Experts Workshops to Comparatively Evaluate Coastal Currents and Ice Movement in the Northeastern Chukchi Sea

Workshop Report

with contributions on Iñupiaq knowledge of currents and ice from the following experts from the communities of Barrow, Point Lay, Nuiqsut, and Wainwright, Alaska: Billy Adams, Linda Agnassaga, Ransom Agnasagga, Raymond Aguvluk Jr., Ben Ahmaogak Jr., Mary Ellen Ahmaogak, Roy Ahmaogak, Cora Akpik, Max Akpik Sr., Marjorie Angashuk, Jim Allen Aveoganna Jr., Frank Bester Jr., Lewis Brower, Fred Ekak, Craig George, Charlie Hopson, Nora Itta, Artie Kittick, Joe Mello Leavitt, Alva Nashoalook Jr., Eli Nukapigak, Thomas Nukapigak, Tommy Olemaun, Margaret Opie, Billy Oyagak, Enoch Oktollik, Ronald Oviok, Ida Panik, Jack Panik, Billy Blair Patkotak, Rossman Peetok, Julius Rexford Sr., Bob Shears, Michael Tagarook

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Executive Summary

In light of increased industrial activities in United States Arctic offshore waters, effective response to spills of oil and hazardous substances in coastal, seasonally ice-covered waters is universally recognized as a critical challenge to sustainable development in northern Alaska. Due to limited *in-situ* and remote sensing observations, current and ice motion patterns in coastal settings are poorly understood. To address this shortcoming, workshops held in March 2013 in Barrow and Wainwright, Alaska, focused on nearshore ice and ocean currents of the coastal Chukchi and Beaufort Seas. Indigenous experts from Barrow, Wainwright, Point Lay, and Nuiqsut met with scientists from the University of Alaska Fairbanks and other institutions to discuss ice conditions and ocean circulation and to identify the knowledge critical to emergency preparedness and response.

This report informs agencies about coastal Chukchi and Beaufort Sea ice and ocean circulation, seasonal freezing, ocean access, and local expertise. Workshop recommendations call for measurements in new places and at specific times of year to improve our understanding of nearshore ice and ocean current variability and seasonality.

Local and indigenous experts described ice and ocean features, often using Iñupiaq terms. Whalers and hunters learn from elders and by experience under conditions critical to success and survival. Local knowledge at the scale related to hunting and travel experience is rich in detail and complements the typically larger scales of remote sensing and ice-ocean models.

Local experts heard scientists with expertise in sea ice and physical oceanography describe remote forcing and local water and ice dynamics. Shared knowledge broadened the collective understanding of coastal currents, river and lagoon freeze-up, nearshore freezing, and ocean circulation of the Chukchi Sea and Beaufort Sea barrier islands.

The wealth of sea ice experience from whaling and hunting on the ocean shared at this workshop clearly demonstrates how local and indigenous knowledge (LIK) can inform and guide sea ice and ocean circulation research and design. Such practical knowledge improves safety and provides the foundation for efficient fieldwork.

Communication issues and different frames of reference arose as a broad range of experts described what they know. Workshop challenges were partially overcome and highlight the beginning of truly shared knowledge established at this workshop. We hope this process continues to advance ice and ocean research particularly in the context of safety and emergency preparedness.

The majority of participants acknowledged that important progress was made toward establishing meaningful contacts and relationships, which may provide a foundation

toward enhancing communication between agencies, response professionals, and local experts in the event of an emergency.

Local experts experienced in navigating the ocean and maneuvering in sea ice 1) described weather, ice, and ocean currents, 2) located convergence zones offshore where birds and animals congregate for feeding or resting, 3) identified places where flotsam washes ashore, 4) shared navigational limits imposed by slush ice formation, lagoon freeze-up, and shoreline freezing, and 5) discussed recently observed environmental change.

The workshops confirmed that local input and partnerships are essential to emergency response planning. There was concern that logistics and infrastructure in coastal communities would be overwhelmed during an emergency or spill response. Participants called for distributed material that aids emergency and oil spill responders to be readable and well documented, first-contact lists to be readily accessible, and known ocean access points and potential staging areas to be described clearly and marked on charts.

Our research recommendations are the result of communication among experts. New research should address knowledge gaps, improve our conceptual model of ice and ocean seasonality, and lead to a better understanding of processes that limit seasonal access to the ocean.

We recommend studies that will:

1. compare observed convergence locations with trajectory model results,
2. document ice seasonality including slush ice formation and shoreline freezing,
3. identify emergency shoreline staging locations and barrier island access points,
4. measure current speed and direction near jets, fronts, and shear zones,
5. provide real-time tracking for sizable drift ice (e.g., multi-year or glacial floes),
6. extend ocean wave measurements into freeze-up,
7. continue high-frequency radar coverage and buoy studies,
8. continue to reconcile disparities between the frames of reference, scales of observation, and vocabularies that exist between local experts and scientists when discussing ice and ocean observations.

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Organizing Committee: Ransom Agnasagga, Matthew Druckenmiller, Hajo Eicken, Craig George, Richard Glenn, Mark Johnson, Enoch Oktollik, Gary Shigenaka, Robert Suydam, and Glenn Watabayashi

Workshop facilitators: Matthew Druckenmiller, Richard Glenn, and Hajo Eicken

Acknowledgements

We thank the participants for their contributions to the workshop and for sharing their knowledge and experience. Our approach of holding "roundtable" discussions allowed details and stories to emerge from participants in an effective and useful way. We are grateful for their collective insights and stories. This report is a step toward developing a clearer understanding of ice and currents in the coastal Chukchi and Beaufort Seas.

Funding support for the workshops and this report was provided by the North Slope Borough of Alaska under a funding agreement through the North Slope Borough – Shell Baseline Studies Research Agreement. Supplemental support came through the North by 2020 Forum at the International Arctic Research Center, University of Alaska Fairbanks and in-kind support through the National Oceanic and Atmospheric Administration, Office of Response and Restoration.

Workshop participants at the Wainwright Community Center.

We thank the North Slope Borough Department of Wildlife Management, Iḷisaġvik College, the City of Barrow, and the City of Wainwright for workshop support. Ronald Brower Sr. and Lawrence Kaplan (both of the Alaska Native Language Center at the University of Alaska Fairbanks) provided important guidance on Iñupiaq terms' spelling and usage. Nokinba Acker was the workshop photographer and Kevin Hillmer-Pegram was the workshop notetaker. Workshop logistics were expertly handled by Malissa Langley and Janell Kaleak.

Our discussions were helped by graphics of research results and model trajectories provided by Seth Danielson (University of Alaska Fairbanks), Meibing Jin (University of Alaska Fairbanks) and Andrey Proshutinsky (Woods Hole Oceanographic Institution). Steve Okkonen (University of Alaska Fairbanks) helped identify specific remote sensing images useful to this report.

Introduction

This report is the result of knowledge sharing among ice and ocean experts from the coastal Chukchi and Beaufort Sea region and from academia. By sharing knowledge, local experts and scientists can better understand the ice and oceans. This workshop, and ones that may follow, grew out of recommendations from a past workshop held in Barrow as part of the International Polar Year in fall of 2008. At that meeting, several Iñupiat experts on ice and ocean currents and other participants from the University of Alaska Fairbanks, the private sector, and agencies involved with oil and gas development, agreed that a more thorough exchange of knowledge on ice conditions and currents from an Iñupiaq and a geophysical or oceanographic perspective would be highly beneficial (see summary in Haley and Eicken, 2011). This workshop's goal was to increase our overall understanding of the Alaska coastal marine environment by first identifying common descriptions and understanding of the coastal sea and its ice cover among participating experts, and then exploring any mismatches between scientific and local knowledge. Such mismatches or gaps in our mutual understanding may guide future studies and help in preventing and, if necessary, responding to environmental hazards and emergencies.

Many challenges and opportunities exist during cross cultural and cross expert communications and collaborations. Frames of reference often differ. For example, scientists study ice "stability" when local ice experts focus on instability to survive and be successful in that environment. Many local experts described conditions that characterize extreme events while scientists typically describe the "mean" rather than focusing on extremes or "outliers".

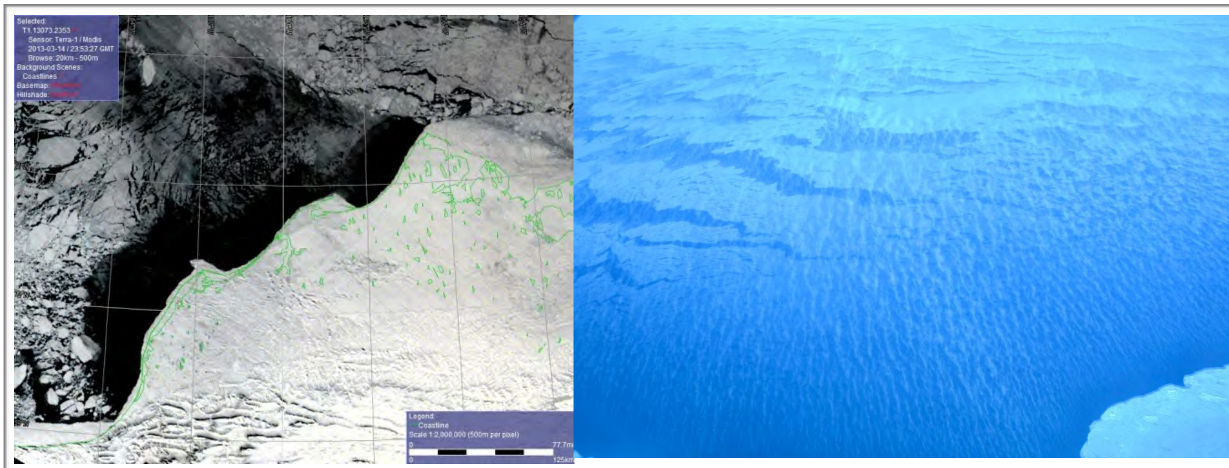


Figure 1. Two scales of observation. (L) A Moderate Resolution Imaging Spectroradiometer (MODIS) image from March 14, 2013 from Barrow to south of Icy Cape. (R) Photo from commercial flight taken by workshop participants on March 13, 2013 showing vapor streaks above the ocean with new ice.

Local experts and scientists work at multiple observational scales. Two scales are shown in Figure 1 reflecting the large-scale satellite view and an aerial view from a small plane. Both scales are larger than the scales that often matter to people hunting on landfast ice or amongst drifting ice floes.

Local and indigenous knowledge (LIK) forms the foundation for descriptions of the nearshore marine environment across seasons. Indigenous knowledge builds on experience living in, and obtaining food and resources from, the surrounding environment (Nelson, 1969; Krupnik *et al*., 2010). Knowledge is shared among community members and through the collective memory of elders. Having been reinforced through survival and hunting experience, this knowledge is fluid and adapts as conditions change.

LIK tends to be context specific but multi-parameter in nature. Cross-disciplinary observations of "what was seen" invigorate academics who then ask more questions. LIK is specific to a geographic region and based on teachings by elders and from personal experience with the ice, ocean and land. At times it reflects the view of a group of people living and working together on a daily basis. It is vetted by survivorship and hunting success on the ocean and in the ice. For these reasons, the process of sharing LIK can be challenging among those without the daily experience upon which LIK builds. The workshops' discussions began a process of collaboration that extended the tradition of sharing LIK and research results.

Margaret Opie, Billy Oyagak, and Richard Glenn

Goals and Objectives

The workshop was guided by three related goals. First, we wanted to share knowledge among Iñupiaq and academic experts and to strengthen communication pathways between these "communities". Second, we aimed to combine that knowledge into a single framework. Third, we wanted to determine its relevance in order to provide recommendations that improve our collective understanding of coastal currents and ice movement. The framework for the workshop was focused by the need for emergency responders to be aware of local conditions.

Invited participants shared knowledge of ice and ocean with an emphasis on improving marine safety and determining how we can make better measurements at the right times and places. When experts work together, resources can be focused where needed.

Participants were encouraged to contribute in ways understandable to others, particularly those having different experiences. Discussions encouraged talking *with* and *among* group members. We wanted to avoid lengthy presentations directed *at* people.

Tom Weingartner, Amy MacFadyen, Billy Oyagak, Joe Leavitt, and Lewis Brower.

We encouraged discussion that ensured clarity of shared knowledge. We wanted to determine where different forms of knowledge appear to be in contradiction and where agreement or complementarity exist. Past experience, such as the Barrow Sea Ice Symposium that brought together Iñupiaq and university scientists (Huntington *et al.*, 2001), has shown that areas where indigenous or local and academic knowledge seem to be in disagreement are often those where the potential for mutual learning is greatest and where scientific advances can be made.

Our collective knowledge and understanding of the coastal currents and ice movement has gaps. To address identified knowledge gaps, the workshops and this report recommend approaches that will improve environmental monitoring, spill trajectory and ocean modeling, as well as risk management and emergency response. The lessons learned in these workshops provide specific, strategic guidance on the role of coastal currents, local weather, and bathymetry in controlling ice and currents that disperse marine life in the northeastern Chukchi Sea and Beaufort Sea barrier islands. The report shares with government agencies and policy-makers detailed and important knowledge held by whalers and hunters that is critical to safe access, navigation, and operations in the ocean and ice. The workshop organizers are preparing a scientific research paper that looks in more depth at our current understanding of the complicated movement of ice and currents in coastal Alaska. This paper will be shared with workshop participants.

The workshops were guided by overarching questions including:

- "How do scientific observations and monitoring reinforce what is already known by local and traditional knowledge experts?"
- "Is the system more dynamic than what is known by scientists?"
- "What conditions are unsafe?"

Why Barrow and Wainwright?

Barrow and Wainwright, located on the Chukchi Sea coast, are part of the North Slope Borough. Both communities have substantial subsistence economies and both are accessible by commercial flight. To be meaningful and useful, our workshop required expert local knowledge, and therefore many people needed to travel. Barrow and Wainwright appeared to satisfy many logistics issues and allowed for participation from the neighboring communities of Point Lay and Nuiqsut (Figure 2).

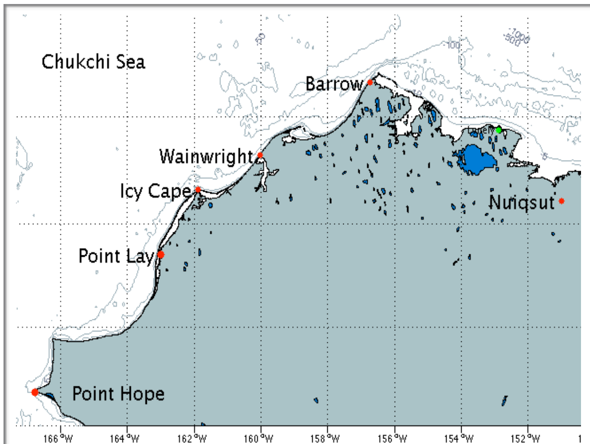


Figure 2. Coastal communities along the northeastern Chukchi Sea.

North slope researchers often rely on local experts to guide project design and field measurements. We hope these workshops with old and new collaborations lead us to a clearer understanding of our ice and oceans and help build partnerships among different types of experts. If the workshops are ultimately successful, they will foster additional discussion that may aid research, coastal navigation, emergency response, and maritime safety.

Structure of the Report

This report presents the results of workshops held in Barrow and Wainwright in mid-March 2013 that brought together local experts and academic scientists. It shares with North Slope communities the information collected from these workshops, which was carefully recorded by a designated notetaker.

Challenges emerged due to stories told in the Iñupiaq language and orally translated to English by Richard Glenn and others. While much of the workshop discussion typically used Iñupiaq terms for the ice and ocean conditions, we have generally not included those terms in the text of this report. Thus, our attempt to capture the nuanced statements in a few written words certainly falls short. A glossary of the commonly used Iñupiaq terms describing ice and ocean conditions is included at the report's end.

This workshop report is characterized more by shared local expert knowledge than by information from scientists. With this in mind, we have tried to capture as much structure and detail as possible about coastal ocean and ice processes from all workshop participants. A brief video produced by Nokinba Acker [http://www.youtube.com/ watch?v=g8SR7H0XW_Q] provides a summary and impressions of conversations from the workshop. The information shared by university scientists at the meeting is accessible in other forms. For example, see chapters on climate change, coastal oceans, and fisheries in books summarizing University of Alaska research during the International Polar Year (Lovecraft and Eicken, 2011).

Andy Mahoney, Lewis Brower, and Billy Adams.

The report contents result from organizing “what we heard” from local experts into “observations from expert observers”. Observations are grouped according to their reference to ice or ocean currents. Some observations are partitioned by region and by issues related to ocean access and emergency response. Much of the knowledge conveyed at the meetings has been summarized in Tables 1-13 below. These tables provide more detail and represent an attempt at grouping some of the information into specific topic areas, such as “Currents”, “Lagoons”, “Onshore convergence zones”, “Freeze-up season” or “Large ice floes and icebergs”.

The section “Recommendations for Agencies”, written specifically for entities with interest in the nearshore environment of the Chukchi and Beaufort Seas, suggests new research and identifies issues relevant to marine safety and ocean access.

Observations From Indigenous Experts

It is important to consider that local experts frequently offered quantitative observations in response to questions probing for specific values (for example, “how far in miles?”, “how thick?”, “on what date?”, etc.). In this report, these numeric values, where provided, should be considered approximations and, in many cases, represent subjective classifications. An observation of distance may be derived from an experience of traveling, which can be influenced by the traveler’s effort and the environmental variables that were at play, such as strong, opposing currents when boating or rough ice requiring a circuitous route when snowmobiling. In many cases, more precise determinations of quantified observations could be achieved through specific and detailed follow-up with local experts; however, the observations listed here do not represent such targeted efforts. Rather, we are intending for these presented observations to serve as a starting point for collaborative follow-up.

Figure 3. Photo from commercial flight between Barrow and Wainwright.

Ice and Ocean Conditions Off Barrow and Wainwright

In the fall, beach ice formation happens quickly, in about 48 hours, then grows from shore in a few weeks. When the shoreline freezes, access to the water from shore without using heavy equipment to break shore ice is difficult. The first slush ice comes from the east, from the barrier islands, around Point Barrow and "floats up" in the lagoons. Slush ice and very thin ice makes maneuvering difficult. Slush ice clogs a water-cooled engine, ending the outboard engine season. Slush ice and ridged ice with deep keels move with currents, not with winds.

Freeze-up used to be around September 22 at Wainwright when defined by rivers and lagoons freezing. A choppy river will delay freeze-up. During dredging days in the 1950s workers from Barrow to Point Lay pulled out by October 5 when outboard engines could no longer run due to the slush ice. Recollections of conditions from the 1950's suggests that the ice was three inches thick in Wainwright Lagoon by about October 7. Now the lagoon freezes around October 15th. At Point Lay the beginning of freezing weather is marked when rain turns to snow which has historically been around October 4-10, a date that has not changed over the years.

After freeze-up, landfast ice forms. Off Barrow, fastice normally allows hunting five to seven miles out from the coast, with 12 miles the maximum distance from shore over the past 20 years.

After break-up, the earliest opening of Wainwright lagoon is June 12th with the latest about the first week of July.

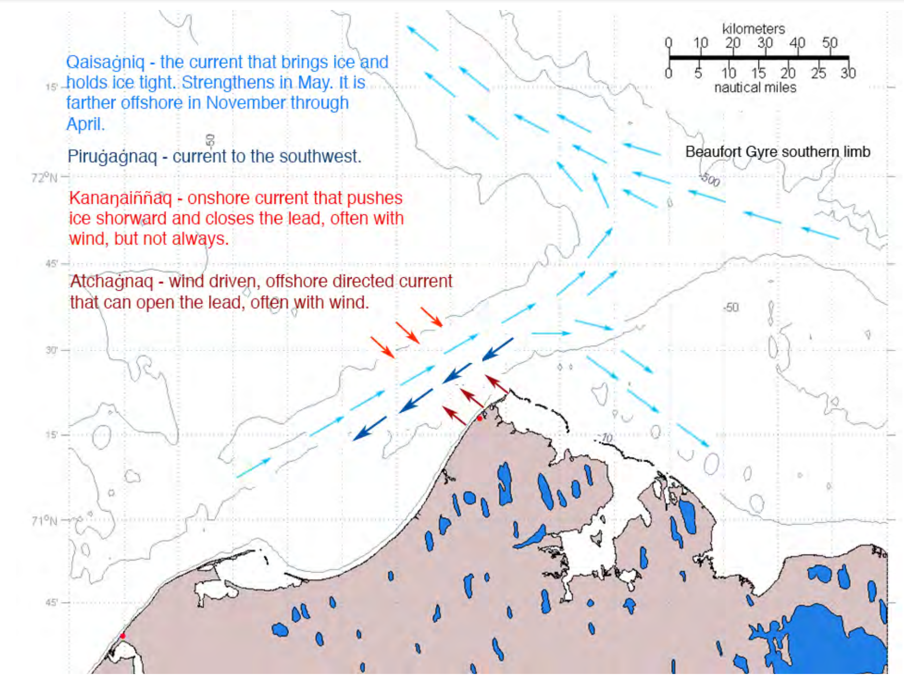


Figure 4. Ocean current structure off Barrow with qaisaġniq, piruġaġnaq, kanaŋaiññaq and atchaġnaq.

West of Point Barrow, during spring break-up, the water generally opens up in mid-May while east of Point Barrow the ice opens up about two weeks later. A wind from the east opens the ice off both Barrow and Wainwright. In the past, the ice used to come back a few times in summer, each time bringing animals. Now, when the ice leaves in summer offshore of

Wainwright, it generally does not come back until winter. In 2011 the ice off Barrow "went out" quickly.

Multiple currents influence local navigation 15, 20, or more miles out from the coast. The currents are described as "stacked", with transition zones at one, two to three, five to seven miles, and farther offshore. For the region between Barrow and Peard Bay there are four to five stacked currents with the current width increasing offshore. Farther offshore of Barrow the "current from Point Franklin" is between seven and 12 to 20 miles out. The current width is five to ~15 miles. A third current is about six miles wide. The fourth current is over 30 miles out. The currents strengthen from Wainwright to Barrow. The water gets "clear" four to five miles out from Barrow, marking the "open waterway" with less ice during the ice season.

Early in the open water season, late June to mid-August, generally a period of relative calm, there is often a visible surface streak of foam and algae in the shear or transition zones marking currents of differing velocities. Later in the season the surface condition becomes well-mixed from wind and storm events making it harder to see the current transition zones.

Off Point Barrow the main current can flow toward the east, north, or northwest depending on season and weather. The current pattern was compared to a three-way intersection (Figures 4 and 10). The northeast flowing current generally turns east at Point Barrow and/or to the north-northwest toward deeper water. Eastward flow around Point Barrow is confirmed by boats that have drifted in surface currents from Peard Bay to Point Barrow and to Lonely, AK. Reversals in the coastal current can occur daily, and are more commonly observed in winter. By April/May the current becomes steady to the northeast with an average speed of one to two knots.

Ice and Ocean Conditions Near Cross Island

Near Cross Island there are four layers of currents from near to offshore with the third and fourth currents being stronger. Currents between Cross Island and West Dock during fall whaling are to the southwest. About 12 miles seaward of Cross Island in 30 to 60 meters (~100 to 200 feet) there is a current reversal that aligns with the steeply sloping bathymetry. The persistent westward current is 30-40 miles out from Cross Island.

Marine Safety

When out on the ice hunters are watching the sky and ocean for signs of change that may indicate whether the ice will close in and create dangerous conditions. A darkened sky indicates whether there may be an open lead in that direction and a changing sky may indicate whether the lead is closing.

To see if the currents are changing, the water velocity is sometimes estimated by lowering a weight into the water and watching how it gets pulled by the current. This sounding is done in about 30 meters (~100 feet) of water every four hours or so, perhaps every two hours if conditions are changing rapidly. It may take a couple of days for the current to build up from the bottom and reach the surface. [A scientific interpretation is that an ocean current building from the bottom is forced remotely and not by local winds.]

At Wainwright a southwest wind means “head home, the ice is coming in”. A southwest wind drives saltwater into the lagoons.

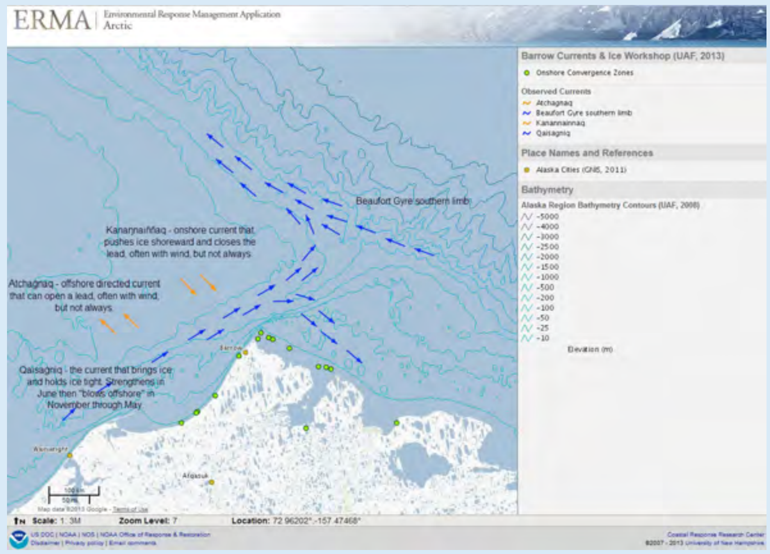
As the sea ice extent trends downward, the presence of large masses of ice has become more noticeable off Barrow. Big ice can ground, altering local currents. Ice “islands” have appeared from the east, and it is important to monitor their trajectory.

Climate Change

Spring whale migration is two weeks earlier compared to 1987. Grey whales have moved farther to the northeast of Point Barrow. The tundra has more grass now. It used to be four inches and now the grass is 30-38 inches.

In 1969, when Wainwright airport was built, the lagoon froze around September 17th. It used to be you could hunt on the ice into July off Wainwright. At Wainwright, freeze-up is now a month and a half later, and break-up is a month and a half earlier, compared to fifteen years ago.

With longer summers, break-up, and freeze-up seasons, and little or no heavy winter ice, it appears as if there are now “four to five seasons”. The seasons are not just ice and no ice, but now there is this “big in-between time that needs to be understood”. Break up used to last through October but now it lasts from October to January. A longer season increases the time for slush ice formation.



Environmental Response Management Application (ERMA) is an online mapping tool offering comprehensive access to localized environmental response information. Arctic ERMA integrates both static and real-time data, such as Environmental Sensitivity Index (ESI) maps, coastal resources and habitats, subsistence use, ship locations, sea ice extent, weather and satellite imagery in a centralized format. It provides environmental responders and decision-makers with access to data for environmental planning, response, assessment, restoration, incident drills, and natural disasters. The system incorporates data into a fast, user-friendly geographic information system (GIS) that can be accessed by command post staff, by active field and remote support teams, and by decision makers and other incident and restoration staff at a variety of locations.

Freeze-up and slush ice formation are key indicators of the timing of the seasonal cycle. After slush ice formation the ability of local experts and first-responders to launch boats and maneuver in the ocean is hampered because slush ice impacts outboard engine cooling, and shore ice formation impacts the ability to launch boats.

Consistent patterns of winds and currents cause convergence of surface debris in the ocean and on the shoreline. A number of places were described during the workshop where debris accumulates at sea or along the coast. These places are marked and available for public viewing through the Arctic Environmental Response Management Application® (ERMA).

The ocean area northeast of Point Barrow, 18-20 miles out, was described as a “dead zone” with floating debris accumulating from late August through early September. East of Point Barrow, at Tapkaluk Island, birds congregate and dead animals have washed ashore. A 30-mile rectangle off Cooper and Martin Islands is also a place where birds congregate. Peard Bay and five miles south of Barrow tend to collect material from the ocean. Cooper Island, east of Point Barrow, tends to collect material as does the east side of Smith Bay, which has lots of driftwood. Dead walrus wash ashore at the mouth of the river north of Skull Cliff. Material washes ashore between Pingorarok Pass and Icy Cape. The points of land that comprise the pass between Pt Franklin and Sea Horse Islands also collect floating material, i.e. buoys, floats, dead walrus, etc. See Tables 1 through 13 for regional summaries of ice and current conditions.

Descriptions From Science

In both Barrow and Wainwright there were questions about remote forcing that affects the Chukchi Sea, a topic well-studied by scientists but still with knowledge gaps. What is known is that big storms in the Bering Sea affect the behavior of the ocean in the Chukchi Sea. Ocean currents, ice, and winds from the Beaufort Sea can account for some extreme conditions in the Chukchi. Workshop participants recalled Ted Fathauer’s finding that the 1957 ivu (ice push event) was driven by strong atmospheric wind systems that drove the ice onshore (George *et al*., 2004).

Ransom Agnassaga, Hajo Eicken, Julius Rexford, Michael Tagarook, and Fred Ekak.

We had a broad discussion about freshening in the Chukchi Sea and the Beaufort Gyre, the strong freeze-up in 2011-2012, and causes of ice depletion on both local and regional scales. We recap below some of the key points of our discussions. Workshop authors and participants should be contacted for additional details.

Hajo Eicken noted that the multiyear ice off Barrow is now younger than before. The ice used to be older than seven years, but now it is commonly three to five years in age with more underneath melting from ocean heat. This warmer water can also melt and potentially destabilize shorefast ice in the winter.

Richard Glenn described the large scale atmosphere patterns that drive surface ice, noting that currents, not winds, move thicker ice. Mark Johnson described the large-scale pan-Arctic climate patterns driving the strength of the Beaufort Gyre that result in storage and release of freshwater on decadal time scales. Tom Weingartner described paths of buoys that drifted from the Chukchi Lease Area toward the coast. The buoys can enter the Alaska Coastal Current and be carried northward. Off Barrow, buoys can be entrained in the westward flow.

Tom Weingartner showed high-frequency radar (HFR) data of the average current near the coast flowing southwest to northeast. The averaged HFR surface currents tend to align to bathymetry with current reversal depending on winds. An east wind greater than 12 knots drives the surface waters west and offshore. Historical current meter data shows that flow up Barrow canyon can bring warm Atlantic Water to the surface and melt ice. This appears to occur intermittently. Over Hanna shoals, the water temperature is near the freezing-point although it is warmer to the south based on buoy observations in late fall. Generally, ocean swell (long waves) comes from the southwest but the chop (wind waves) come from the northeast and northwest.

Meeting Outcomes

The workshop was a successful demonstration of a Community of Practice at work where identified experts shared relevant knowledge. The workshop revealed a complex current structure and identified mismatches between descriptions from local experts and scientists. For example, local experts identified surface aggregations and described fine detail smaller than the resolution of high-frequency radar measurements and numerical models.

In response to a possible oil spill, the National Oceanic and Atmospheric Administration (NOAA) provides support to on-scene responders, usually the United States Coast Guard (USCG), in addition to providing information on ice, currents and pathways. During a possible spill there will be overflights to identify surface features for people tracking the spill and 48 hour forecasts of where it may go. The National Weather Service will be making wind predictions using the Weather Research Forecast model and NOAA will deploy meteorological stations if needed. It was not clear how deployments would take place under typically cold and dark winter conditions.

It is well known that the presence of sea ice markedly complicates numerical models. Rates of encapsulation of oil into ice and release during melt need to be known in addition to understanding ice concentration and thickness distributions over the seasonal cycle. Part of the complexity is the location and distribution of any spilled material that could be on top or underneath the ice.

Many participants suggested that logistics and infrastructure in coastal communities could be overwhelmed during an emergency or spill response. Material that aids emergency, first-responders, and oil spill responders should to be readable and well documented. First-contact lists must be readily accessible. Known ocean access points and potential staging areas need to be described clearly and marked on charts.

Recommendations for Agencies

- Compare identified convergence zones nearshore and in open ocean with convergences computed by spill-trajectory models. While some model grids may be too coarse to resolve certain convergence regions, observed convergences are regions with a higher probability of collecting spilled material, so identifying such regions is a worthwhile goal for spill trajectory models.
- Deploy GPS tracking devices on “big ice” such as the ice islands coming from the Canadian Arctic and drifting to Barrow and Wainwright. Tracking devices should be available to use opportunistically through community contacts with the North Star Borough Department of Wildlife Management, Barrow Whaling Captains, Native Village, Iñupiat Community of the Arctic Slope, and similar organizations.
- Deploy drifters and acquire boat-based measurements near fronts and other hydrographic features identified by local experts such as convergence (“stagnant”) zones and spring leads.
- Measure waves at least into the storm season if not year-round. Wave sensors need to be deployed and measuring well past September because the big waves come in October and November.
- Perform tide measurements beyond Prudhoe Bay and Red Dog.
- Collect current measurements at lagoon mouths. Use local monitoring to assess navigational issues in passages and between barrier islands particularly where relevant to possible emergency response. For example, the pass by Pingot Island is now closed but was open in the 1970s and 1980s. The southern and northern beach edges of Pingorarok Pass have the same width, however both points moved 0.2 miles north between 2006 and 2013. Similar observations at other locations including Utukok Pass and Point Franklin suggest coastal currents are migrating the coastal geography. Local experts know how to access open water through the barrier islands where the nautical charts are out-of-date, yet it is not clear that this information is readily available to spill responders.

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- Record lagoon freeze up dates and keep records of the last day for access to the ocean with water-cooled engines (slush ice timing).

- Measure currents near Cross Island, Camden Bay, and from Barrow to Icy Cape. Camden Bay's currents used to be stronger than they are now. Camden Bay is a feeding place and, when it is windy, a resting place for whales (within a mile of the Hulahula River mouth). In the 1970s and 1980s hunting occurred among the barrier island, never in the ocean farther offshore. These days ice "jams up" and you can't cross the barrier island.
- Define the most useful, specific measurements to record, and then encourage systematic data gathering, including weather, currents, and ice at specific times and locations by users on the ice.
- Study the "natural seep" of oil and tar at Cape Simpson, which is a "couple hundred yards wide" and "several miles long".
- Address the knowledge gap between the area covered by local and indigenous expertise, which extends to 30-50 miles offshore, and the location of the Chukchi oil and gas lease areas, 70 miles offshore.

Linking Workshop Contributions on Current and Ice Movement From Local and Indigenous Knowledge and Geophysics

The workshop discussions revealed different contexts and concepts used by LIK experts and by oceanographers or geophysicists in describing ice movement and currents. LIK describes ice motion and ocean currents as they relate to ice and ocean use and hazards, such as conditions that are unsafe, may bring animals, or require immediate action. LIK descriptions, which may include a seasonal context, are based upon direct observations and traditional knowledge that are context-specific and infused with temporal nuance and detail. These meaningful descriptions are important to daily life and can determine whether a hunt is successful and safe.

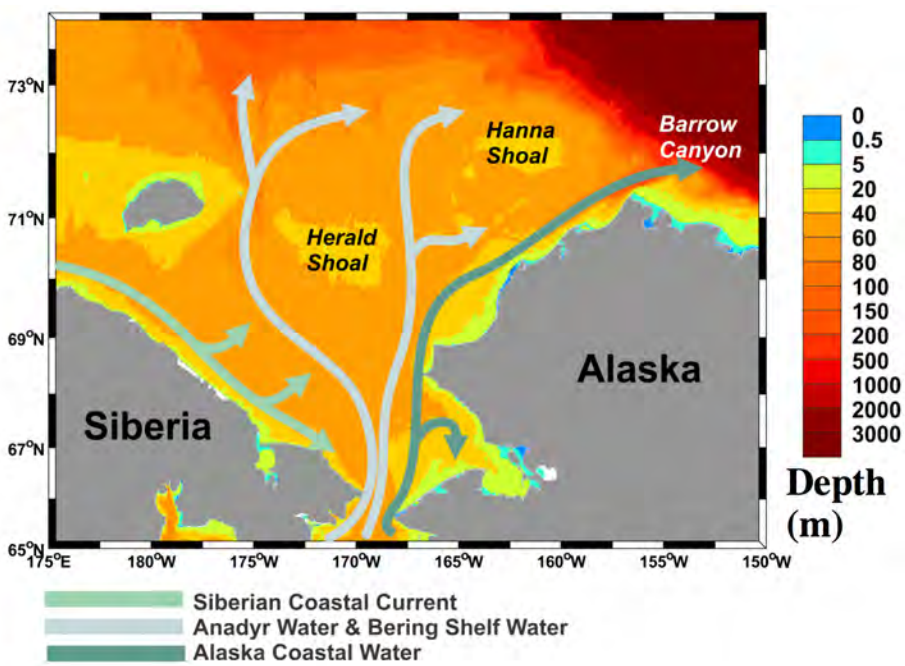

Figure 5. Mean circulation pathways from Bering Strait northward. Alaska Coastal Water flows north past Barrow toward the northeast. Graphic courtesy of Seth Danielson, University of Alaska Fairbanks.

Geophysical or oceanographic descriptions of ice and currents rarely focus on conditions related to hunting success or survival. Instead, scientists are often interested in mean conditions ("ocean climate") as a first approach toward understanding, and then they look at variations about the mean.

Although scientists may initially focus on defining a mean, understanding oceanographic variability is the focus of multiple scientific studies. Typically, this work involves the deployment of instruments in the water to obtain year-round records of ice movement, currents, water temperature and salinity.

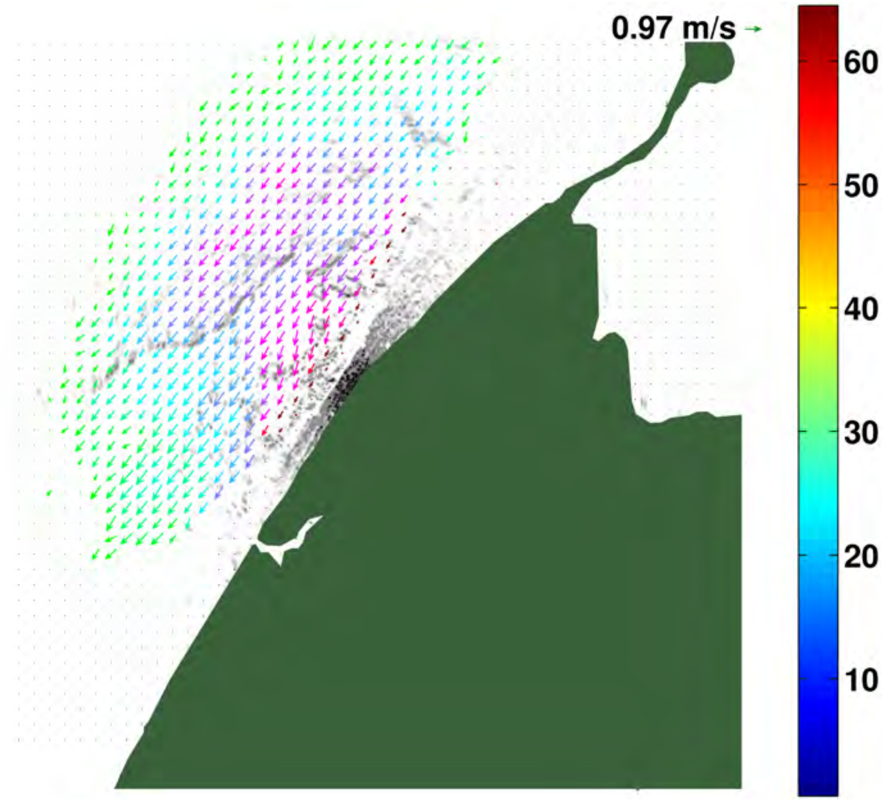

Figure 6: Mean ice movement pattern for 3 February 2010, as obtained from the University of Alaska Fairbanks Coastal Ice Radar at Barrow (http://seaice.alaska.edu/gi/observatories/barrow_radar). The arrows point in the direction of ice movement and their length indicates the speed of the ice (the arrow length at the top is proportional to ice moving at close to one meter per second, or just over three feet per second). The colors indicate how many individual radar targets were tracked to arrive at this mean ice speed. Figure from Rohith *et al*., 2013.

Current naming is often based on the source of the water or the forcing that drives the current. For example, Figure 5 shows the mean currents of the Chukchi shelf with current names reflecting sources in Siberia, Gulf of Anadyr, Bering Shelf, and coastal Alaska.

The map of the *mean* Chukchi Sea currents (Figure 5) is based upon multiple years of current meter mooring observations. Water from Bering Strait is diverted eastward by Hanna Shoal and mixes with the flow of Alaska Coastal Water toward Barrow Canyon and the Beaufort Sea. The flow north of Hanna Shoal turns eastward toward Barrow Canyon. The northward current has a mean flow of 20 cm s^{-1} (Weingartner *et al*., 2005), and is known to reverse, particularly in winter, based on measurements from high-frequency radar and drifting buoys.

By comparison, Figure 4 summarizes important aspects of water and ice movement from the Iñupiaq perspective. The northeast flowing current off Alaska is named in Iñupiaq "qaisaġniq," a current "that brings ice" and "is holding it" (ice). The naming of this current reflects its impact on people who may be on the ice or navigating the water, and provides information about the direction of the current.

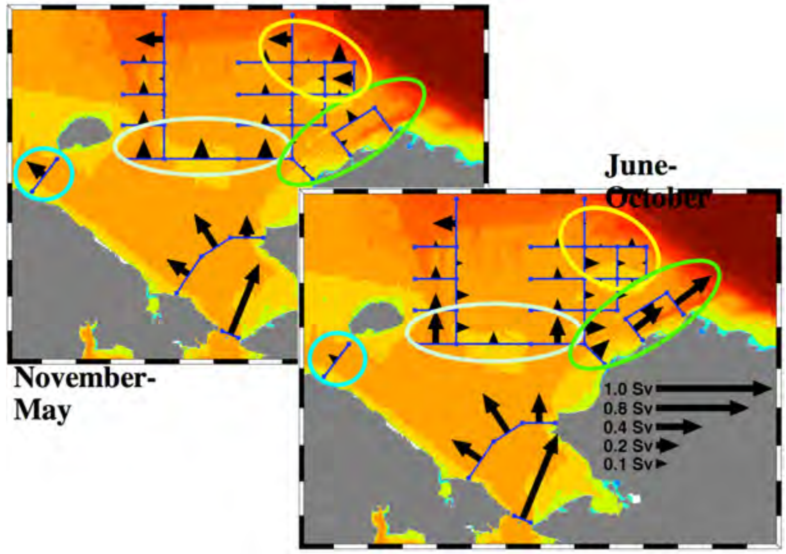

Figure 7. Seasonal mean currents of the Chukchi Sea and southern Beaufort Sea. Figure courtesy of Seth Danielson, University of Alaska Fairbanks.

Iñupiaq captures this variation in directionality by naming the southward flow "piruġaġnaq," the dominant current *from* the northeast during winter that "allows one to be out on the ice". Following the workshop oral descriptions, we drew the image shown in Figure 4 to represent qaisaġniq and piruġaġnag. Qaisaġiniq strengthens during June through October and it is further offshore during November through May. Piruġaġnag generally occurs in winter.

Figure 4 also shows kanaŋaiññaq, a current that "closes the lead" and atchaġnaq, a current that "opens the lead". These Iñupiaq names convey information about the behavior of the ice by telling whether the lead is closing or opening, information critical to hunting and safety. Whether the current and ice motion are caused by winds or remote forcing is not a necessary part of the description.

As is well known by local experts, and as seen in coastal ice radar imagery collected by the Geophysical Institute/University of Alaska Fairbanks Sea Ice Group, currents are able to move ice into strong winds if the draft of the ice is sufficiently deep and/or the currents are sufficiently swift.

Such complex, and to the uninitiated seemingly counterintuitive, movement patterns were repeatedly mentioned at the workshop. Figure 6 shows an example of the mean pattern of ice movement for a typical winter day with piruġaġnaq current conditions.

As with the currents, the mean movement of ice, even during a single day, provides little information about potentially hazardous ice conditions or brief openings and closings of the shore lead. Nevertheless, maps such as the one shown in Figure 6 can help us to understand the relative importance of different kinds of current and ice movement patterns and how they might change over years.

Figure 8a. MODIS image from June 17th, 2009 with easterly winds and a newly opened lead. MODIS image by NASA/ GSFC Rapid Response.

A scientific perspective on kanaŋaiññaq is that it may be a current driven by winds from the west, or it may be driven by the current from Bering Strait that passes Hanna Shoal. Figure 7 shows seasonal averages of the water column-averaged currents for the Chukchi Sea, including both wind and remotely forced currents. The current vectors (arrows) are proportional to the mean flow from the ocean surface to the bottom (a "volume transport" with units of 10^6 m^3 s^{-1}). Off Barrow, this flow is directed offshore during November through May and directed onshore between June through October. If this flow is linked to the Bering Strait currents shown in Figure 5, then remotely forced currents likely have a role in kanaŋaiññaq.

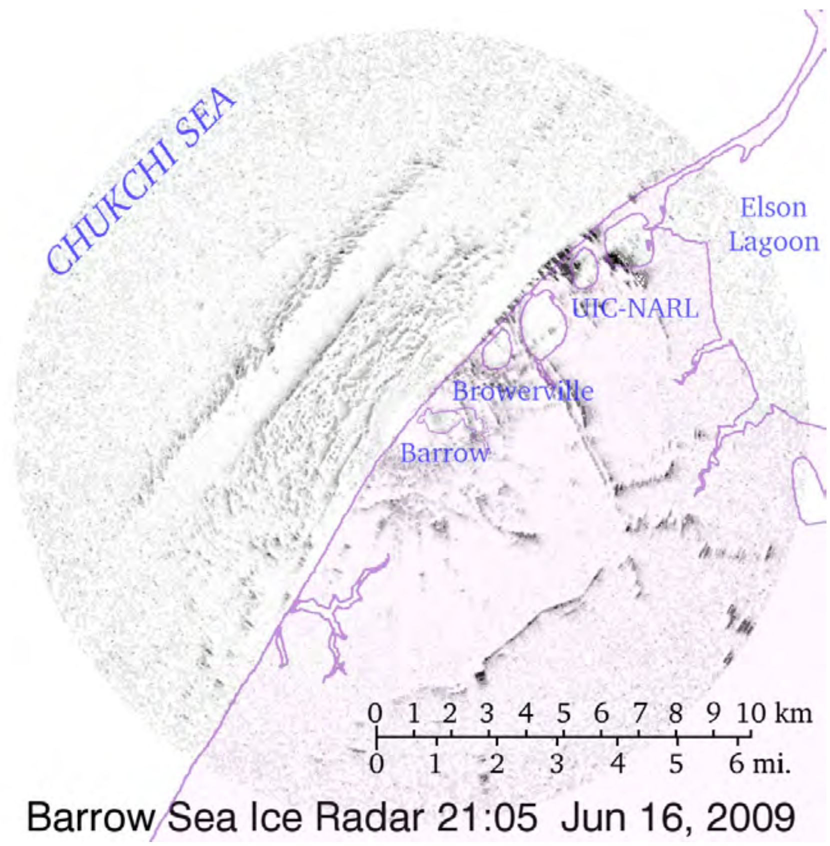

Figure 8b: Lead off Barrow a few hours after its initial opening, from the Barrow Coastal Ice Radar operated by University of Alaska Fairbanks ((http://seaice.alaska.edu/gi/observatories/barrow_radar). Radar imagery can provide detail about ice movement to complement large-scale satellite images such as Figure 8a.

Atchaġnaq, however, is clearly associated with wind driving (an easterly wind is atchaġniq in Iñupiaq [see MacLean]). This condition is shown in Figure 8a where an easterly wind has created a new lead off Barrow that is visible in its very early stages in radar imagery collected by University of Alaska Fairbanks Barrow Coastal Ice Radar a day earlier (Figure 8b).

Onshore and offshore directed surface currents, evident in high-frequency radar images, are three days apart (Figure 9). Whether the forcing is local winds or remote events, the frequency and timing of kanaŋaiññaq and atchaġnaq could be usefully discussed in detail at a future workshop.

The current pathways north of Point Barrow were described during the workshop as a "trifurcation" or splitting into three branches (Figure 10). The central branch is evident in the satellite image on the bottom of Figure 10. One of the three branches likely dominates at any given time.

One recurring feature in this dynamic region described by LIK experts is the presence of an eddy north of Point Barrow. This feature, which may be present intermittently throughout the year, is a "stagnant zone" where flotsam converges.

Figure 11 shows images consistent with an eddy off Point Barrow. (A smaller "eddy" near the head of Barrow Canyon has been used successfully by Wainwright whalers.) The eddy region and the eastward turning of the current north of Point

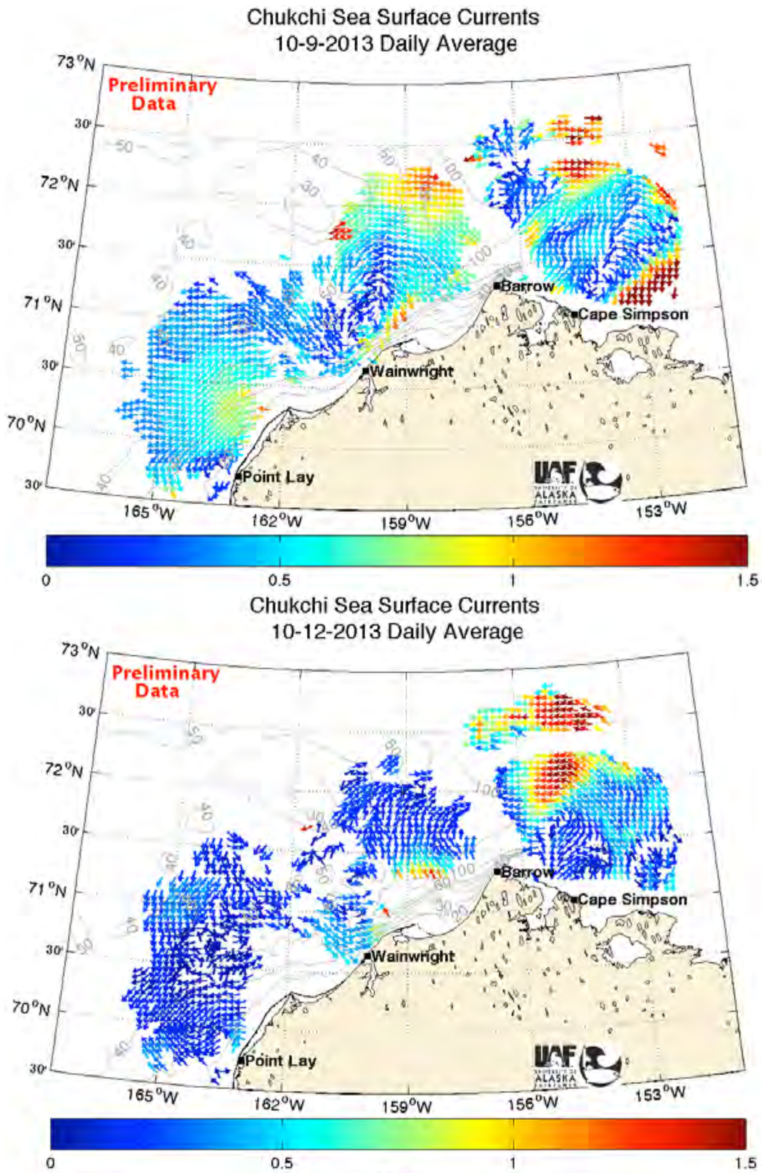

Figure 9. October 2013 high-frequency radar data from Tom Weingartner's group at the University of Alaska Fairbanks showing daily-averaged surface currents separated by three days. (Top) Onshore directed and (Bottom) offshore directed currents. The current vectors miss the nearshore currents off Barrow but suggest current and ice motion consistent with kanaŋaiññaq and atchaġnaq.

Barrow are evident in drifter trajectories deployed by University of Alaska Fairbanks scientists Tom Weingartner and Peter Winsor (Figure 12). Other trajectories (not shown) show the reversal (piruġaġnaq) described by the LIK experts.

Descriptions at the workshops mentioned "murky water" off Barrow that extends for "five to seven" miles. The satellite images in Figure 13 show "green" water west of Point Barrow, in Elson Lagoon, and the nearshore Beaufort Sea coast. These August images suggest a westward current extending past Point Barrow.

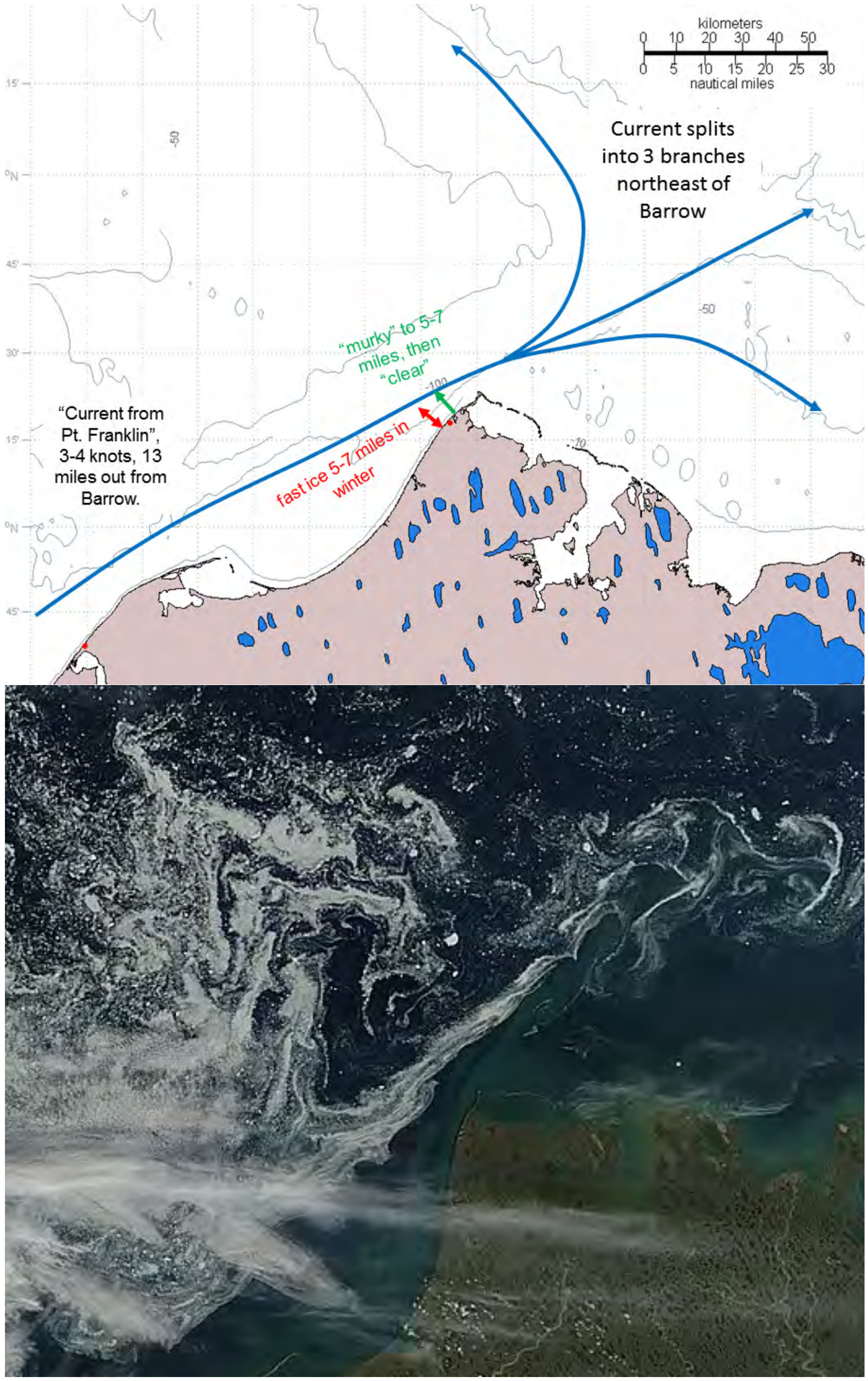

Figure 10. (Top) The nearshore current "trifurcates" northeast of Barrow, splitting into three branches, with generally one branch dominating at a time. (Bottom) Image from 12 August 2012 showing current extending northeast of Point Barrow. MODIS image by NASA/GSFC Rapid Response.

Future Work and Next Steps

LIK describes ocean and ice phenomena as events to be encountered while hunting, navigating or working on the ice. Described events often relate to short-term variability, potential hazards, or anomalies encountered in the environment. Conversely, geophysical scientists are often initially focused on mean conditions, and then seek to characterize the variability of ice and currents.

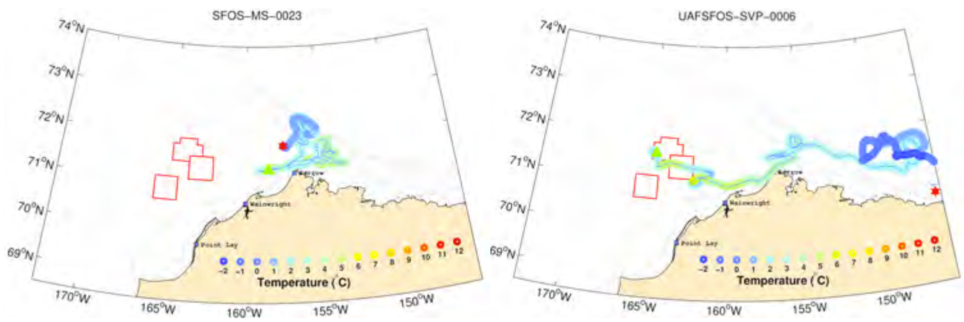

Figure 11. Drifter trajectories showing (L) eddy region tracked by a surface drifter and (R) eastward turning of the current from deep-tracking instrument.

Both LIK and geophysical descriptions seek understanding at time scales of hours and days. The shorter time scales are particularly important to those hunting in the ocean and on the ice where real-time information is more useful than “mean” conditions. A focus of a future workshop may be identifying the scales of variability and frequency of events relevant to both LIK experts and geophysicists.

The results of the workshop and this report should be shared with community members. A workshop building on local experts’ perspectives on the potential behavior of oil-in-ice and initial response scenarios will aid planning and preparedness for emergency responders.

We want to continue the cross cultural and cross-expert communications because traditional knowledge frequently retains descriptions of large events that stand out from the mean, while scientists often think of “average” or “mean” conditions. It is not clear that the “average” condition relates at all to extreme events which are highlighted by local and indigenous knowledge.

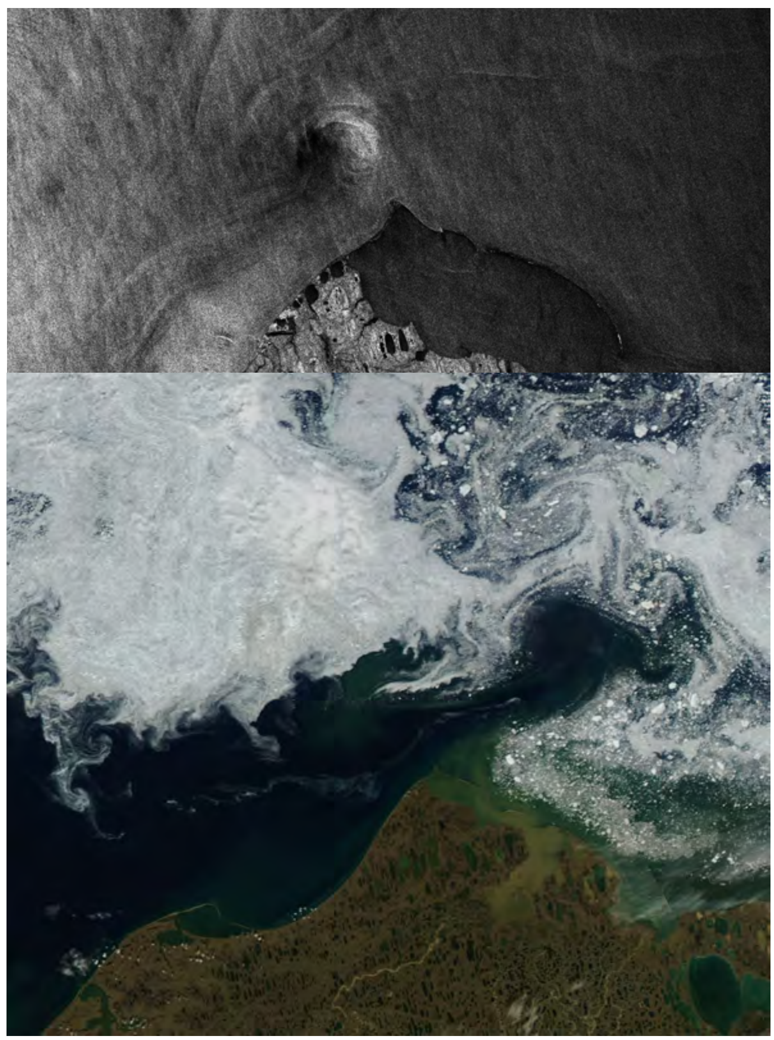

Figure 12. (Top) Eddy north of Point Barrow on Sept 12, 2009 from SAR image, European Space Agency, Earth Observation Ground Segment Department. (Bottom) Eddy-like feature in ice field north of Point Barrow, July 24th, 2010. MODIS image by NASA/GSFC Rapid Response.

The workshop identified the need to link local expert knowledge “near shore” with knowledge “off shore” to develop a complete description of the marine environment. To that end, workshop participants asked whether the Arctic Pilot Guide to Mariners needs to be updated given the increasing presence of new cruise ships, industry and shipping. The Arctic Pilot might be used to identify sensitive areas or areas that should be avoided by larger ships. The USCG is currently looking at “sensitive” areas from Wales to Barter Island, east of Camden Bay.

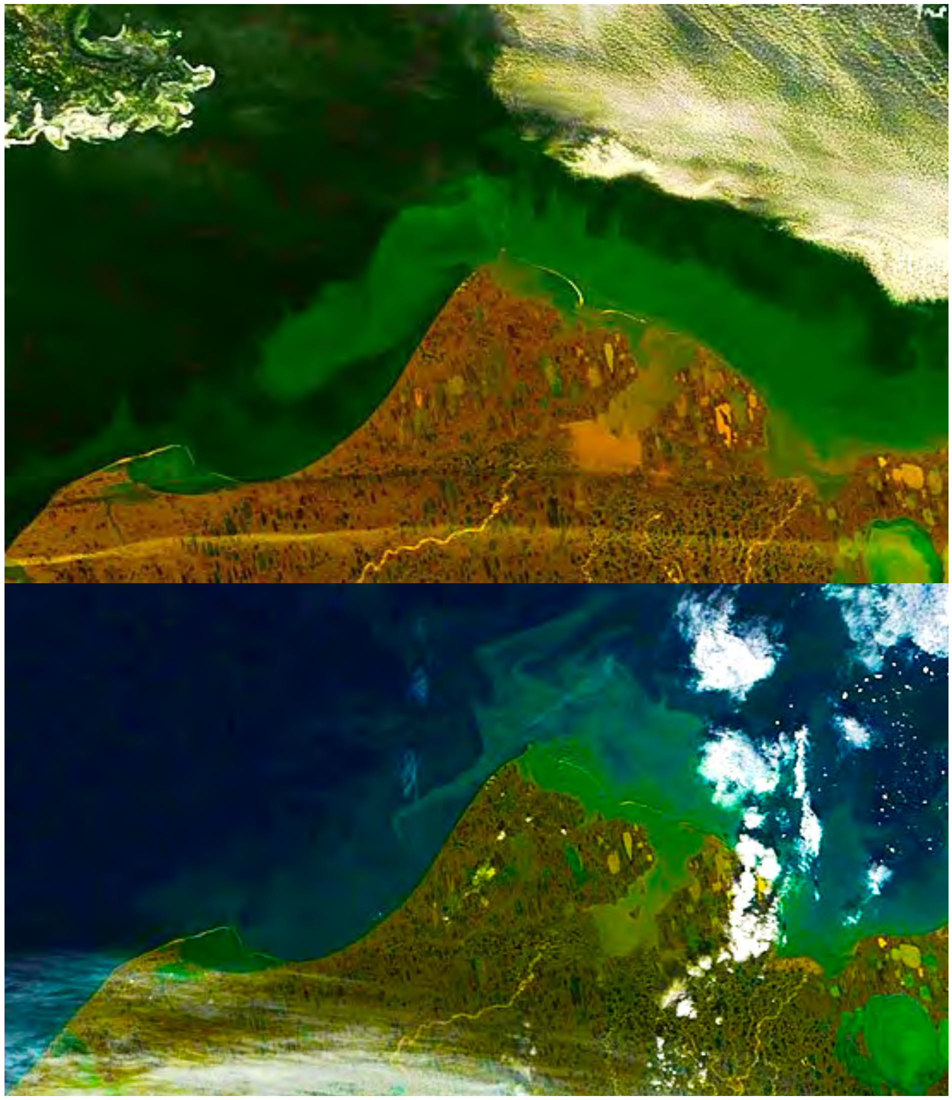

Figure 13. “Green” water is evident off Barrow and in the nearshore region east of Point Barrow from (Top) August 16th, 2008 and (Bottom) August 14th, 2010. MODIS images by NASA/GSFC Rapid Response.

The workshop discussions and the figures shown in this report suggest both LIK experts and geophysical scientists are observing and describing similar features, although the descriptions are part of different frameworks and address different uses or interests. At the same time, both groups present at the workshop use different language and nomenclature to describe specific events or features. Further work is needed to clearly establish what is meant when referring to a “current” or specific ice movement patterns. The workshop highlighted a number of interesting contrasts in thinking about and reporting on environmental conditions, such as differences between water masses and water movement that are reflected in descriptions of current boundaries.

Summaries of Ice and Current Conditions Off Barrow

The following tables represent best effort to summarize, in a consistent manner, the specific topics discussed at the workshops. These represent only the observations and knowledge shared by local experts during the workshops.

Table 1. The four stacked currents off Barrow

Time or season	
Weather conditions	
Currents and ocean state	
Ice movement and conditions	Ice floes are sometimes seen traveling in opposite directions or at different speeds, indicating that the floes are in different currents
Human activities and hazards	One current sometimes clears ice away from coast when another might not, thus providing a boating corridor
Animals	Birds (e.g., shearwaters) sometime are seen feeding at shear line
Other information	These four currents are observed between Point Barrow and Peard Bay; First current is usually about 5-6 miles out
Source of observation	Visibly observe shear line between currents; current nearest coast can be murky; sometimes during summer (July) when ice is still lingering the presence of a “hallway” of open water between the ice along shore and ice further out can indicate one of the currents
Implications for search & rescue and spill response	
Scientific follow-up	Are the four currents ever observed at the same time?

Table 2. Currents north of Point Barrow

Time or season	Anytime of year
Weather conditions	
Currents and ocean state	The current from the southwest splits north of Point Barrow into two or three and meets with the current from east of Point Barrow. Prevailing conditions are the currents from the southwest being present and not always with current from the east
Ice movement and conditions	Ice floes can be observed spinning in circles where the currents come together
Human activities and hazards	Hunting north of Point Barrow with a strong current from the east is very dangerous; the current that goes to the north (and splits off from current from southwest) can be strong and present a challenge to hunters hauling a whale back to Barrow; current paralleling the barrier islands to the east is the weakest and thus a way to exit the stronger currents and eventually enter the barrier islands
Animals	A good place to hunt seals; a place where animals concentrate
Other information	Where the currents meet is “yuayuk”.
Source of observation	Whaling in fall time near Point Barrow; seeing the shear line between currents; experiencing the drift by boat; current paralleling the barrier islands can be murky; observing ice floes spinning in circles and or dunes on the water indicate the meeting of the two opposing currents
Implications for search & rescue and spill response	Potentially dangerous area
Scientific follow-up	Are these two (or three) streams that split off from the southwest current usually occurring together, or are these observed independently at different times?

Table 3. Stagnant zone beyond Point Barrow

Time or season	Mid- to late July
Weather conditions	Calm?
Currents and ocean state	Weak qaisaġniq. This zone develops in particular during calmer conditions with weak currents in early summer.
Ice movement and conditions	Stagnant or trapped patch of ice 18 to 25 mi to northeast of Point Barrow; ice may contain material discarded on ice during whaling season (trail markers, even sleds)
Human activities and hazards	People go out into this region by boat to look for items to pick up; break-out event in landfast ice in 1997 also had gear left on ice drift into this zone where it was picked up later
Animals	
Other information	
Source of observation	Observations from boats traveling into this area
Implications for search & rescue and spill response	Potential for gear left on ice during break-out events to collect in this region for some time to allow for rescue by helicopter
Scientific follow-up	Identification of this region in surface current data from radar; is this region correctly captured in regional ice-ocean model simulations?

Table 4. Onshore convergence zones

Time or season	Spring through fall
Weather conditions	
Currents and ocean state	Currents converge at points along the shore, leading to accumulation of debris or animal carcasses
Ice movement and conditions	
Human activities and hazards	People collect driftwood and other material here
Animals	Dead animals (walrus, whales) tend to aggregate in such areas along the shore
Other information	Examples of such points (see also maps) include: Skull Cliff; barrier island half-way between Point Barrow and Plover Point; Tapkaluk Islands, 2/3 of the way towards Cooper Island from Point Barrow, and area off Meade Inlet would collect dead walrus or grey whales, attracting fox that could be trapped at those sites; SW of Nuvuk a lot of drift wood and glass floats would accumulate at points along shore; east side of Smith Bay (Drew Point) accumulates much more wood and debris than other areas
Source of observation	Direct observation on the beach or from boat
Implications for search & rescue and spill response	These regions are more likely to see oil or other floating debris come onshore.
Scientific follow-up	Identify points of onshore convergence of currents from local and traditional knowledge; compare with model predictions to guide improvement of model simulations

Table 5. Surface aggregation

Time or season	Late spring through fall
Weather conditions	
Currents and ocean state	
Ice movement and conditions	Ice trapped in eddies or "dead water" such as off Point Barrow
Human activities and hazards	
Animals	Invertebrates in high concentrations at surface, fed upon by seabirds (e.g., thousands of shearwaters, that can detect smell; also phalaropes), hundreds of bowheads; birds move around within approximately 30 mile rectangle in the area towards Cooper and Martin Islands where animals congregate; no belugas present in this surface aggregation, but occasionally walrus may join in
Other information	
Source of observation	Direct observations from boats
Implications for search & rescue and spill response	Floating material and oil will collect in such areas
Scientific follow-up	Identify areas where oil will collect at surface (SAR remote sensing?)

Table 6. Slushy season

Time or season	Fall (Oct-Jan)
Weather conditions	Wind and waves favor slush ice formation (qinu) over quiet freezing
Currents and ocean state	
Ice movement and conditions	Slush ice blown downwind; slush ice collects along current boundaries or confluence zones; slush ice travels deeper into the water column (10s of feet) and picks up sediment and other material
Human activities and hazards	Slush ice potentially hazardous, can creep up into boat if pushed against hull, clog cooling water intake on in/outboards, difficult to make progress in; slush ice appears in early fall first in lagoons and in patches on ocean and is present during late stages of fall whale hunt
Animals	
Other information	
Source of observation	Observations from shore, from boats and on foot on ice
Implications for search & rescue and spill response	Oil entrained into slush ice behaves like sediment in slush ice, i.e., distributed throughout and collected at depth in the water column (incl. if oil is dispersed)
Scientific follow-up	Improved detection of slush ice from satellite remote sensing; mapping of ice drift patterns during this season challenging because HF ocean radar and ice radar have difficulty detecting ice/currents

Table 7. Slush ice outside of fall season

Time or season	Winter and spring
Weather conditions	
Currents and ocean state	
Ice movement and conditions	Ice grinding against another, shear movement, agiuppak; can contain snow that falls into water or is present during ice shear; can form high vertical walls along shear line (tens of feet)
Human activities and hazards	Can disintegrate quickly during warmer conditions in late spring
Animals	
Other information	
Source of observation	Observations from edge of landfast ice
Implications for search & rescue and spill response	
Scientific follow-up	

Summaries of Ice and Current Conditions Off Wainwright

Table 8. Currents off Wainwright and Point Lay

Time or season	Spring to fall
Weather conditions	
Currents and ocean state	
Ice movement and conditions	Ice floes are sometimes seen traveling in opposite directions or at different speeds, indicating that the floes are in different currents
Human activities and hazards	Currents at Icy Cape very strong (mostly from West) and easily capsize a boat and can bring in ice quickly that is hazard to boaters; in past few years at Point Lay shorefast ice was more than 20 mi wide, with hunters going out another 10 mi to catch whales; strong qaisaġniq moved boat for miles within less than an hour while towing whale; at Pt Lay typically three currents with the center one strongest and clear of ice; at Wainwright both qaisaġniq and piruġaġnaq exist, in spring time current gets weaker moving away from the shorefast ice edge (fastest along the edge); strength of currents seems to drop as water gets deeper; 2-3 currents observed typically observed at Wainwright (1-4 mi, 4-15 mi, 15->25 mi out; but can fluctuate); furthest out if water surface has appearance of rolling hills (but calm, glassy) it is very dangerous to be out farther from land.
Animals	Animals move with currents, hunters have to be quick to catch animals as they come through; eddy to the northeast of Point Franklin can trap floating debris and also attracts a lot of animals (seabirds, whales)
Other information	
Source of observation	Direct observations from boat or edge of landfast ice; floating ice shows strength and direction of current; yuayuk where two currents meet off Pt Franklin
Implications for search & rescue and spill response	Need to clarify whether currents are taken into consideration for spill response; may require additional current measurements at Icy Cape
Scientific follow-up	Current measurements at Icy Cape

Table 9. Lagoons

Time or season	Spring to fall
Weather conditions	
Currents and ocean state	
Ice movement and conditions	Rossman Peetook made thickness observations in early 1950s with lagoon ice up to three feet thick in October; now often little to no lagoon ice in October; aayuġaq – cracks along the edges of lagoons along which ice is raised up or down that can set ice on top of adjacent ice (very strong movement); creates little bluff at edge; can result in lowered ice and ice freezing to bottom and then overflow
Human activities and hazards	Point Lay: For hunting of seals, water needs to clear up from break-up river outflow first; 12 June is the earliest to get out of the lagoon; the first week of July is the latest with access to drifting ice with seals/walrus in recent years; latest beluga hunt last year; lagoon was unusually deep and they were difficult to hunt; Wainwright: top current speeds into or out of Wainwright Lagoon can reach up to 4.5 knots (August); near entrance of lagoon behind shallow bar there is a deeper area (up to 30-35 feet deep) where currents are always strong
Animals	
Other information	Lagoon water fresh and tea-colored during break-up and brackish (with seaweed coming in from ocean) later in the season; in the winter salt water may enter lagoon 20 miles in; during break-up freshwater discharge from lagoons enhances current near the coast
Source of observation	Direct observations from boats or the ice
Implications for search & rescue and spill response	Strong currents into and out of lagoons at all times – implications for boom deployment?
Scientific follow-up	Current measurements near mouths of lagoons and tracking of changes in water depth into lagoons

Table 10. Large ice floes and icebergs

Time or season	Spring and summer
Weather conditions	
Currents and ocean state	Local circulation is affected by the presence of icebergs
Ice movement and conditions	
Human activities and hazards	Icebergs impact whale migration, last year whales at Wainwright were observed and hunted north of grounded icebergs
Animals	Elders mention that whales are deflected by grounded icebergs; sometimes plankton can be concentrated near iceberg, possibly attracting whales.
Other information	
Source of observation	Observations by larger number of hunters out of Wainwright traveling by boat or snow machine earlier in the year; first observation of grounded iceberg (“tall as Hotel Captain Cook”) near Wainwright in early spring 2012 came from local hunter and was passed on to others including oil companies.
Implications for search & rescue and spill response	Grounding of icebergs can generate substantial gouges (measurements completed by oil company contractor at grounding site off Wainwright?); icebergs may be hazards in marine environment
Scientific follow-up	Place trackers on icebergs; learn more about origin of icebergs

Table 11. Onshore convergence zones

Time or season	Spring through fall
Weather conditions	
Currents and ocean state	Currents converge at points along the shore, leading to accumulation of debris or animal carcasses
Ice movement and conditions	
Human activities and hazards	People collect driftwood and other material here
Animals	Dead walrus tend to aggregate in such areas along the shore
Other information	At Wainwright such convergence zones are situated towards Point Franklin between Atanik and Point Franklin at Pingusutuġuq and southwest of town towards Killimatoġuq; in the Point Lay region Icy Cape is a prominent spot that catches driftwood and other floating debris
Source of observation	Direct observation on the beach or from boat
Implications for search & rescue and spill response	These regions are more likely to see oil or other floating debris come onshore.
Scientific follow-up	Identify points of onshore convergence of currents from local and traditional knowledge; compare with model predictions to guide improvement of model simulations

Table 12. Freeze-up season

Time or season	Fall (Oct-Jan)
Weather conditions	Wind and waves favor slush ice formation (qinu) over quiet freezing
Currents and ocean state	
Ice movement and conditions	Slush ice blown downwind; slush ice collects along current boundaries or confluence zones; slush ice travels deeper into the water column (10s of feet) and picks up sediment and other material
Human activities and hazards	Slush ice potentially hazardous, can creep up into boat if pushed against hull, clog cooling water intake on in/outboards, difficult to make progress in; slush ice appears in early fall first in lagoons and in patches on ocean and is present during late stages of fall whale hunt
Animals	
Other information	
Source of observation	Observations from shore, from boats and on foot on ice
Implications for search & rescue and spill response	Oil entrained into slush ice behaves like sediment in slush ice, i.e., distributed throughout and collected at depth in the water column (incl. if oil is dispersed)
Scientific follow-up	Improved detection of slush ice from satellite remote sensing; mapping of ice drift patterns during this season challenging because HF ocean radar and ice radar have difficulty detecting ice/currents

Summaries of Ice and Current Conditions Off Cross Island

Table 13. Current structure offshore of Cross Island

Time or season	Late summer and fall
Weather conditions	
Currents and ocean state	Around four currents seaward off Cross and Reindeer Islands; current bands widen with distance from shore; the outermost current is the strongest; inside of barrier islands at Cross/Reindeer Island towards West Dock there are four currents, but they change direction depending on the wind direction; shear line between currents is down the middle between West Dock and the islands
Ice movement and conditions	Ice is taken down the coast (towards the West) by the strong outermost current
Human activities and hazards	The strongest outermost current cannot be crossed by boat; during fall whaling one crew drifted 40 miles off Cross Island towards West Dock in strong current
Animals	
Other information	
Source of observation	Observations by boat during fall whaling season off Cross Island (Nuiqsut crews)
Implications for search & rescue and spill response	High rates of drift and significant shear moving into outermost currents
Scientific follow-up	How is the outermost current related to the Beaufort Gyre and its variable dynamics (e.g. as driven by freshwater content)?

Glossary of Iñupiaq Terms Describing Ice and Ocean

The following Iñupiaq words arose during the workshop or are included as a relevant supplement from the Iñupiaq language on-line dictionary at www.alaskool.org (based on Iñupiat Eskimo Dictionary, D.H. Webster & W. Zibell, Summer Institute of Linguistics, Inc., Fairbanks, Alaska, 1970) and/or Ron Brower's language dictionary "Barrow Iñupiaq Sea Ice Terminology" (unpublished manuscript) and/or Iñupiatun Uqaluit Taniktun Sivunniuġutiŋit North Slope Iñupiaq to English Dictionary compiled by Edna Ahgeak MacLean, 2011 (available at http://www.uaf.edu/anla/collections/search/resultDetail.xml?id=IN%28N%29971M2011), and/or in the book SIKU: Knowing Our Ice, Documenting Inuit Sea-Ice Knowledge and Use, Krupnik, Aporta, Gearheard, Laidler and Holm, Editors, Springer. 2010.

Some words used at the workshop were not in any of the above dictionaries. They could be misspelled and may be phonetically captured at best.

aayuġaq - rising water that can set ice on top of other ice. (see MacLean: "crack in sea or lake ice kept open by shifting currents.")

agiuppak - wall of sheared ice along the edge of the open lead formed by the grinding action of the free ice against the shore-locked ice (see MacLean).

atchaġnaq - offshore directed current that can open the lead; usually wind driven; "yawning". (MacLean has atchaġnaq as ocean current flowing away from shore. W&Z and MacLean: atchaġniq as an easterly wind.)

ivuniġauraq - little pressure ridge, not necessarily grounded (W&Z, Brower; MacLean)

kanaŋaiññaq - onshore current that pushes and closes ice shoreward and closes the lead, generally, but not always wind driven. (Not in W&Z; MacLean: kanaŋŋaq - to come from down there, on or near the ocean. L.Kaplan: kanaŋŋa meaning "onshore". See also MacLean: taksaġnaq as "ocean current flowing directly toward shore".)

muġałłiq - slush ice. "Looks more like junk ice, today." (MacLean: slush ice, waterlogged snow on ocean, foam like in appearance.)

muġrak - slush ice (MacLean)

muqutipkaq - a boat unable to move in slush ice, ice bound boat (W&Z, Brower, MacLean)

piruġaġnaq- current from the NE that often allows one to be out on the ice; more frequent in winter. The dominant current off Barrow that flows from the northeast during winter. (SIKU; MacLean has "to flow from the east out to sea" and "ocean current flowing from the east.")

piqaluyak - salt free ice or old ice gone through several seasons [multi-year ice], perhaps glacial ice (Brower; W&Z says “glacial ice blue in appearance”)

pullianiq - strong currents. (L.Kaplan and R.Brower, personal communication: meeting of currents that can be on top of or alongside each other and create turbulence or undertow.)

qaisaġniq - “The current that brings ice.” Current off Barrow, 3-4 knots, from the southwest that may bring warm water. May accelerate melt and breakup of shorefast ice (SIKU: “That is holding it” - broken floes are being held tight. It is something you can hear as the ice packs together. May be accompanied by current from the west that brings offshore ice shoreward. More common after late-May. MacLean has “ocean current from the west flowing toward shore.” L.Kaplan and R.Brower, personal communication: current that flows along the shore near Barrow from southwest to northeast.)

qaimŋuq – brash ice accumulating in piles. Qaimŋuq is common when there is open water along the beach. It is the berm of ice on the beach during freeze up. (SIKU: qaimuquq - “slush ice berms that offer protection to the coast from waves.” MacLean: white frozen edge of water frozen foam on beach; smooth ice parallel to shore. L.Kaplan and R.Brower, personal communication: qaminŋaq - a verb meaning for water to rise through cracks in ice, so qaminŋaqtuq is a “conjugated verb” meaning “water is rising through cracks in ice”)

qinu – newly formed slush ice. Slush ice in early fall that is snow mixed with seawater that consolidates and freezes. Very dangerous and cannot support weight (SIKU; MacLean: layer of slush ice which forms on ocean at freeze up and clings to shore; to form a thin layer of slush ice.)

qisuk – dark overcast that tells of open water (W&Z; MacLean: “the black color of open water reflected in a low overcast”)

quyagagallak - lines in water where two currents meet near Point Franklin.

sagrat - broken ice that breaks up off of lagoons and comes around the point. A few small cakes of ice in mostly open water or lead that originates as a result of miġiallak (Brower; MacLean: assembled pieces of ice traveling with the current in the ocean.


Nokinba Acker - workshop photographer. See his video of the workshop: http://www.youtube.com/watch?v=g8SR7H0XW_Q

saġvam killiŋa – current’s boundary (two words, a description) (L.Kaplan personal communication) saġvaq – ocean current, also a verb meaning “to flow, of current” (SIKU. MacLean: water current, to have strong current; to drift with, to be carried away by the current. L.Kaplan: verb meaning “to flow, of current”.)

sarri - old ice, pack ice from the north, hangs around as pack ice (W&Z, Brower; MacLean: floating ice pack located away from land-locked ice.)

sikuliaq - ice thick enough to walk on (W&Z). Young ice formed around edge of old solid ice on open lead (Brower; MacLean)

sikuliqiruq - in the process of break-up (W&Z)

sikuaq - young ice, maybe rotten ice; (Brower: thin ice dangerous to walk on; MacLean: thin ice on body of water.)

tuuq - chisel shaped ice impacting fast ice edge, chipping away at it. (W&Z: ice chisel on pole for making fish holes in ice. MacLean: ice chisel; ice pick.)

uliq - sealevel rise due to wind near coast and rivers (MacLean has uliq as “to crack”; ulinniq as “flood”, “high water”; ulit as “to rise, flood”)

yuayuk - standing wave where two currents meet; (MacLean: “to point upward of waves resulting from the crashing of ocean current against waves driven by the wind”. Joe Leavitt, pers. communication, 2008: "yuayuk [...] can also refer to qaisaġniq that is strong enough to push huge iceberg into the strong easterly wind so the icebergs is actually moving into the wind, when the qaisaġniq is strong enough with a strong easterly wind creating waves one can also see splashes going into the air when there is actually nothing there to create the splash.”)

Agendas for Barrow and Wainwright Workshops

March 11–12, 2013 (Monday–Tuesday) at Iḷisaġvik College (Tom Albert Room) in Barrow, Alaska
March 14–15, 2013 (Thursday–Friday) at the Community Center in Wainwright, Alaska

Summary

- Two round table workshops of 2 days in duration each will be held in Barrow and Wainwright.
- Participants will include Iñupiat ocean and ice experts, geophysicists, oceanographers, operational and industry representatives, etc.
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- Workshop goals:
    1. **Sharing knowledge.** Invited participants will share their knowledge of coastal currents and ice movement in the northeastern Chukchi Sea. Participants are highly encouraged to make contributions that are understandable to others that may not share the same expertise or culture. Information will be shared in various forms (stories, summaries of observations, graphical material such as animations or maps, web resources, etc.). Printed material that can be placed on the walls or tables, or provided as handouts, is generally preferred over PowerPoint presentations; however, a computer and projection screen will be available.
    2. **Combining knowledge.** We will identify areas where different bodies of knowledge agree and disagree and where one body of knowledge or available information may complement another. We will focus on dominant, persistent, or recurring spatial patterns, processes that aggregate marine life, and case studies of marine hazards or emergency events.
    3. **Identifying relevance and making recommendations.** We will apply our collective understanding of coastal currents and ice movement in the northeastern Chukchi Sea toward identifying data and knowledge gaps and making joint recommendations on how to improve environmental monitoring, ocean and oil spill trajectory modeling, and risk management and emergency response capabilities.
- Outcomes:
    1. **Improved understanding.** Sharing knowledge between different experts will improve the collective understanding of the role of coastal currents, local weather patterns, and bathymetry in controlling ice movement and the dispersal of marine life in the northeastern Chukchi Sea.
    2. **Report for improved monitoring and response.** A report will be prepared to convert lessons- learned into strategic guidance for improving environmental

monitoring programs, ocean and oil spill trajectory modeling, and risk management and emergency response capabilities.

3. **Report for communities.** A report to will be prepared for participating communities that summarizes the knowledge and information shared during the workshop and the practical outcomes. Much of the workshop will be recorded, especially the shared knowledge of the invited experts. These recordings will available as part of the report.

Agenda (two-day agenda applies to Barrow & Wainwright workshops)

Primary Organizer: Matt Druckenmiller, **Facilitator:** Richard Glenn

Day 1 AM – Welcome, Introductions, Overview, Objectives

8:00-8:15 AM – Arrival

8:15 AM – Invocation (TBD)

8:15-8:45 AM – Local expert from Barrow/Wainwright to introduce the workshop setting (TBD)

8:45-9:15 AM – Background and purpose of workshop (Hajo Eicken, UAF)

9:15-9:30 AM – Introductions

9:30-9:50 AM – Break

9:50-10:10 AM – Background on ocean circulation (Mark Johnson, UAF)

10:10-10:30 AM – Background on sea ice movement (Matt Druckenmiller, NSIDC)

10:30-11:00 AM –Additional comments on topics of concern by participants

11:00-11:20am – Break

11:20-12:00 AM – Preliminary discussion on what to accomplish

12:00-1:30 PM – Lunch at Iḷisaġvik College Cafeteria in Barrow / Catered in Wainwright

Day 1 PM – Knowledge Sharing

1:30-4:15 PM (with one scheduled break) – Contributions from:

- Local experts on their knowledge and observations of marine mammal behavior, coastal currents, sea ice, and search and rescue issues
- Summary of past efforts to document local expert knowledge – Craig George
- Observations of surface currents by high frequency radars – Tom Weingartner
- Shell's observation activities and information needs – Michael Macrander
- General NOAA Operational Modeling Environment (GNOME) - Amy MacFadyen
- Alaska Ocean Observing System (AOOS) Data tools, Ellen Tyler
- Arctic Environmental Response Management Application - Zach Winters-Staszak

4:15-4:30 PM – Break

4:30-5:00 PM – Summarize key points from the day and set priorities for Day 2

The wrap-up discussion from Day 1 will set discussion priorities for Day 2. To the extent possible, we will devote scheduled time blocks to these priorities so that outside participants who wish to join by teleconference can appropriately plan.

Day 2 AM – Combining Knowledge

Identify areas where different bodies of knowledge agree and disagree and where one body of knowledge or available information may complement another.

8:30-12:00 AM (with one scheduled break) – Focus on:

1. Dominant, persistent, or recurring spatial patterns
2. Processes that aggregate marine life
3. Case studies of marine hazards or emergency events

12:00-1:30 PM – Lunch at Iḷisaġvik College Cafeteria in Barrow / Catered in Wainwright

Day 2 PM – Synthesis and Recommendations

Apply collective understanding of coastal currents and ice movement in the northeastern Chukchi Sea toward identifying data and knowledge gaps and making joint recommendations.

1:30-4:00 PM (with one scheduled break) – Focus on:

- Identifying data and knowledge gaps
- Recommendations on improving environmental monitoring
- Recommendations on improving ocean and oil spill trajectory modeling
- Recommendations on improving emergency response capabilities

4:00-4:15 PM – Break

4:15-4:45 PM – Summarize progress, ensure key points, and discuss next steps

4:45:00-5:00 PM – Complete survey on workshop approach and effectiveness

List of Participants

Barrow Workshop:

Billy Adams (Barrow), Roy Ahmaogak (Barrow), Lewis Brower (Barrow), Matthew Druckenmiller (National Snow and Ice Data Center), Hajo Eicken (University of Alaska Fairbanks), Craig George (North Slope Borough Department of Wildlife Management), Richard Glenn (Arctic Slope Regional Corporation), Kevin Hillmer-Pegram (University of Alaska Fairbanks), Charlie Hopson (Barrow), Mark Johnson (University of Alaska Fairbanks), Joe Mello Leavitt (Barrow), Amy MacFadyen (NOAA), Michael Macrander (Shell Oil Company), Andy Mahoney (University of Alaska Fairbanks), Eli Nukapigak (Nuiqsut), Margaret Opie (Barrow), Billy Oyagak (Nuiqsuit), Robert Suydam (North Slope Borough Department of Wildlife Management), Ellen Tyler (Alaska Ocean Observing System), Tom Weingartner (University of Alaska Fairbanks), and Zach Winters-Staszak (Arctic ERMA). Geoff Carroll (Alaska Department of Fish and Game), Tommy Olemaun (Native Village of Barrow), Todd Sformo (North Slope Borough Department of Wildlife Management), Leandra Souza (NSB Department of Wildlife Management), Rafaela Stimmelmayr (North Slope Borough Department of Wildlife Management), Dawn Winalski (North Slope Borough) and by phone Allan Mearns, Nicolle Rutherford, Gary Shigenaka (NOAA) and Glenn Watabayashi (NOAA).

Wainwright Workshop:

Billy Adams (Barrow), Ransom Agnasagga (Wainwright), Matthew Druckenmiller (National Snow and Ice Data Center), Hajo Eicken (University of Alaska Fairbanks), Richard Glenn (Arctic Slope Regional Corporation), Kevin Hillmer-Pegram (University of Alaska Fairbanks), Mark Johnson (University of Alaska Fairbanks), Amy MacFadyen (NOAA), Enoch Oktollik (Wainwright), Billy Blair Patkotak (Traditional Council President, Wainwright), Rossman Peetok (Wainwright), Julius Rexford, Sr. (Point Lay), Bob Shears (Wainwright), Ellen Tyler (Alaska Ocean Observing System), Tom Weingartner (University of Alaska Fairbanks), and Zach Winters-Staszak (Arctic ERMA). Linda Agnassaga (Wainwright), Raymond Aguvluk Jr. (Wainwright), Jr., Cora Akpik (Wainwright), Max Akpik, Sr. (Wainwright), Marjorie Angashuk (Wainwright), Jim Allen Aveoganna Jr. (Wainwright), Jr., Frank Bester, Jr. (Wainwright), Fred Ekak (Wainwright), Nora Itta (Point Lay), Arttie Kittick (Wainwright), Ryan Klimstra (NSB Department of Wildlife Management), Alva Nashoalook, Jr. (Wainwright), Jack Panik (Wainwright), Ida Panik (Wainwright), Michael Tagarook.

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