuit knowledge which should be recognized by agency and forecast partners in interpreting localized Arctic conditions, designing communications of various and unique uses of landfast ice, and validating ice model outputs across geographies.

Workshop participants also discussed the linguistic diversity across the U.S. Arctic, including Inuit languages and dialects. There are four major Inuit language groups of the U.S. Arctic:

Iñupiaq, St. Lawrence Island Yupik, Yup'ik, and Cup'ik. The language groups can have various dialects based upon communities and regional areas which are often reflected in place-based Indigenous knowledge of the marine and land environment.

- *"Acknowledge the number of languages and dialects in the Arctic which also help inform sea ice knowledge specific to regions and communities." -Nome Participant*

Create and Sustain Partnerships with Inuit in Sea Ice Forecasting Systems

Workshop participants discussed recommendations for agency and university partnerships with Inuit experts as active co-researchers and sustained staff or consulting positions for comprehensively improving forecast models and systems in their design, interpretation, validation, and communication—not only as data contributors after the fact. As part of this recommendation, Inuit knowledge holders should be paid and included as co-principal investigators (PIs), research staff members, project advisors, and/or consulting experts with acknowledgements of the deep knowledge of the environment which contribute to projects and ongoing work. Ensuring the compensation of Inuit knowledge holders is key to sustaining involvement and honoring valuable knowledge in research and forecasting. Note that this knowledge is rarely found in a single individual; therefore more than one staff position with peer contributors will be needed from various communities with plans to compensate for their involvement as Inuit Elders, hunters, crabbers, fishers, and other active sea ice users or knowledge holders.

Based upon creating and sustaining these Arctic community partnerships and positions, researchers and agencies can develop needed and long-term professional work relationships with Inuit to incorporate Indigenous languages and cultural knowledge of sea ice science, processes, and behaviors. Overall, this can significantly improve forecast models and tools, ice descriptions, advisories, maps with Inuit place names, forecast communications, and presentation of information by integrating Inuit expertise of ice types, behaviors, travel conditions, and subsistence-use areas.

Overall, participants recommended that significant improvements in sea ice modeling and forecasting will require the development and commitment to sustain Inuit partnerships which recognize the expertise with unique scientific worldviews brought to projects and products with new opportunities to better shape sea ice forecasting pathways from research design through public communication.

- *"At the village level, we sacrifice our input and the Elders know a lot. For example, several years ago, somebody collected about a hundred different names of ice conditions that we observe here; but make sure it's not at our expense. We live in a different world now where we're more cognizant of sacrificing a lot of our million-dollar questions." -Gambell Resident*
- *"This knowledge is valued and should be cited as well as compensated for use." -Gambell Resident*

Develop Arctic Field Training with Inuit for Western Modelers and Forecasters

Workshop participants recommended that Western modelers and forecasters should spend time in the field to learn with Indigenous experts about the ice environments they are modeling. Both short- and long-term term field experiences are needed with Inuit experts to promote collaboration and advance applied knowledge integration with modelers and forecasters on local ice processes over many seasons. For example during the workshop discussions, participants from St. Lawrence Island shared how southwest winds and currents around Gambell Point or west of Savoonga affect ice movements and conditions.

Workshop discussions also raised recommendations for agencies (such as NOAA, FAA, and others) to improve their coordination with Inuit organizations and communities in the installation and operations of Arctic weather stations, ice radar, and monitoring systems. This will require funding to support stronger community involvement and collaborative approaches to infrastructure, such as regional hub offices that connect many stakeholders like federal agencies, Tribal governments, regional Tribal nonprofits, universities, and local community members around sea ice research, forecasts, weather, and communication.

These efforts should also include Indigenous college students, especially through the University of Alaska system. These students can benefit from applied learning in the field with Inuit experts for building local Arctic capacity in sea ice research, forecasting, and communication.

Ice Forecast Model Improvements

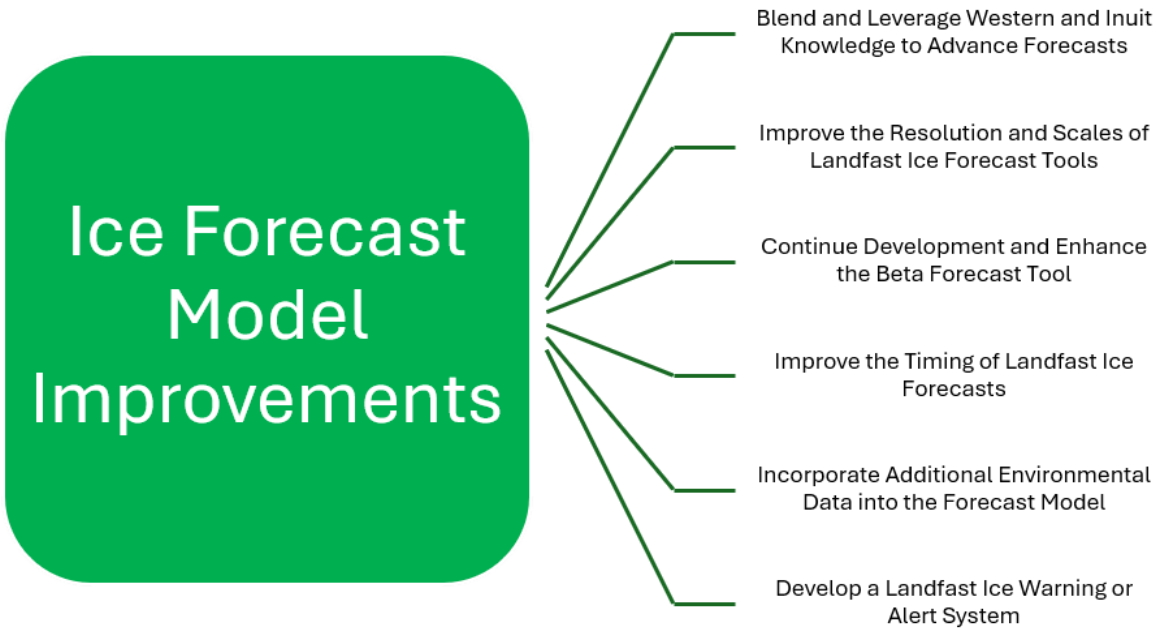


Figure 5. Summary of workshop recommendations related to ice forecast model improvements.

Blend and Leverage Western and Inuit Knowledge to Advance Forecasts

Participants recommended updating approaches in ice research, modeling, and forecasting to blend and leverage Western and Inuit knowledge which can greatly complement and advance overall systems for understanding, modeling, and promoting safety on the ice.

During workshop discussions, participants highlighted both the differences and strengths in Western and Inuit knowledge of sea ice. Western knowledge and modeling are generally based upon remote sensing and monitoring data with staff and researchers based outside of the Arctic and utilizing academic and scientific methods with little lived experiences in the Arctic. These data inputs primarily depend upon satellite imagery and sensors for temperature, wind, currents, tides, and weather data. Inuit knowledge and modeling are generally based upon lifetimes of firsthand coastal monitoring and environmental observations with long-term intergenerational experiences of people living in the Arctic and using ice. These data inputs primarily depend upon direct field experiences along the coastal and sea areas, multiple seasons of observations, and understanding the Arctic weather, currents, tides, winds, temperature, snow, ice, and other environmental conditions.

Blending and leveraging the two knowledge sets represents a great opportunity to improve data and this approach is currently underutilized. This can lead to significant improvements in ice models, forecasts, and monitoring to be more accurate and relevant while helping agencies,

researchers, and communities better understand how Arctic sea ice behaves. By comprehensively co-working with Inuit experts as active partners in approaches that honor and include cross-cultural integration of knowledge sets, this will facilitate important updates among agency-university research, design of tools and products, and lead to better models and outputs.

For example, currently NOAA's products of numerical ocean and sea ice forecast guidance for marine navigation are designed by Western agencies to meet the user requirements from commercial and recreational mariners, port authorities, operational forecasters, marine educators and researchers, search and rescue, manufacturers of marine navigational systems, and offshore wind energy operators[1]. The ongoing design of Arctic sea ice forecast guidance for marine navigation will require a new involvement of Arctic users to meet their requirements as stated above plus subsistence and ice based travel activities. The engagement and integration of Inuit into these efforts are important to coordinate knowledge and address community to regional needs. This will be integral for operational Arctic sea ice forecast products to be improved, actionable, and usable by and with Inuit, Alaskan communities, and existing stakeholders. The engagement process with cultural knowledge holders in identifying and forming the user requirements will be different from the "typical" marine stakeholders, and will naturally require reasonable compensation and credits for the cultural knowledge holders and Inuit experts.

- *"At the village level, we sacrifice our input and the Elders know a lot. but make sure it's not at our expense. We live in a different world now where we're more cognizant of sacrificing a lot of our million-dollar questions." -Gambell Resident*
  [Note: comment on the equity of western and traditional knowledge as well as the compensation of Indigenous knowledge holders in research and projects.]

Improve the Resolution and Scales of Landfast Ice Forecast Tools

Workshop participants recommended improving the resolution and scale of landfast forecast products and tools particularly in high use community and subsistence areas.

During workshop discussions, participants noted the existing scales of weather and ice monitoring systems. Western models often operate at broad regional scales (basin-scale coverage at 10^0-10^1km resolution) based upon remote sensing data. While Inuit knowledge is at the community, coastal, and subsistence-use scale where people travel, hunt, fish, crab, and launch small boats (specific local sites, at 10^2m-10^0km scale). Indigenous experts could be included in modeling approaches and project teams to help "data truth" or ground-check model outputs through field observations, traditional knowledge, and cross cultural discussions of

[1] Seroka, G., Kelley, J., Sienkiewicz, J., Seaton, C., Anderson, E.J., Allen, A., Forbes, C.,Fujisaki-Manome, A., Haas, K.A., Lindley, C., Roman, D., and Weston, A. (2022), UnifiedForecast System (UFS) Coastal Applications Team - Water Quantity Marine Navigation Sub-Application Tiger Team: Report, NOAA Technical Memorandum, NOS(34), 1–27. https://doi.org/https://doi.org/10.25923/x7zr-nj33

recent and expected conditions, including larger climate patterns such as El Niño/La Niña, storms, and typhoons.

As part of this recommendation, participants also discussed the development of useful landfast ice forecast products and tools to include a wide Arctic to local community scales for multiple views of the marine environment, weather, and ice patterns. In regards to wide scales, workshop participants discussed the need to track storms from the south such as those forming around Japan which influence wave action, ice movements, and influence diminishing ice stability through warmer temperatures and south winds. Participants also discussed the need to track northern ice movements from Siberia like Anadyr Bay and the Alaska North Slope.

Overall, forecast products and tools should help predict and present landfast ice stability with high resolution and provide ways to zoom out and in (or broad to local scales) for monitoring and anticipating ice movements so residents and communities can make safer decisions about when and where to travel, fish, crab, and/or hunt marine mammals. By bringing these scales and resolution capabilities together with advances in remote monitoring and partnerships with Inuit there can be improved ice forecasting systems to inform community-level based “go/no-go” subsistence and travel scenarios, issue advisories that are relevant for travelers like local small boat crews, and support scalable maps that allow users to interpret local and broad impacts.

Continue Development and Enhance the Beta Forecast Tool

Participants discussed recommendations for continuing development and enhancing the beta forecast tool with options and features to support safe travel and community subsistence activities. After viewing the beta forecast tool, participants recommended display improvements such as the ability for users to see the data numbers in addition to the forecast visual, reducing the size of wind vector arrows, adding marine current vector arrows, adding the ability to see high and low tides for gauging the daily influences, adding contrast color options to better view ice and water, and ensuring the website is formatted for viewing with smart phones. Participants also recommended the beta tool maps to have enhanced abilities to view the coastal outlines with the location and structure of landfast ice around communities, bays, river drainages, points, trails, boat launch areas, and subsistence use routes.

Workshop participants recommended additional basemap options when viewing forecasts such as topographic, realistic and other satellite imagery options, and/or marine charts. These options can better present ice forecasts with characteristics in relationship to communities that can help identify known ridging in shallow areas, thin ice covered with snow, and the location of leads or open water. During the UAF GINA presentation, there were a number of satellite imagery products reviewed like the snow/cloud discriminator, snowmelt RGB, microwave products, and mosaics – which each can be helpful as basemap options.

The participants also would like abilities to choose or toggle among imagery and base maps, view ice history of areas, see real-time information with frequent (hourly) forecast updates, and clear details about the forecasted ice stability, movement, and access conditions.

Improve the Timing of Landfast Ice Forecasts

Participants recommended landfast ice forecasts with hourly or near-hourly updates because winds and currents can create swift movements and warming trends can weaken landfast ice quickly. They emphasized these shorter and regular timeframes to track ice speed, direction, breakup, leads, openings, and changes along coasts and the ice edge. They also recommended forecasts to focus on time periods of late winter to early summer, the most dangerous periods which are also important for landfast ice subsistence activities.

Workshop participants also recommended abilities to view past ice formations and movements for comparisons between short-term and historical periods. The short-term periods of the past 5-7 days or four weeks can inform local decision-making as it often depends on comparing this recent history of ice behavior with current and forecasted conditions. The historical periods can help view past “normal” ice conditions to current conditions which can help gauge changing patterns.

Incorporate Additional Environmental Data into the Forecast Model

Workshop participants recommended incorporating additional environmental data into landfast ice models to improve forecast capabilities and reliability with factors known to influence the formation and stability of ice. Relevant data recommended by participants included near shore bathymetry, marine currents, winds, waves, tides, ocean swells, water surface temperatures, river drainages, warm weather spells, rain, low-pressure systems, and storms.

During discussions, participants highlighted warm spells during ice formation, mid-winter, and spring are important to monitor and incorporate into modeling of landfast ice forecasts. During mid-winter and spring, these warm spells are often associated with storms, blizzards, and rain which drive sea ice changes including melt. Participants also noted rains “rot” the ice and the monitoring and predicting of precipitation will be an important factor to incorporate into models.

Participants also discussed the environmental influence of currents (surface, upwelling, and deep sea) and tides in sea ice conditions and forecasting. They recommended including the marine currents with vector displays as well as displaying the daily high and low tides for gauging these influences.

Coastal land features are also important to incorporate into Arctic landfast ice maps, conditions, and forecasts. Discussions included the bathymetry of the near shore and identifying sand bars, rivers, and other land features which influence the ongoing formation, ridging, and break-up of ice. For example, the mapping and modeling of river drainages are important as fresh water flows affect landfast ice stability.

Develop a Landfast Ice Warning or Alert System

Participants recommended developing a warning or alert system for anticipating landfast ice movements and breakouts/break up[2]. This could be an important system for injury prevention and emergency preparedness that could save lives and reduce accidents. This would also aid travelers and subsistence providers by facilitating safe adjustments to plans and updating navigation around leads, ice cakes, and other conditions.

As climate change has made ice and Arctic weather more unusual, these forecast tools are increasingly seen by participants as needed resources for safe travel, subsistence, and navigation among landfast ice conditions which can become overly dangerous. Workshop participants encouraged enhanced forecasts to support, develop, and interface with warning and alert systems for improving local navigation, supporting emergency response, helping crews plan and return safely, and anticipating ice movements that could close or cut off access to safe travel routes.

[2] Breakout is defined as mid-season landfast ice detachment, and break up is defined as end of the season detachment.

Communications Enhancements with End Users

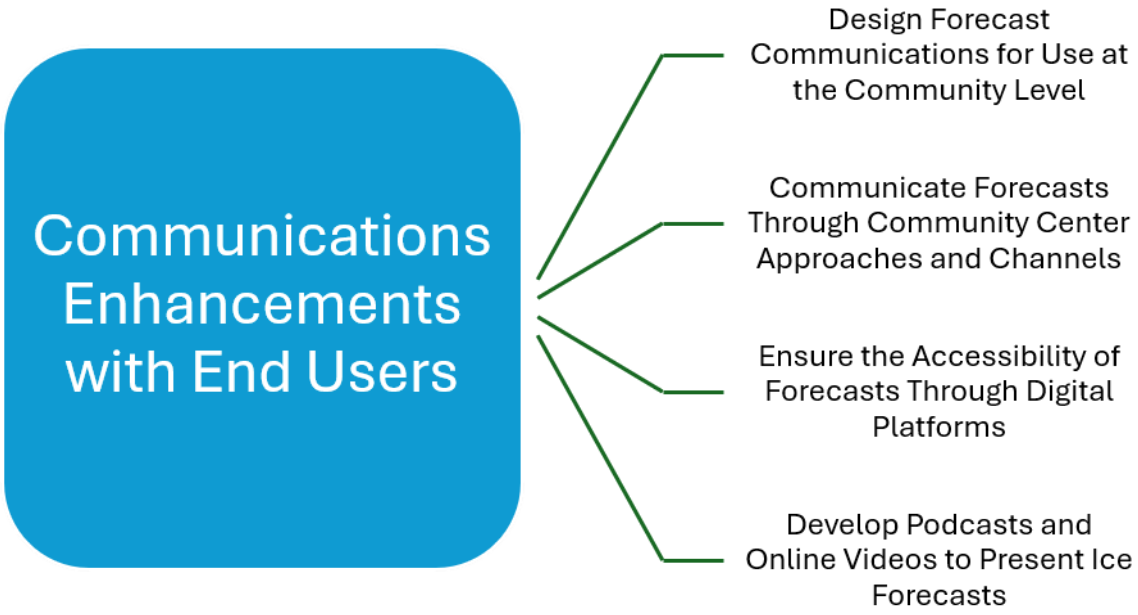


Figure 6. Summary of workshop recommendations related to communications enhancements with end users.

Design Forecast Communications for Use at the Community Level

Workshop participants recommended the project to design forecast communications in understandable terms for use at community levels across Alaska. This will require the project to develop communications for non-specialists and provide clear visuals with plain-language explanations and Inuit language terms for ice types and conditions. This would help to ensure the usability of the information and promote communication among end users like subsistence crews and ice travelers.

Participants also recommended ways to explain the beta tool variables for end users to understand the representations in the ice forecast model, where information is coming from, and what is included in the models for best interpreting and using the product. For example, if winds, tides and water temperature are included, and how the ocean current is or is not included.

Communicate Forecasts Through Community Center Approaches and Channels

Workshop participants recommended forecast communications should be continuous and presented through community centered approaches. They recommended sharing forecasts and updates through trusted Arctic media channels at both local and regional levels such as daily VHF/CB announcements with individual villages, public AM/FM radio broadcasts, community

newspapers, quarterly Arctic organization newsletters, and direct outreach through community, regional, and subsistence forums.

In regards to community, regional, and subsistence forums, these can build awareness of the forecast products and strengthen dialogue with end users for ongoing improvements. Participants recommended such forums be coordinated with existing meetings and workshops which could offer follow-up communications and facilitate the involvement of agencies and research organizations.

Participants also recommended the project to continue organizing and hosting workshops with hybrid options on ice and forecasts such as the Nome workshop. This workshop was noted to be successful in bringing various ice researchers and agencies together with community members and subsistence providers. The workshop promoted meaningful exchanges of current and future projects with opportunities to hear research and Indigenous perspectives. Participants also recommended scheduling informal community meeting options in the evening with door prizes and food so subsistence providers and other working community members can participate.

Ensure the Accessibility of Forecasts Through Digital Platforms

In the workshops, participants recommended delivering landfast ice forecast information through digital platforms commonly used by Arctic residents which can promote wide access and sharing among communities. Participants also recommended publishing digital information on publicly accessible websites and digital platforms without pay walls or subscription costs.

Participants highly recommended a free website with companion use of social media in communicating information, particularly via Facebook which has become a very usable and accessible source of information. For example, the *“Seward Peninsula/Bering Strait Weather and Climate Info”* Facebook group created and maintained by the Alaska Climate Research Center was cited by participants as an accessible source of data which is relevant and followed by many residents (2.1k members as of August 2026). This Facebook group shares weekly posts on regional weather and climate data published by the Center with companion weekly radio broadcasts on KNOM and columns in the Nome Nugget Newspaper. The online group allows members to reshare or message group posts, comment on posts for dialogue, and share their own posts. This could serve as a model to this project and/or provide an existing digital platform to partner with for sharing landfast ice forecasts based on cross organization collaboration.

Workshop participants also recommended the project to develop a free smartphone app for delivering landfast ice forecast information. This would promote quick mobile reference with one click on a phone as well as allow push notifications to users. Participants recommended modeling after the *Windy, Alaska Weather Source,* and/or *Zoom Earth* apps based upon familiarity and abilities for users to combine real-time local observations with digitally published information on the ice, winds, tides, and weather. The app for the project could also include

features for the end user to share real-time field observations via written comments, audio recordings, pictures and/or videos.

Workshop participants also supported the development of regular email and text messages to communicate forecast information. Participants mentioned *Thrill Share as* an example of text messages by area schools to regularly share news, updates, and information with community members.

Develop Podcasts and Online Videos to Present Ice Forecasts

Workshop participants recommended the development of podcasts and online videos to present forecast information. Participants saw these as important and accessible ways to present information verbally for promoting local residents to understand forecasts and then share the information in communities among peers. These could also be helpful in providing tutorials and explanations of the website and forecast tools to orient new users.

Podcasts were recommended via a seasonal daily or weekly format and envisioned as an audio program to share ice forecast information as a companion to the website and app. The podcast could also involve Arctic communities through guest appearances with village representatives, Elders, and/or subsistence providers for sharing Indigenous and traditional knowledge of sea ice.

Workshop participants also recommended the future development of a YouTube program and/or channel for Alaska weather and ice forecasts (instead of just websites). Participants highlighted the usefulness of the discontinued TV program *Alaska Aviation Weather* which was publicly broadcast on the Alaska Rural Communication Service (ARCS-TV, https://arcstv.org/). They recommended this program as a model for combining visual and oral presentations of climate conditions on maps and explaining the factors of ice forecasts. Participants also recommended creating program segments with guests featuring ice topics and cultural knowledge of the environment and subsistence activities. Participants again recommended this as a free program or channel to promote community access online, versus a subscription fee.

Conclusion

Across all three workshops, participants discussed that landfast ice is not only a physical feature of Alaska's coasts, but an important ecosystem and foundation of Arctic food security, safety, Inuit cultural continuity, and community well-being. The workshop discussions clearly identified climate change has accelerated Arctic sea ice loss with more dangerous and unusual conditions. This has increased the need for accurate, accessible, and culturally grounded short-term ice forecasts.

During workshop discussions, the participants recommended that meaningful development of landfast ice forecasting requires both Western scientific innovation and partnerships with Inuit in Arctic communities. Participants consistently highlighted that Inuit environmental knowledge—rooted in generations of lived experience, observation, and language—provides essential insight into ice behavior, patterns, and safety indicators that Western models alone cannot capture. They also emphasized that blending these knowledge systems produces more accurate, more relevant, and more trusted information for all users.

Input and feedback from the three workshops pointed to three major recommendations for future development and best approached as collaborative endeavors: *Indigenous knowledge integration, ice forecast model improvements, and communications enhancements with end users.*

Overall, the workshops underscored that improving landfast ice forecasting is not only a scientific endeavor —it supports efforts for community safety, food security, and cultural preservation. The discussions and recommendations shared by participants offer a path forward with forecasts that must be accurate, localized, culturally informed, and accessible to the people in the Arctic who rely on them most.

Next steps for the project should focus on expanding Arctic community engagement, maintaining relationships with the three participating communities, and refining the beta sea ice forecast tool based on workshop feedback. As funding allows, the team could hold additional workshops in other Alaska coastal communities to better understand the range of local sea ice conditions, subsistence uses, communication needs, Indigenous knowledge systems, and tool preferences. At the same time, continued engagement with the original communities will be essential as the beta tool develops, including sharing updates, gathering additional feedback, and creating opportunities for residents to test and respond to new beta tool features. The project team can also use workshop feedback to make targeted edits and improvements to the beta tool for end user usability and usefulness.

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- Indigenous knowledge holders for sharing workshop presentations and networking with the project: Gerald Oxereok, Alaska Nannut Commissioner, Wales; Edwin Noongwok, Native Village of Savoonga; Orlin Booshu, Sr., Native Village of Gambell; and Bivers Gologergen, Subsistence Provider, Nome.
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Appendix A: Workshop Agendas

NORTHWEST PLANNING LLC

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COMMUNITY WORKSHOP

ENHANCING ALASKA SEA ICE FORECASTS

LOCATION: **GAMBELL QERNGUGHVIK / Q BUILDING**

DATE: Wednesday, February 25, 2026

TIME: 1:00 PM to 3:30 pm

I. WELCOME & OPENING

- Project Overview
- Workshop Values: Safe Space, Participation, & Creativity.
- Introductions
  - English & Heritage Names
  - What is your favourite ice related activity?

II. CURRENT SEA ICE FORECASTING TOOLS & MODELS

- **Current sea ice forecast tools**
  - National Weather Service: https://www.weather.gov/afc/ice
  - Sea Ice Research Group at UAF Geophysical Institute: https://seaice.alaska.edu/coastal-ice-observations/gambell/
  - Sea Ice Walrus Outlook: https://aoos.org/networks/sea-ice-for-walrus-outlook/
- **Beta online version of the project sea ice forecast:** https://live-seas-alaska-sea-ice.pantheonsite.io/

III. COMMUNITY INPUT & RECOMMENDATIONS TO ENHANCE SEA ICE FORECASTING

1. Sea ice forecasting tools & models
2. Communities' sea ice activities & uses
3. Recommendations to better include Indigenous sea ice knowledge

IV. CLOSING & NEXT STEPS FOR HELPING THE PROJECT

- Timeline for the next steps
- Workshop in Nome April 16-17, 2026, at the Northwest Campus
- Project contacts
- Door prize drawing (based upon workshop sign-in)

NORTHWEST PLANNING LLC

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COMMUNITY WORKSHOP

ENHANCING ALASKA SEA ICE FORECASTS

LOCATION: **SAVOONGA MULTIPURPOSE BUILDING**

DATE: Tuesday, February 24, 2026

TIME: 1:00 PM to 3:30 pm

I. WELCOME & OPENING

- Workshop Values
- Project Overview
- Introductions

II. CURRENT SEA ICE FORECASTING TOOLS & MODELS

- **Current sea ice forecast tools**
  - National Weather Service: https://www.weather.gov/afc/ice
  - Sea Ice Research Group at UAF Geophysical Institute: https://seaice.alaska.edu/coastal-ice-observations/gambell/
  - Sea Ice Walrus Outlook: https://aoos.org/networks/sea-ice-for-walrus-outlook/
- **Beta online version of the project sea ice forecast:** https://live-seas-alaska-sea-ice.pantheonsite.io/

III. COMMUNITY INPUT & RECOMMENDATIONS TO ENHANCE SEA ICE FORECASTING

1. Sea ice forecasting tools & models
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3. Recommendations to better include Indigenous sea ice knowledge

IV. CLOSING & NEXT STEPS FOR HELPING THE PROJECT

- Timeline for the next steps
- Workshop in Nome April 16-17, 2026, at the Northwest Campus
- Project contacts
- Door prize drawing (based upon workshop sign-in)

NORTHWEST PLANNING LLC

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NOME WORKSHOP

IMPROVING ALASKA SEA ICE FORECASTS

LOCATION:	**GRAND HALL AT THE NORTHWEST CAMPUS** **400 EAST FRONT STREET, NOME** **OR ZOOM** **HTTPS://US06WEB.ZOOM.US/J/88109000992?PWD=CJ2IOVZPILL8IX1AKEPXJH4K2TL7J7.1**
DATES & TIMES:	**Thursday, April 16 1 pm to 4:30 pm AKDT** **& Friday, April 17 8:30 am to 1 pm AKDT**

DAY 1: THURSDAY, APRIL 16

1:00 – 1:10 PM OPENING & REGISTRATION

- Doors open, sign-in & coffee

1:10 – 1:30 PM WELCOME & WORKSHOP OVERVIEW

- Opening & Words of Welcome
- Workshop Values: Safe Space, Participation, & Creativity.
- Project Overview
- Participant Introductions: English & Heritage Names, Organization

1:30 – 3:15 PM CURRENT ALASKA SEA ICE DATA & TOOLS

- Presentations: forecast/monitoring services & projects
  - National Ocean Service, Greg Seroka
  - U.S. Army Corps of Engineers, Jonathan Waddell
  - National Weather Service, Mike Lawson
  - Alaska Ocean Observing System, Lisa Sheffield Guy
  - Alaska Center for Climate Assessment & Policy, Rick Thoman
  - Geographic Information Network of Alaska (GINA), Jennifer Delamere
  - Sea Ice Research Group at UAF Geophysical Institute, Andy Mahoney
- Presentation: sea ice forecast beta version, John McClure & Ayumi Fujisaki-Manome

3:15 – 3:25 PM AFTERNOON BREAK

3:25 – 4:30 PM PARTICIPANT INPUT & RECOMMENDATIONS TO ENHANCE COLLABORATION

- What do you like best about these tools?
- What do you wish could be improved in those tools?
- How can the beta version of the project sea ice forecast be improved?
- What sea ice information gaps do we still see?
- How can we better foster collaboration between communities, agencies, tools and forecast programs to improve overall abilities to present information around Alaska sea ice?

4:30 PM ADJOURN DAY 1

DAY 2: FRIDAY, APRIL 17

8:30 – 8:45 PM WELCOME & REFLECTION

- Door open, coffee
- Welcome & reflections on day one

8:45 – 10:15 AM INDIGENOUS SEA ICE KNOWLEDGE

- Presentations: Indigenous sea ice & environmental knowledge
  - Gerald Oxereok, Alaska Nannut Commissioner
  - Edwin Noongwok, Native Village of Savoonga representative
  - Orlin Booshu, Sr., Native Village of Gambell representative
  - Bivers Gologergen, Subsistence Provider

10:15 – 10:30 AM MORNING BREAK

10:30 – 11:45 AM PARTICIPANT INPUT & RECOMMENDATIONS TO IMPROVE SEA ICE FORECASTING

- What community activities & uses could benefit from improved sea ice forecasts? Such as subsistence, emergency response, business, and community planning.
- How can Inuit sea ice knowledge & real-time observations better supplement agency sea ice forecasts & monitoring tools?
- What are ways forecast systems & models can better & comprehensively include Inuit sea ice knowledge?
- How can we ensure sea ice tools & forecasts actively reflect & honor Inuit cultures?
- What are ways to promote ongoing partnerships with Inuit communities in enhancing sea ice forecasting & improving overall abilities to present information around Alaska sea ice?

11:30 – 1 PM LUNCH, CLOSING & NEXT STEPS FOR HELPING THE PROJECT

- Lunch onsite
- Closing participant reflections
- Project next steps & host closing comments

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