Human geographies of sea ice: freeze/thaw processes around Cape Dorset, Nunavut, Canada

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ABSTRACT. Sea ice has been, and continues to be, an integral component of life in the Inuit community of Cape Dorset, Nunavut. Located on an island of the same name off the southwestern coast of Baffin Island, the strong Hudson Strait currents prevent extensive ice formation around the community. Nevertheless, sea ice remains an important travel and hunting platform, enabling access to Baffin Island, hunting and fishing grounds, and nearby communities. With the combined importance, dynamism, and continuous use of this frozen ocean environment, local Inuit elders and hunters have developed a detailed and nuanced understanding of sea ice conditions, freeze/thaw processes, and the influences of winds and currents on ice conditions. Working collaboratively with the community of Cape Dorset since October, 2003, we present the results of 30 semi-directed interviews, 5 sea ice trips, and 2 focus groups to provide a baseline understanding of local freezing processes (near-shore, open water, sea ice thickening, landfast ice, floe edge, and tidal cracks), melting processes (snow melt, water accumulation and drainage, break-up, and cracks/leads), wind influences on sea ice (wind direction and strength affecting sea ice formation, and movement), and current influences on sea ice (tidal variations and current strength affecting sea ice formation, movement, and polynya size/location). Strong emphasis is placed on Inuktitut terminology and spatial delineations of localised ice conditions and features. Therefore, this paper provides insights into local scale ice conditions and dynamics around Cape Dorset that are not captured in regional scale studies of Hudson Bay and/or Hudson Strait. Results have the potential to inform future research efforts on local/regional sea ice monitoring, the relationship between Inuit knowledge, language, and the environment, and addressing community interests through targeted studies.

Contents

Introduction

> [I]n the winter [the sea ice] is very useful. We rely on it, that's why we have to know the conditions so much because we [use] it from beginning to the end. It was so much so in the past, but not as much now. We don't rely as much on country food, like it's only a percentage now of our daily diet. [B]ut still we use that information. [It] is good for as long as we live here because we're still going to use [the ice]. I don't see any highways out on the land, so it's still going to be our highway. The kids still have to learn the points, the fall and the spring and the winter, the conditions, they will have to learn that. [A] big part of our life is spent on the ice, especially here where our name is, where our regional name is so much recognizable as people who live 'where there's water', not just ice, but where there's water. It's very important to know [about the sea ice] (Joanasie 2004).

Sea ice is an important platform upon which Inuit have been travelling, hunting, gathering, and living for at least 5000 years (Riewe 1991). While many Inuit are now settled in coastal communities, sea ice continues to form an integral social, economic, and traditional component of their lives (Wenzel 1991; Pelly 2001; Poirier and Brooke 2000; Aporta 2004; Robards and Alessa 2004). The knowledge they have developed of the ice, its nature, and its processes is embedded within their culture and identity (Aporta 2002). Inuit are astute observers of the sea ice edge (Nakashima 1993) as their harvesting practices, livelihoods, and/or personal safety depend on their knowledge and perception of changing ice, sea, and weather conditions. As such, Inuit elders and active hunters may be considered the experts on local ice conditions and dynamic processes because of their extensive use and experience of traveling on, and observing, ice conditions in order to assure safe travel and successful hunting (Nelson 1969; Freeman 1984; Krupnik 2002). As climate change is now at the forefront of public and scientific consciousness, the implications of changing sea ice environments on northern communities and wildlife are often at the centre of current research and debates (Kerr 1999; Copley 2000; IPCC 2007; Symon and others 2005). However, relatively little has been done to document systematically, or to understand, Inuit knowledge of these environments in efforts to learn about potential implications from local perspectives (Thorpe and others 2000; NCE 2000; NRI 2002). Yet this is an important foundation for discussions around adaptation and vulnerability/resilience.

Within the scientific community, there is a limited understanding of sea ice at local scales, especially in relation to Inuit culture, lifestyle, and socio-economic practices. This paper is the first in a series of three coordinated by the first author, and with different other authors, that presents an initial attempt to document and communicate sea ice conditions and Inuktitut (Inuit language) terminology based on detailed local expertise in different Inuit communities around Baffin Island, Nunavut. Here, we present the results of research undertaken in Cape Dorset, Nunavut, from April 2004 to May 2005. Documenting Inuktitut terminology and explanations of local freeze-thaw processes, and the related influences of winds and currents on ice formation or movement, provides a unique glimpse of Inuit expertise on local-scale physical ice conditions and processes. Such detailed Inuit understanding has been documented previously in Alaska through Nelson's (1969) in-depth account of sea ice conditions and use around Wainwright, the important volume of Oozeva and others (2004) depicting local ice conditions and Yupik terminology for Savoonga and Gambell, and the description of Barrow ice conditions by Gearhead and others (2006). Freeman (1984), McDonald and others (1997), Aporta (2002) and Gearheard and others (2006) also touch on some key ice conditions and Inuktitut terminology in the eastern Canadian Arctic. The aim of the present paper is to build on these works by providing a detailed account for Cape Dorset, but also to move beyond glossaries by emphasising the interrelations between terminology, ice conditions, and seasonal processes.

Methods

Community

Cape Dorset is located on a small island of the same name off the southwestern tip of Baffin Island (Foxe Peninsula), in Hudson Strait (64°14′N, 76°40′W) (Fig. 1a). This area was named by Luke Foxe who explored parts of Hudson Bay and Foxe Basin in 1631, with the cape being named after the Earl of Dorset (Kemp 1976). However, in Inuktitut Cape Dorset is known as *Kinngait* (meaning 'mountains') (Milne and others 1995; Laird 2004). In the past it has also been referred to as *Sikusilaaq* (meaning 'where there is no ice') because of the strong Hudson Strait currents that result in the nearby presence of open water throughout the winter (Walk 1999; Henshaw 2006). The surrounding region has a rich archaeological history, with evidence of Inuit land use and occupancy dating back at least 3000 years (Henshaw 2006). A Hudson Bay Company (HBC) trading post was established in this area in 1913, which became the basis of community settlement in the 1950s (Kemp 1976; Laird 2004). Now with a population around 1236 (93% Inuit) (StatsCan 2006), Cape Dorset is renowned for its art, cultural history, and proliferation of marine wildlife (Blodgett 1991; Milne and others 1995; Walk 1999; Doubleday and others 2004).

Research approach

This project was undertaken with community members of Cape Dorset using a collaborative approach adapted from Gibbs (2001), and described in Laidler (2007), in order to develop cooperatively, and to refine, research directions, questions, plans, and results. This was essential in order to gain community support, involvement, and feedback (ACUNS 2003; Gearheard and Shirley 2007). The research was initiated by a preliminary visit to Cape Dorset in October 2003 in order: i) to propose the project to community groups and organisations; ii) to discuss community interest in the project; iii) to establish jointly research priorities; iv) to answer questions or concerns; v) to assess project feasibility; and, vi) to determine appropriate field work timing and duration. Subsequently, several field research visits were planned according to community suggestions to return at various stages of sea ice freezing and decay (April and November 2004, and January and May 2005), totalling nearly three months spent in the community. A more thorough discussion and evaluation of methods is provided in Laidler (2007). The main methods relevant to this paper are described here.

Semi-directed interviews

Inuit elders and hunters deemed to be the most knowledgeable about sea ice by community members and representatives (that is community organisations such as the Hunters and Trappers Association, interpreters, and other elders and hunters), were recommended as key informants in a purposeful sampling strategy. In total (over the four research trips), 30 semi-directed interviews (Huntington 1998; Bennett 2002; Esterberg 2002) were conducted with 21 different people, 17 male, 4 female (out of a recommended list of 30 people) (Table 1). No fixed questionnaire was administered, and no time limit was placed on discussion (an average duration of which was approximately 2 hours). Instead, general questions about Inuktitut sea ice terminology, descriptions of freeze/thaw processes, and the influences of winds and currents on sea ice formation or movement, were asked in order to initiate discussion and explanation of related topics. All interviews were conducted by the first author, with the second author interpreting or facilitating where the interviewee was most comfortable (or unilingual) in their native language of Inuktitut. Interviews were conducted in people's homes, the Hamlet Council Chamber, and the Malikjuaq Visitor's Centre, depending on what space was available and where the interviewee felt most comfortable. Where consent was provided, interviews were recorded with audio and/or videotape. All originals (and transcripts) are stored at the Community Learning Centre (Nunavut Arctic College) to ensure community access to these materials.

Four National Topographic Service (NTS) map sheets at the 1:250,000 scale (36B, C, D and 35N; see Fig. 1b) were incorporated in interviews: i) to facilitate

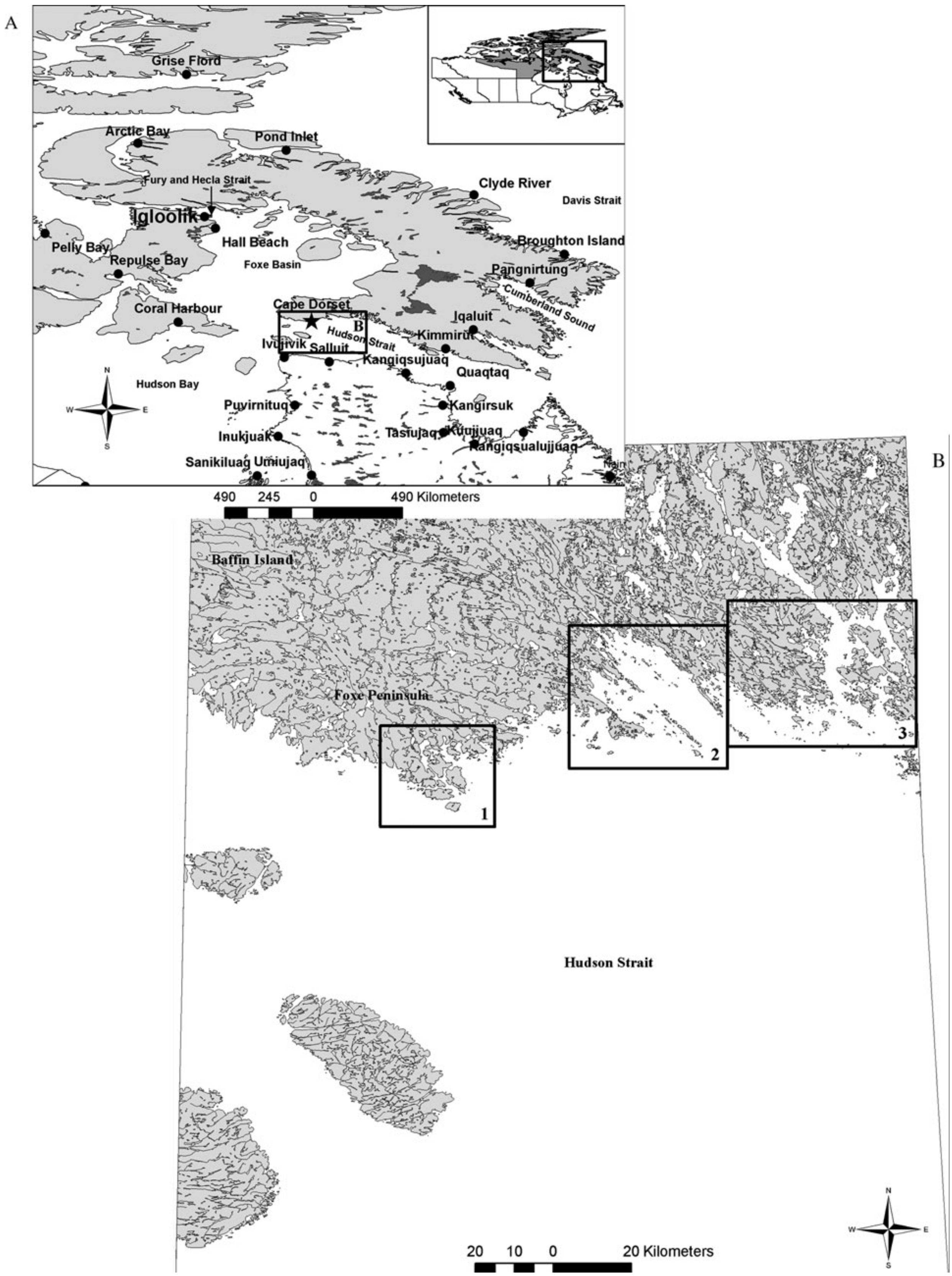

Fig. 1. Study area maps, including: a) map showing the location of Cape Dorset (Nunavut highlighted in grey in inset, and the square indicates the Baffin Island region shown in the larger map); b) map sheets and extent used in interviews, with squares indicating the areas of interest portrayed as subsets throughout the paper (1 = Cape Dorset Island and surroundings (Figs. 7, 9b, 10, and 14b); 2 = Andrew Gordon Bay (Fig. 9a); 3 = Chorkbak Inlet (Fig. 14a)).

Table 1. Interview participants (sorted alphabetically by code to facilitate interviewee identification throughout the text).

Code	Name	Interview date
AA1	Atsiaq Alasuaq	Apr 27/04 (×2)
AE1	Ashevak Ezekiel	Jan 18/05
AN1	Adamie Nuna	Apr 15/04
AP1	Aleka Parr	Nov 30/04
EE1	Etulu Etidlouie	Nov 14/04
EE2	Etulu Etidlouie	Nov 15/04
EM1	Eliyah Mangitak	Apr 16/04
EP1	Etidlouie Petaulassie	Nov 25/04
IN1	Iqadluq Nunguisuituq	Apr 19/04 (×2)
JM1	Jimmy Manning	Jan 19/05
JM2	Jimmy Manning	Jan 28/05
KS1	Kanayuk Solomonie	Apr 28/04
MJ1	Mathewsie Joanasie	Nov 20/04
MK1	Mangitak Kellypalik	Apr 15/04
MK2	Mangitak Kellypalik	Apr 16/04
MS1	Mikisiti Saila	Nov 26/04
NP1	Ningeoseak Peter	Nov 22/04
OM1	Oqutaq Mikigak	Nov 26/04
OM2	Oqutaq Mikigak	Nov 27/04
OO1	Oqsuralik Ottokie	Apr 27/04
PP1	Paulassie Pootoogook	Apr 23/04 (×2)
PP2	Paulassie Pootoogook	Jan 13/05
QP1	Qatsiya Petaulassie	Nov 29/04
QT1	Quvianaqtuliaq Tapaungai	Nov 29/04
QT2	Quvianaqtuliaq Tapaungai	Jan 21/05
SK1	Sandy Kelly	Jan 29/05
SS1	Simigak Suvega	Apr 28/04

knowledge-sharing; ii) to enhance explanations of sea ice conditions or uses; iii) to enable spatial delineation of key sea ice features, regional sea ice extent, or uses (for example hunting areas, travel routes); and, iv) to promote discussion or to spark memories (Laidler 2007). Each interviewee had his or her own clear mylar (plastic) overlay upon which he or she could draw sea ice features that were most familiar or that he or she wanted to document.

Sea ice trips

In order to begin to understand, and conceptualise, Inuit expertise of sea ice it was imperative that the authors (and mostly the first author) experience, and participate in, sea ice travel and/or hunting. This is often referred to as participant observation (Kearns 2000; Fox 2002), but it is preferred to emphasise the experiential aspects because it was more than simple observation. Such trips were encouraged by elders as being the best way to learn about sea ice from an Inuit perspective, a more traditional method of teaching and learning (Thorpe 1998). Therefore, these were prioritised wherever possible, and the first author was fortunate to participate in five different sea ice trips (on foot, by dog team, and by snowmobile) to various locations around Cape Dorset (the floe edge, Tellik Inlet, a nearby polynya, and fishing lakes/goose hunting grounds around Andrew Gordon Bay), at least once during each of the research trips. These trips were guided by elders that had been interviewed and a local outfitting/tour company.

Focus groups

Focus groups (Lindsay 1997; Fox 2002) were employed to bring small groups of local experts together: i) to link Inuktitut terminology for various ice conditions to pictures taken on sea ice trips; ii) to develop and verify terminology links within a sequential order of sea ice formation/decay based on compiled interviews; and, iii) to verify sea ice features drawn on maps. Two focus groups were conducted in one in each of the third and fourth research trips (January and May 2005). These sessions were an important means of acquiring feedback and helping to ensure the accuracy of the interpretation of results.

Data analysis

Audio recordings were used to compile word-for-word transcripts of the translated (English) components of the interviews. This was followed by content analysis that consisted of coding transcript statements into key themes/topics (Patton 1980; Dunn 2000; Esterberg 2002). Codes were created to reflect the questions asked in interviews, as well as any new concepts identified through the interview process. Coding was done manually, but was assisted by qualitative analysis software Atlas.ti (version 5.0.66), making it easier to compile similar themes in order to facilitate analysis and the development of conceptual models, explanations of sea ice terminology, and process descriptions. The specific codes relevant to the results and discussion in this paper include: cracks, currents and ice, floe edge, freezing processes, importance of sea ice, Inuktitut terminology, landfast ice, map features, melting processes, moving ice, polynyas, snow influences on sea ice, and winds and sea ice. The conceptual models presented in the following sections attempt to highlight the relationships between each of these ice types/features/processes, based on Inuit expertise, in order to provide an overview of the human geographies of sea ice around Cape Dorset.

Knowledge representation

The results presented in the following sections are based on what Inuit elders and hunters shared during interviews, sea ice trips, and focus groups. Because they are the experts regarding local ice conditions, each interview is formally referenced the first time it occurs in the paper. However, for later occurrences, a coding system is used to identify interviewees to save space within the text (Table 1). Square brackets [ ] are employed within quotes to replace third person references used by the second author in interpretation. Every effort has been made to present the information that was provided accurately and consistently to form a comprehensive picture of local ice conditions. Nevertheless, such results cannot be static, and they will evolve as terminology and explanations are refined, new descriptions are added, or formats are changed. It is also important to note that Inuktitut terminology is not standardised across Nunavut,

Table 2. Inuktitut terminology, descriptions, and brief definitions for sea ice conditions associated with freezing stages (in approximate order as shown in Fig. 2).

Term	Description	Brief definition
	Near shore freezing	
sikuvaliajuq	Action, ice formation	when the ice is just starting to form (harden)
qinnu	Autumn ice condition	early stage of ice formation, slush
ilaupalia	Action, ice formation	process of *ilu* forming
ilu	Autumn ice condition, near shore	early freezing in the low tide area
kuiviniq	Autumn ice condition, near shore	ice frozen over rocks along the shore
qaikut	Autumn ice condition, near shore	ice recently frozen to the ground
sikurtusijuq	Autumn ice condition, near shore	ice that has formed just past the low tide area
sijja	Ice condition, near shore	ice that forms along the edge of land (usually rough from tidal variations)
	Open water freezing	
qaikuin	Autumn ice condition, in open water	chunks of ice that form in open water, after *qinnu*
qalligirtuq	Action, ice formation	sea ice being pushed together (by winds or currents) into overlapping formations
sikuliaq	Autumn ice condition, in open water	newly formed, smooth ice in open water
	Sea ice thickening	
sikuaqtuq	Action, ice formation	the process of *sikuaq* forming
sikuaq	Autumn ice condition	the first thin layer of frozen ice
millutsiniq	Ice condition	slushy patch on the ice caused by snowfall on thin ice
sallivaliajuq	Action, ice thinning	ice thinning due to rain, wind, or snowfall
qamittu	Autumn ice condition	ice with a little bit of water on it
nigajutaq	Autumn ice condition	an area of sea ice that freezes later than others
qangutaituq	Action, ice formation	process of *qanguti* forming
qanguti	Ice condition	ice with crystal-like snow formation on top
sikuqaq	Autumn ice condition, near shore	ice that is a few weeks old, covering inlets
sikujuq	Autumn ice condition	ice that is travelable
	Landfast ice	
kuvvilukajuq	Autumn ice condition	ice that will not break off and is safe for travel
siku	Ice condition	general term for solid sea ice
tuvaq	Ice condition	solid ice that is attached to the land
tuvatuqaq	Ice condition	after snow has accumulated on *tuvaq* (old *tuvaq*)
	Floe edge	
sinaaq	Ice feature, ice edge	floe edge, delineation between *tuvaq* and open water
uiguaq	Ice condition, ice edge	new ice that forms at the floe edge
uqaq	Action, ice edge	process of ice breaking off at the floe edge
uqaqtuq	Action, ice edge	when *uqaq* is occurring
uqakuti	Ice feature, moving ice	ice that has broken off the floe edge (*uqaq*), and is now free floating
	Cracks	
nagguti	Ice feature, tidal crack	a crack that forms in the winter and re-freezes
qullupiarniq	Ice feature, tidal crack	a crack in the ice that opens, freezes, and then re-opens (creates a peaked formation)
ajuraq	Spring ice feature, crack/lead	tidal crack that does not re-freeze, open water remains within it
ikiqtusijuq	Action, cracking	a crack that is widening
nipittupaliajuq	Ice feature, crack	a crack that you have to jump over to cross
ikiqtuq	Action, cracking	a widening crack that would require a boat to cross

or even within Cape Dorset, so the terms presented here reflect the majority of descriptions provided, but cannot necessarily be extended to other communities within, or outside, Nunavut because of dialectical differences. Furthermore, the authors have incorporated Inuktitut sea ice terminology throughout the text, to the best of their ability, in order to present Inuit expertise in a manner that closely resembles the way in which it was shared with them. Where possible, the scientific sea ice terminology (according to World Meteorological Organization (WMO) standards, as summarised in Laidler (2006a)) has been stated that most closely approximates to the meaning of Inuktitut terms.

Freezing processes

In this section, Table 2 and Fig. 2 should be consulted as references for Inuktitut terminology and links between processes.

When sea ice begins freezing around Cape Dorset it is referred to as *sikuvaliajuq* (Nungusuituq 2004

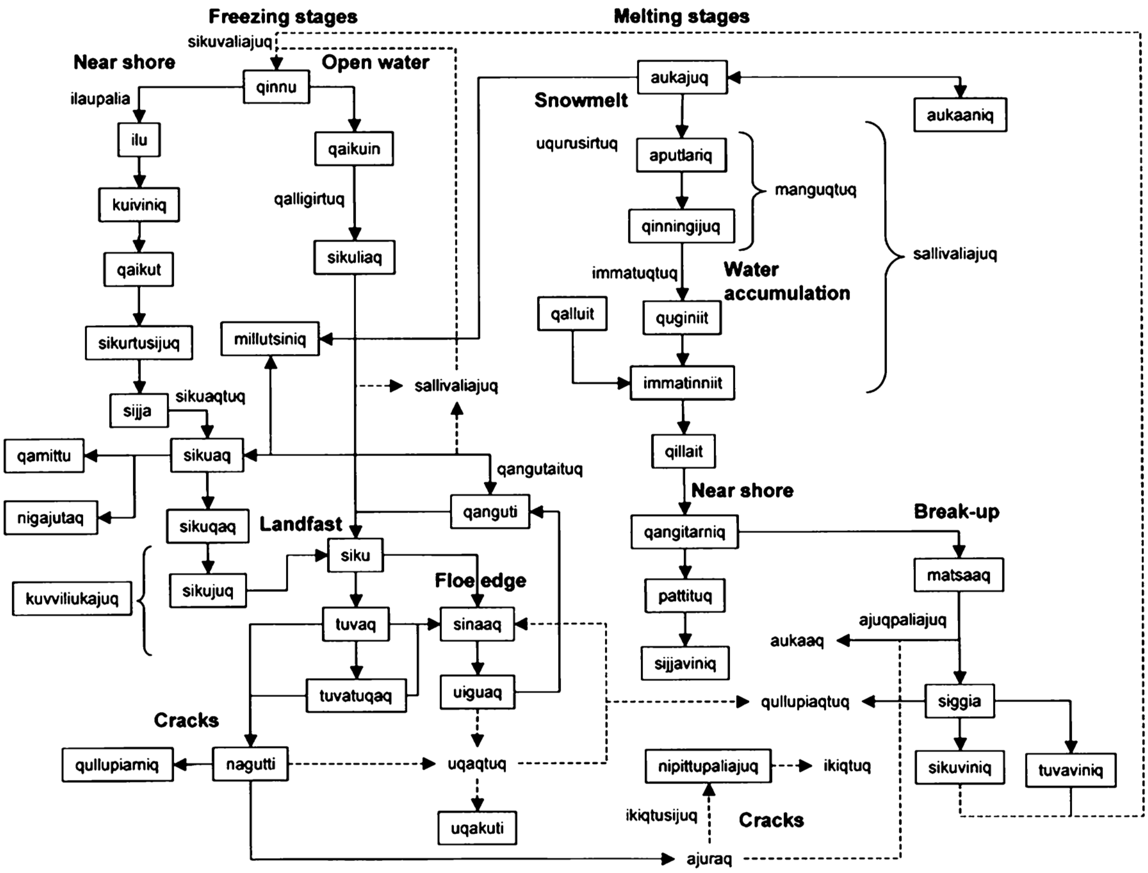

Fig. 2. Conceptual diagram of freeze-thaw processes, interactions, and terminology based on interviews conducted in Cape Dorset. Where: a solid line = general process direction, a dashed line = cyclical/intermittent process direction. Inuktitut terms in boxes are ice conditions or features, while those outside boxes are sea ice processes. English terms in bold font highlight the general freezing/melting stages.

(IN1); Mikigak 2004a (OM1); Pootoogook 2004 (PP1); Petaulassie 2004b (QP1) (Fig. 2). The earliest ice formation is *qinnu*, a slush-like consistency that begins to form with the colder temperatures (likened to frazil or grease ice) (Alasuaq 2004 (AA1); Ezekiel 2005 (AE1); Joanasie 2004 (MJ1); Ottokie 2004 (OO1); Kelly 2005 (SK1)) (Fig. 3a). However, as freezing progresses, different terms are used concerning whether the ice is extending from the shoreline or forming in open water.

Near-shore freezing

Along the shoreline, the process of *ilaupalia* (OM1) contributes to the formation of *ilu*, where ice has frozen to the ground when the tide was low (Parr 2004 (AP1); Etidlouie 2005a (EE1); Kellypalik 2004a (MK1); Saila 2004 (MS1); OM1; QP1; Tapaungai 2004 (QT1)).

> [The] beginning stage of freezing up, that is when it's low tide, rocks or the sand will start freezing when it's low tide and it starts to be cold. But [when] high tide comes that ice will float up from the frozen part, and then it will keep freezing until then, unless it's windy. [W]hen it starts freezing, *ilaupalia*, is the first stage. Sometimes [there] will be chunks forming where it's freezing, that's kind of where it's shallow, you will see [ice] that has formed where there was a rock right under it, but actually the rock is like 4 feet down under there (Mikigak 2004a).

Ice then begins to freeze to the rocks in shallow areas (*kuiviniq*), but it will break off when the tide is high (Petaulassie 2004a (EP1)) (Fig. 3b). This ice eventually freezes to the ground (*qaikut*), but it will pop up after several tides (AP1; Peter 2004 (NP1); QT1). Following this, as the ice extends past the low tide area it is referred to as *sikurtusijuq* (QT1). Once the shoreline ice has formed fully, and is attached to the land, it is known as *sijja* (Nuna 2004 (AN1); EE1; MK1; QT1) (Fig. 3c). From the *sijja*, ice extends outwards from the land as it freezes, thus coming together with other ice conditions that have formed in open water (Fig. 2).

Open water freezing

Away from shore, after *qinnu* has formed, there are different terms used to describe sea ice freezing (Fig. 2). Chunks of ice that form because of movements in open water are referred to as *qaikuin*, which may also be found along the floe edge (see below) after it has been established.

> [*Q*]*aikuin* the next stage after qinnu, that's when chunks of ice will form on top of the slushy water. After that stage it will [stay] like that for a few days

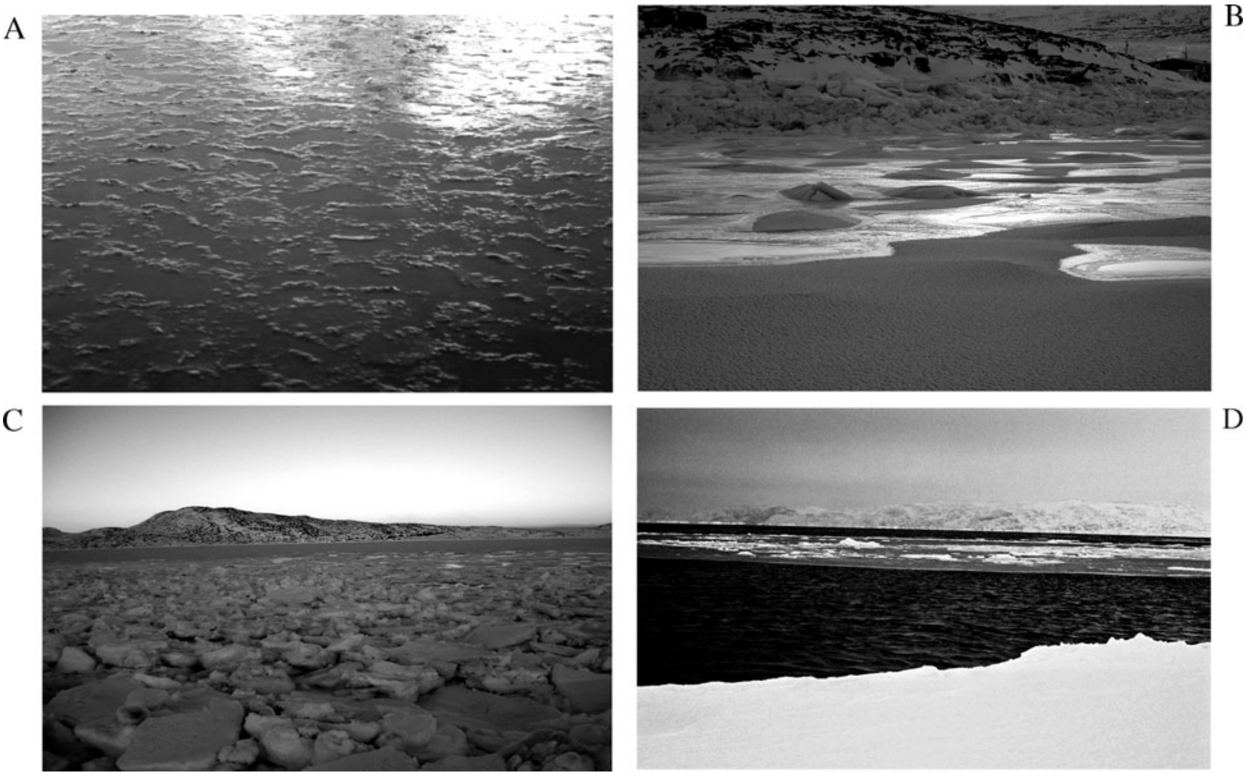

Fig. 3. Photos of early near-shore freezing, including: a) *qinnu*, early slush-like ice formations; b) *kuiviniq*, ice freezing to the rocks; c) early formation of *sijja*, shoreline ice; and, d) *sikuliaq*, new ice forming in open water.

> until it either gets colder or warmer. *Qaikuin* is the word that's used when the ice is still kind of wavy (Ezekiel 2005).

These *qaikuin* are usually created during windy conditions, where waves push the *qinnu* together into distinct 'chunks', thus forming patches of rough, free-floating ice that move with the currents (likened to pancake ice) (AE1; Mikigak 2004b (OM2); SK1). Similarly, when ice is freezing in open water, especially with the influence of winds or currents moving it around, ice tends to thicken as it is pushed together with, or onto, other pieces of ice. This process is referred to as *qalligirtuq* (EE1). Following this, newly formed, relatively flat ice that freezes in open water is called *sikuliaq* (likened to ice rind) (AE1; AN1; IN1; QT1) (Fig. 3d). From there, early ice formations in open water tend to begin joining up with ice formations that have extended from the shoreline (Figs. 2, 4).

Fig. 4. The freezing process, gradually extending away from shore, 23 November 2004, Cape Dorset.

Sea ice thickening

> [The] first layer of freezing ice is called *sikuaq*. Also, depending on the ice thickness you can say *sikuaqtuq* or *sikuaq* depending on what sentences you use or what subjects you use on the ice. [The] first night when it freezes it's usually very shiny, after one night it could be maybe a 1/4 inch thick or so (Alasuaq 2004).

The first continuous layer of frozen ice is *sikuaq* (likened to nilas or young grey/white ice), whereby *sikuaqtuq* is the process of *sikuaq* forming (AA1; MJ1; Suvega 2004 (SS1)) (Fig. 5a). Because *sikuaq* can refer to a range of thicknesses of newly frozen ice, it may be possible to walk on *sikuaq*, but a person must carefully test it with a harpoon to determine its strength and thickness.

> In terms of freezing up, *sikuaq* is very thin, you can puncture a hole [with a harpoon] in one or two strokes into the same spot . . . Usually [by the] second day if it's the same coldness or colder when it was freezing, you can go on it, but you have to [travel] with a harpoon . . . [I]f you strike the same spot twice and it goes through that's too dangerous, once very dangerous (Joanasie 2004).

Fig. 5. Photos of sea ice thickening, including: a) *sikuaq*, thin, newly formed ice (note that although *sikuaq* is described as thin, it is also sometimes described as being capable of supporting a person's weight; therefore, *sikuaq* can be within a range of thin ice conditions, not necessarily only the thin film of ice shown here); b) *nigajutaq*, an area in the ice that freezes over later than others; c) *qanguti* forms on thin ice, or at the floe edge, due to the temperature differences between the air and the ocean; d) a closeup view of *qanguti*, showing the crystal- or snowflake-like formations; e) *sikujuq*, the ice is thickening and will soon become *siku*; and, f) *tuvaq*, solid ice that is attached to land, here *tuvaq* is shown in Tellik Inlet, and *sijja* is shown in the foreground.

Because sea ice does not freeze in a completely uniform manner, there can be areas where water remains on top of the ice (*qamittu*) (MK1) or where certain small patches remain open (*nigajutaq*) (Fig. 5b) (EE2). For either *sikuaq* or *sikuliaq*, snowfall on this newly formed thin ice could lead to a thinning of the sea ice (*sallivaliajuq*) (MS1; QP1). Snow can influence the freezing process in several ways. If the ice is very thin, falling snow will sink into the ice, creating soft ice conditions that may turn into slush (AA1). If the new ice is a little thicker, snow could accumulate on the ice cover, but it then acts as an insulator (*uqurusirtuqsimajuq*) from the cold air above, allowing the warmer ocean temperatures to melt the ice from below (EP1).

> [*U*]*qurusirtuqsimajuq* means like when you have a jacket, you know down-filled jackets that have feathers in them? When it has snowed in some areas where ice usually forms, in that area if it isn't that cold and the snow is thickening, the snow won't harden and acts as insulation (Etidlouie 2005a).

If this occurs, the ice conditions become very dangerous, and the freezing processes would begin anew (Fig. 2). Furthermore, *millutsiniq* is a specific condition in which a patch of ice remains mushy after snowfall has accumulated on new, thin ice (Fig. 2) (EE1; EP1; QP1). For example, this could occur if snow had fallen over a crack, where the ice is thinner than either side of the crack. Again, the snow would contribute to the ice melting from underneath, leading to a slushy consistency (EE1; EP1; QP1). An additional condition called *qanguti* (likened to frost flowers) may form on *sikuaq*, or on ice at the floe edge (Figs. 2, 5c). The process of *qangutaituq* leads to the formation of *qanguti*. This condition is identifiable when the ice is covered with what looks like little crystal-like snowflakes, or flowers growing out of the ice (Fig. 5d) (AA1; EE1).

> The second part of freezing ice is called *qangutaituq*. It is called that because sometimes in a few days when the ice is freezing, if it hasn't been snowing or anything, even though it hasn't snowed crystals start growing from the ice. It's like plants are growing on the ice, that's when it starts getting freezing (Alasuaq 2004).

The formation of *qanguti* is also used as an indicator of areas where the ice will form smoothly once it has thickened (AA1; EE1).

As the ice gradually thickens it changes from *sikuqaq* to *sikujuq* and finally to *siku* (Fig. 2). Generally, the ice thickens first in inlets, where it stops moving as it becomes more solid (*sikuqaq*) (AE1; EE1; EP1; NP1; OM2). At this point seals are making breathing holes (*atluan*) through the ice, it is a few weeks old, and it is possible to walk on the ice. Then, having thickened past a few inches, *sikujuq* can be used for seal breathing hole hunting (NP1) and careful travelling (Fig. 5e) (EE1; MK1; OO1). Any ice thicker than *sikujuq* is referred to as *siku*, a general term for sea ice (likened to first-year ice), which also implies that any kind of sea ice travel is now possible (AE1; AN1; EP1; MJ1; NP1: QT1; SK1; SS1). After *siku*, *tuvaq* is used to refer to ice that is older and more solid (thicker) than *siku*, and is securely attached to the land (likened to landfast ice) (Figs. 2, 5f) (AE1; EP1; MJ1; QT1; SK1).

> [*S*]*iku* is like loose ice, but *tuvaq* is land locked ice, it's part of the land. But *siku* is more loose, could be part of the sea ice if it's broken off, *siku*. But a lot of people will use *siku* now [to refer to] *tuvaq* (Joanasie 2004).

When the *tuvaq* thickens and snow accumulates it then becomes *tuvatuqaq* (old, mid-winter ice) (EP1; NP1). It must be noted that once the ice becomes *siku* or thicker, snowfall no longer contributes to melting when the temperatures remain cold. Furthermore, ice conditions from *sikujuq* onwards in the freezing process can be considered *kuvvilukajuq* (where the ice will not be breaking off anymore) (OM1) (Fig. 2).

Tidal cracks

Cracks are usually formed by the movement of the sea ice, from contraction or expansion in the freeze-thaw process, or from the force exerted by winds and/or currents. Tidal cracks tend to form in the same location annually, and go through cycles of cracking, opening, and re-freezing through the winter in synchronisation with the lunar cycle (MS1; NP1; QP1; Tapaungai, 2005 (QT2)). They are also affected by the diurnal tidal cycle, where the difference in daily high and low tides causes ice movement and cracking (MK1; SS1). When this kind of crack forms in the winter it is referred to as a *nagguti*, which means tidal crack but implies that it refreezes after it opens (Fig. 2, 6a) (AA1; AE1; AN1; AP1; EE2; Manning 2005a (JM1); MK1; NP1; OM2; QT1; SK1). This same crack in the spring would be called *ajuraq* because after it opens it does not re-freeze (likened to a lead) (Figs. 2, 6b) (AE1; AN1; AP1; EE2; JM1; NP1; MJ1; MK1; OM2; OO1; PP1; QP1; QT1; SS1; SK1). The term *qullupiarniq* is also used to refer to a crack that opens, re-freezes, and then opens again in the same spot with a peaked ice formation over the crack (Figs. 2, 8c) (QP1).

Cracks were frequently drawn on the maps as occurring near Aupaluktuk Point (Apalooktook Point on the map), near Iglukjuak Point, as well as between islands or in narrow areas (Fig. 7).

> [P]retty much where there are islands, closer to the islands it will usually form these cracks, except for the mainland area. Usually around the small islands it forms these kinds of cracks. Every little island that you see there's some kind of crack that's going to form (Tapaungai 2004).

Cracks typically form from land to land (usually at points, or between islands) (Fig. 7) (AE1; EE1; EP1; JM1; QT1; SS1), and are thus identified by the nearest placenames on each shore (AP1). Where cracks form by tidal action is also where the ice tends to break off (*uqaq* or *aukaaq*) with the influence of winds (EP1; MJ1; MS1; OM2). Essentially, cracks form when stress is placed on the sea ice cover, such as when: i) ice collides or pushes onto, or into, each other; ii) tides or currents move the ice up or down; and/or, iii) winds force the ice together or apart. There can be little cracks all over the ice surface, but *naggutiit* (plural for *nagguti*) are both important hunting destinations and potentially dangerous areas where the ice may break off.

Floe edge

The floe edge (*sinaaq*) is the edge of landfast ice, the delineation between the *tuvaq* and open water (Figs. 8a,

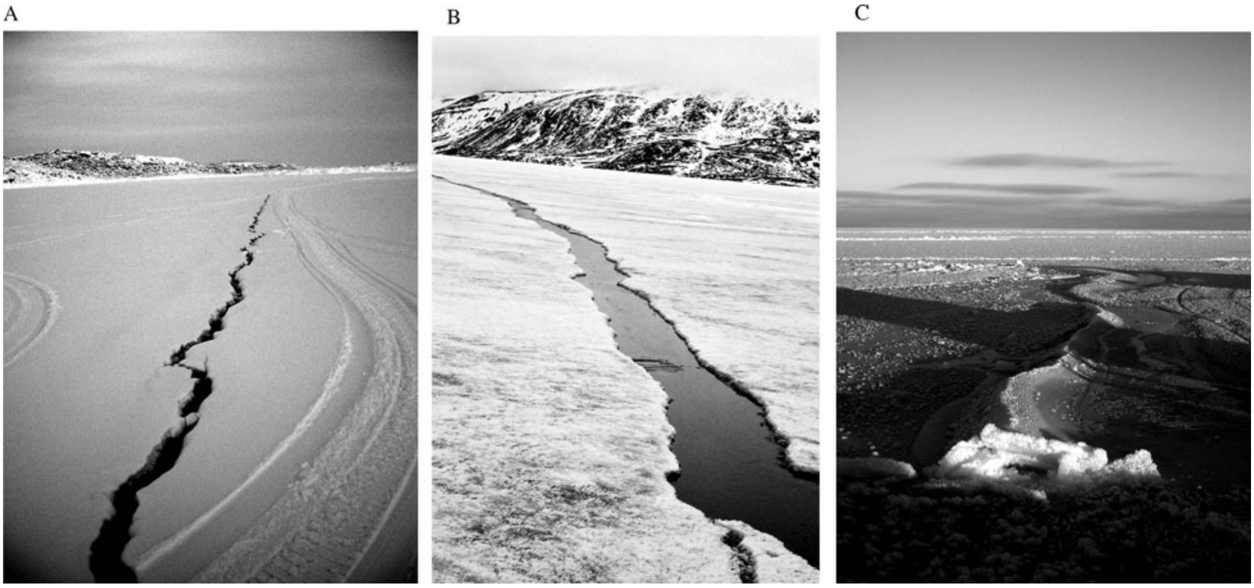

Fig. 6. Photos of different types of tidal cracks, including: a) *nagguti*, a tidal crack that forms in *tuvaq* in the winter and re-freezes; b) *ajuraq*, occurs in the spring and does not re-freeze after opening; and, c) *qullupiarniq*, a crack that opens, re-freezes, and opens in the same spot (it can become peaked over where the crack has formed).

8b) (SK1; SS1). At the *sinaaq*, any new ice that forms is termed *uiguaq* (literally meaning 'an addition'), whether it is extending from the edge of the *tuvaq* or it is re-freezing after ice has broken off (Fig. 8c) (AN1; EE1; JM1; MJ1; MK1; NP1). The action of ice breaking off from the *sinaaq* is termed *uqaqtuq* (Figure 8d) (JM1; MK1; OO1). Once a piece of breaks off from the *sinaaq*, it changes from being *siku* or *tuvaq* (while it was attached) to being *uqakuti* (MK1).

> [W]e would call that *uqaq*, *uqaqtuq*, when a big pan of ice breaks off from a good floe edge. That happens when we have solid ice, and then we have like *nagguti*

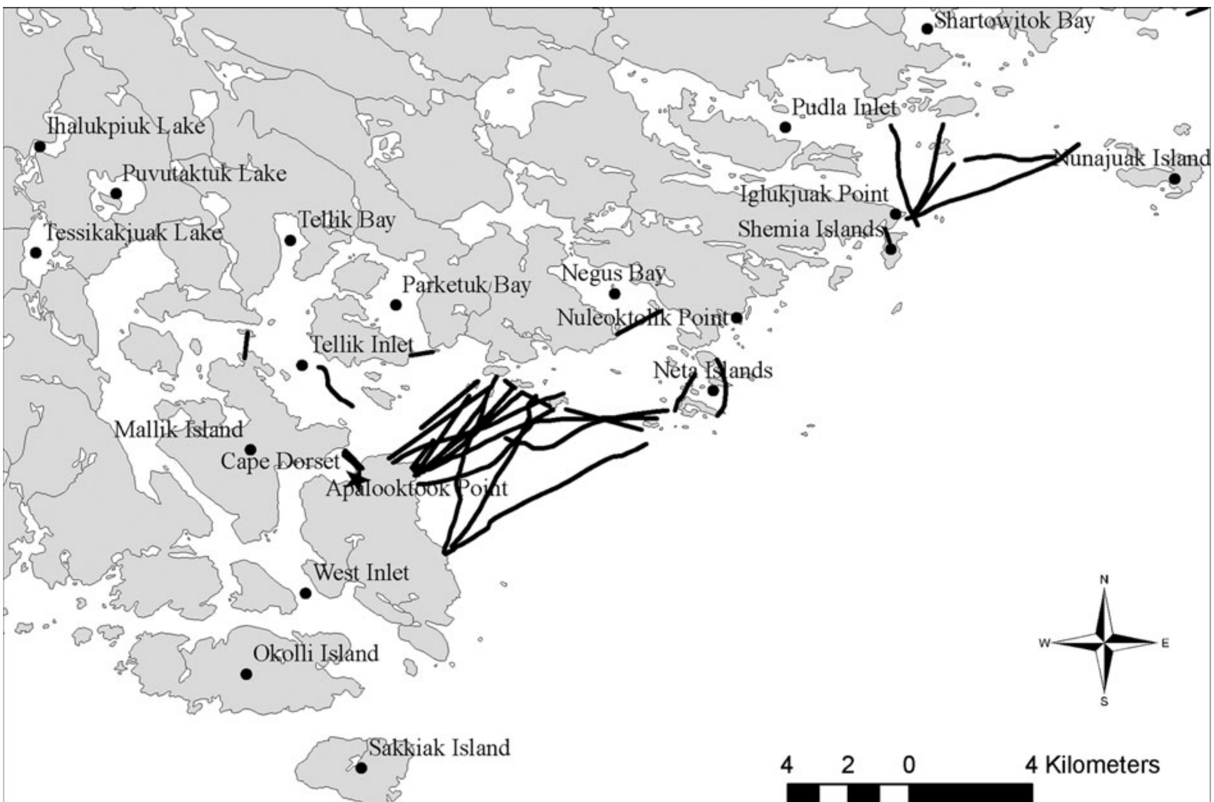

Fig. 7. Key *naggutiit* (plural for *nagguti*) in the Cape Dorset area. Sources: AE1; AP1; EE1; JM1; MJ1; OM2; OO1; Pootoogook 2005 (PP2); SK1.

Fig. 8. Photographs of the floe edge, and ice formations/dynamics along the floe edge, including: a) the winter floe edge *sinaaq* is continually in flux, freezing, breaking off, re-freezing, depending on current and wind conditions; b) the spring floe edge (*sinaaq*) is more defined, as the ice is thicker and it is no longer re-freezing at the edge; c) *uiguaq* is the new ice that forms at the *sinaaq*, shown here to the right, where the second author is about to walk; and, d) *uqaqtuq* is the action of ice breaking off, usually where a *nagguti* has formed.

> or *ajuraq*, that's when the strong tide comes it'll start to move a bit more, and it's not frozen anymore so it breaks off. We call that *uqaqtuq* (Manning 2005a).

The location of the *sinaaq*, and experience of it, varies within and between years. So, while the *sinaaq* positions drawn on the map sheets do vary, they are consistently close to the southern coastline of Baffin Island. Hudson Strait is ice-free, or full of moving ice, throughout the year due to the strong currents moving from Foxe Basin and Hudson Bay into the Atlantic Ocean, or *vice versa*. Along the eastern map portion the greatest ice extent is found in Andrew Gordon Bay (Fig. 9a). On the other hand, nearer to Cape Dorset in the western map portion, the sea ice does not extend far offshore in any area (Fig. 9b). However, solid ice does form consistently in Tellik Inlet, and between some of the islands northwest and northeast of Cape Dorset, enabling access to Baffin Island.

Melting processes

In this section Table 3 and Fig. 2 should be consulted as references for Inuktitut terminology and links between processes.

During sea ice decay, conditions can deteriorate unevenly based on a number of factors: current strength, snow cover, water accumulation or drainage, ice thickness, wind direction or strength, air temperature, water depth, etc.

> [A]round March time, where there are currents . . . those areas will probably start to get dangerous to travel on. If there are currents in that area, then around March those areas start getting [unsafe] to be travelling on (Saila 2004)

An *aukaaniq* is an area that opens up earlier than others, usually located near areas of stronger currents (Fig. 2) (AE1; EE2; NP1). Around Cape Dorset these tend to concentrate in the areas where polynyas occur. This happens because the ice around polynyas wears out faster than areas in which there is ice cover all winter, due to thinner ice as well as to the strength of currents that wear away the ice ('wearing' away of the ice as described by interviewees may be likened to the scientific concept of ablation, related to thermal exchanges, and not necessarily limited to the implied frictional effect). These *aukaaniit* (plural for *aukaaniq*) may also be found along the coast

A

B

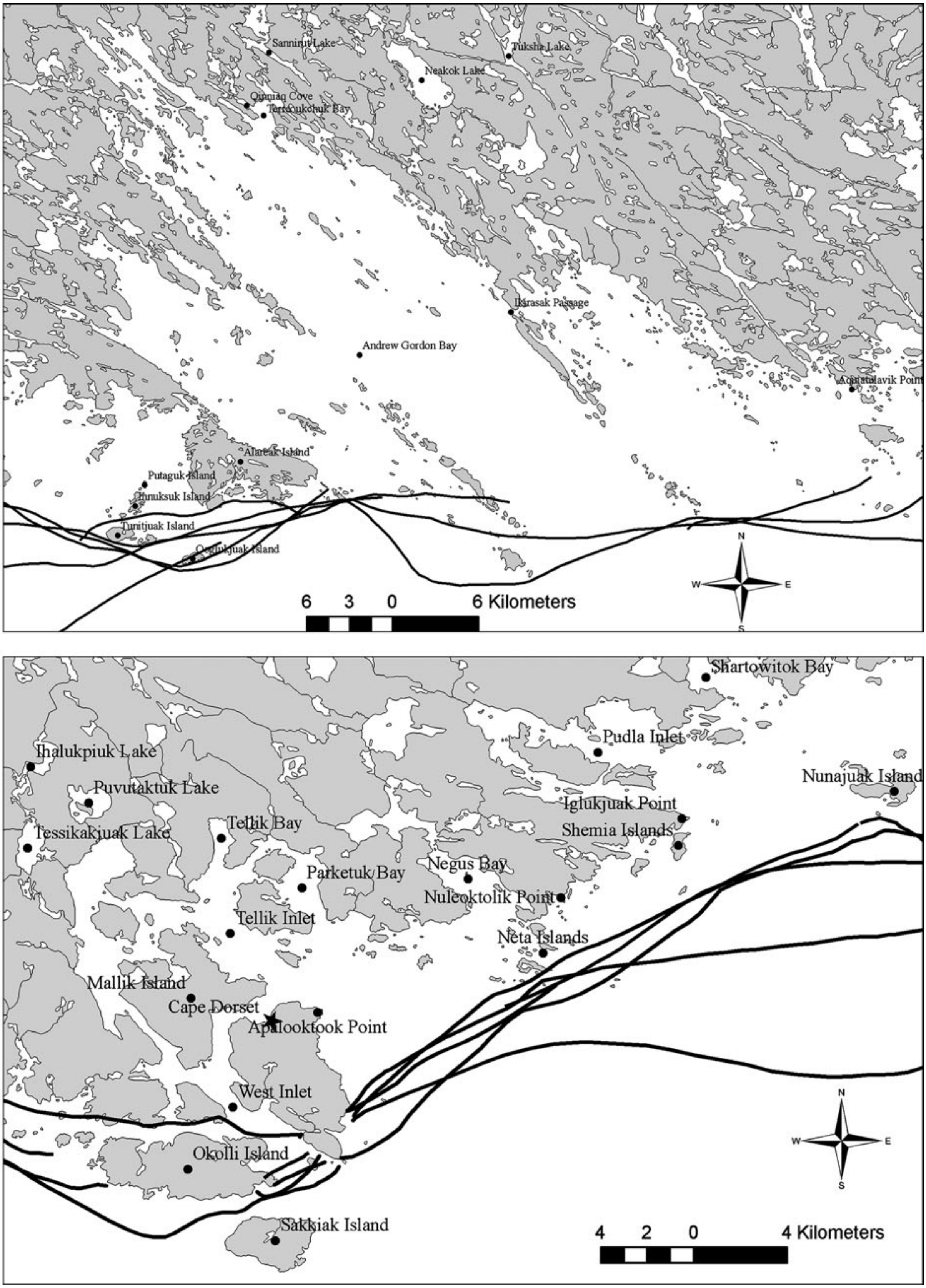

Fig. 9. Maps showing the approximate location of the *sinaaq* around: a) Andrew Gordon Bay; and, b) Cape Dorset. Sources: AN1; EE1; EP1; IN1; MJ1; OM2; QT1.

Table 3. Inuktitut terminology, descriptions, and brief definitions for sea ice conditions associated with melting stages (in approximate order as shown in Figure 2).

Term	Description	Brief definition
	Snowmelt	
aukajuq	Early spring ice condition	general term for early indications of melting
aukaaniq	Early spring ice condition	patches of sea ice that melt/open up earlier than other areas
millutsiniq	Ice condition	a slushy patch on the ice caused by snowfall on thin ice
uqurusirtuq	Action, ice deterioration	the process of snowfall contributing to spring ice melt (acts like insulation and allows melting from below)
aputlariq	Early spring ice condition, ice deterioration	when snowfall, or snowmelt, contributes to ice melt in the spring
qinningijuq	Early spring ice condition	soft wet snow on top of solid ice
manguqtuq	Action, ice deterioration	general process indicating the onset of sea ice melt, comprising *aputlariq* and *qinningijuq*
sallivaliajuq	Action, ice deterioration	ice thinning due to the influences of rain, wind, or snowfall
	Water accumulation and drainage	
immatuqtuq	Action, ice deterioration	process of meltwater formation
quginiit	Spring ice condition	like little creeks on top of the ice
immatinniit	Spring ice condition	melt puddles on the ice
qalluit	Spring ice condition	holes formed in the ice by sunken seaweed or other debris on the ice
qillait	Spring ice condition	melt holes
	Break-up	
qangitarniq	Spring ice condition	when the ice has popped up from the bottom and is floating
pattituq	Spring ice condition	when there is no more ice along the tidal zone
sijjaviniq	Spring ice condition	used to be *sijja*
matsaaq	Spring ice condition	when water drains through the ice
ajuqpaliajuq	Action, ice breaking up	ice breaking off where the cracks are widest
aukaaq	Action, ice breaking up	when the ice is breaking up/off in the spring
siggia	Spring ice condition	when the ice is breaking up
qullupiaqtuq	Action, ice breaking up	ice colliding and being pushed on top of other ice
sikuviniq	Spring ice condition	used to be *siku* (now free-floating)
tuvaviniq	Spring ice condition	used to be *tuvaq* (now free-floating)

where *sinaaq* dynamics affect ice thickness and stability (Fig. 10).

Snowmelt

> [T]his time of year [April], thinning of the ice usually starts from the bottom, and also this time of year it's where there are usually currents . . . that are not safe to be travelling on anymore. And our inlet areas will be safe until the ice actually gets out of the inlet (Alasuaq 2004).

Because ice thinning begins underneath the snow cover, it cannot necessarily be detected visually, so early melt stages are assessed based on snowmelt and snow conditions on top of the ice (Fig. 2).

> [W]hen [I] check to see if the ice is melting, [I] will go on the ice if [I] can't tell from looking at it. [I] will get a handful [of snow], if it makes a snowball, if it sticks together, [I] know it's melting now. But if [I] do that and it doesn't stick, it just crumbles off, [I] know it's not melting then (Alasuaq 2004).

The earliest melt stage is identified as *aukajuq* (AA1; JM1; MK1; OO1). Snowfall around April and May begins to contribute to ice melting (*aputlariq*) (Etidlouie 2005b (EE2); MS1). The snow starts to become soft and wet, but if the ice underneath is still solid it is termed *qinningijuq* (EE2). The process of *manguqtuq* is a general descriptor for the onset of ice melt, beginning with snowmelt and then influencing the ice underneath, and thus comprises both *aputlariq* and *qinningijuq* (AA1; PP2; QP1). The process of *sallivaliajuq* also extends over several melt stages, generally referring to when the ice is thinning due to influences of the snow, rain, or wind (Fig. 2). In the spring this stage also refers to a period where the seals are having their pups (around April or May) (MS1; QP1).

Water accumulation and drainage

Once the snowmelt is underway, water begins to form on top of the sea ice, a process called *immaqtuqtuq* (QT1).

> [*I*]*mmatuqtuq* mean[s] water is starting to form on top of the ice, that's one of the beginning stages of melting ice. And then *immatinniq* is where water is staying on there, [until] the end of the month or something, until it starts draining down. And then [you can also] say *tasiaruq* meaning pretty much the same thing as *immatinniq* (Tapaungai 2004).

This leads to melt rivers (*quginiit*) (AA1; NP1) and melt ponds (*immatinniit*) (EE2; NP1; QT1) forming before there is sufficient drainage to decrease the water accumulation (Fig. 2, 11a). These i*mmatinniit* can also be caused by *qalluit*, holes formed in the ice by seaweed (or other debris) that has melted downwards (such debris absorbs more heat than the ice surface, thus forming

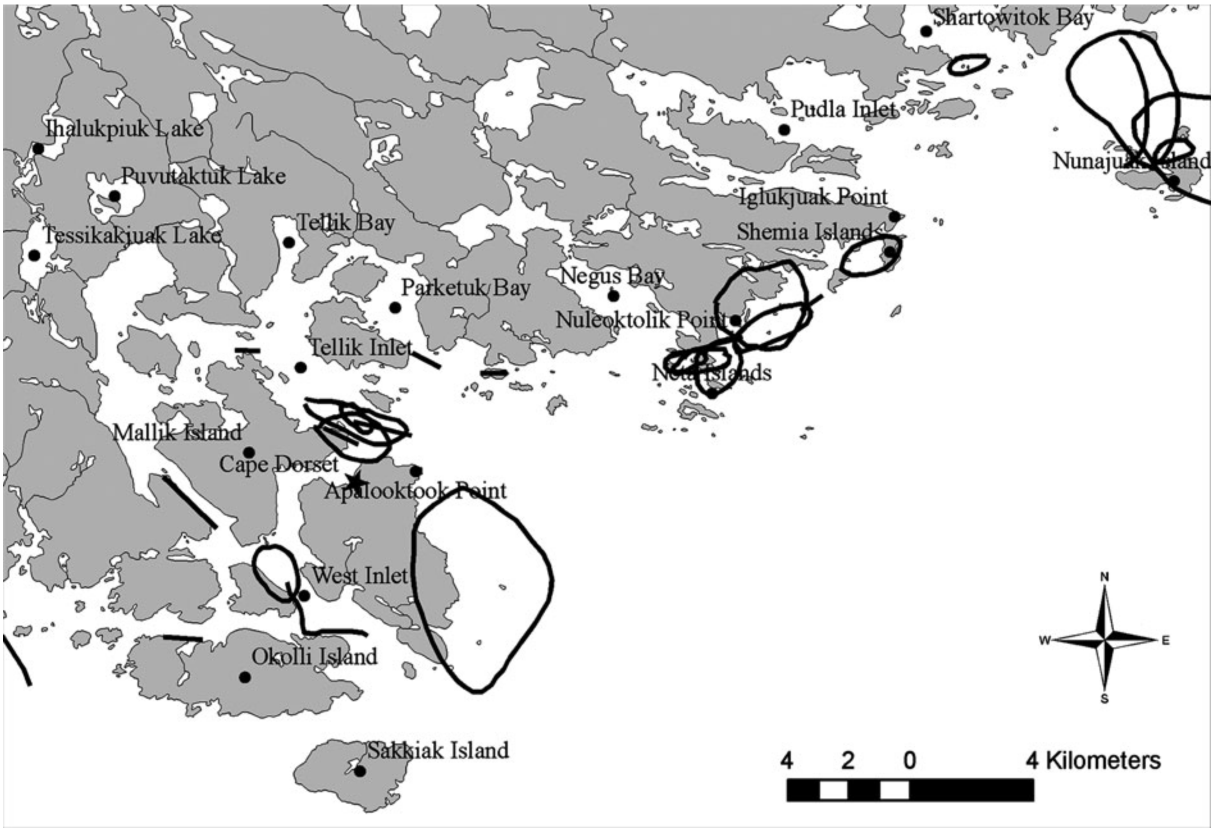

Fig. 10. Key *aukaaniit* around the Cape Dorset area. These areas wear out earlier than others in the melt process, and can thus be dangerous to travel near or around. Sources: EE1; JM1; Kellypalik 2004b (MK2); MJ1; MS1; QT1.

melt puddles around it) (Fig. 11b) (EE2; OM2). Finally, water begins draining through *qillait* (likened to thaw holes) once the ice has melted all the way through in areas (Fig. 2, 11c) (EE2). Drainage (*matsaaq*) (EP1) also occurs through *atluan* and *ajurait* (Fig. 6b). After substantial water drainage has occurred, the ice actually pops up from where it was frozen to the ground, becoming free-floating but remaining a large, intact, continuous ice surface (*qangitarniq*) (Fig. 2) (AA1; OM2).

Break-up

After *qangitarniq*, *pattituq* is when there is no longer ice along the tidal zone (Fig. 2) (OM2). The sea ice tends to melt faster along shore, just as it also freezes faster along shore. Once all the shoreline ice (*sijja*) breaks off, it becomes *sijjaviniq* when it is floating around (EE2). Away from the shore the ice tends to begin breaking off where the cracks are widest (*ajuqpaliajuq*) (EE2).

> The ice that breaks off first, usually comes almost from the point here, there's a point just over here where it breaks off first [referring to the map]. And then next point up it will form a crack where the other point is, and then next point it will break off, and then a big chunk usually comes off all at once (Petaulassie 2004a).

Ice breaking off in the spring time, usually caused by winds, is referred to as *aukaaq* (EP1). When the ice is breaking up (*siggia*) (MS1; QT1; OO1) *qullupiaqtuq* may occur (when ice collides and is pushed on top of other ice as it breaks, likened to rafting) (AA1). Finally, once the landfast ice breaks into floating pieces, *siku* and *tuvaq* become *sikuviniq* and *tuvaviniq*, respectively (Fig. 2) (MJ1).

Cracks/leads

As mentioned previously, an *ajuraq* is a *nagguti* that remains open in the spring time (likened to a lead). As the ice deteriorates this kind of crack then widens (*ikiqtusijuq*, likened to a flaw) to become jumping distance (*nipittupaliajuq*). As it widens further an open lead forms, requiring a boat to cross the opening (*ikiqtuq*) (Fig. 2) (OM2).

Wind and current influences on sea ice

> Both wind and currents, when they stop at a certain time, like in the fall time, that's when it's time to freeze. [W]hen the wind stops, the water will freeze, and when the current stops, it will freeze (Kellypalik 2004a).

Mentioned briefly throughout earlier sections, winds and currents greatly influence how and when ice forms, moves, or deteriorates. For both winds and currents, the general conditions around Cape Dorset are described, followed by a characterisation of their influence on sea ice.

A B C

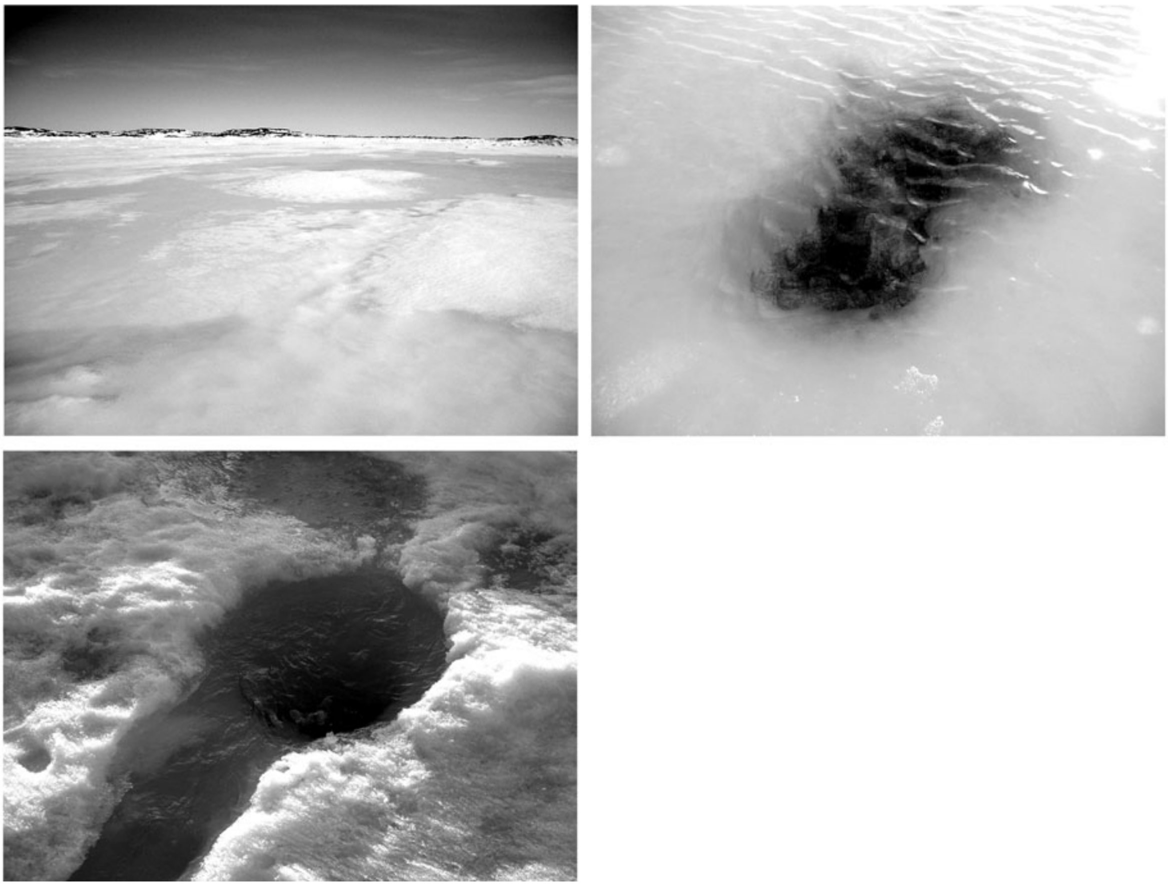

Fig. 11. Photos of early melt processes, including: a) *immatinniit* refers to the accumulation of meltwater on the sea ice, either puddles or substantial water cover; b) *qalluit* form when seaweed or other material has melted into the ice; c) *qillait* act as drainage outlets for meltwater.

Prevailing winds

There is little consensus on a predominant wind direction around Cape Dorset, and the related sea ice conditions (Table 4). The predominant wind direction was identified as being somewhere between west and northeast, with northerly winds being the most commonly cited as prevailing (Table 4). In contrast, southerly and southwesterly winds were most often mentioned as being influential on ice conditions, mainly by causing break-off events or keeping moving ice near town (Table 4). There are a few possible explanations for this variation:

a) the interviewee, or the interpreter, was unclear about which direction they were referring to (for example mixed up the directions, or said one and meant another);
b) wind directions are not easily translated into English, which can lead to confusion or misinterpretation after translation (for example northwest is the most commonly cited predominant wind, but in popular media, the Inuktitut term for northwest is often translated into English as north (T. Ikummaq, personal communication, 2005));
c) the wind directions have noticeably changed in recent years, and respondents did not distinguish ‘usual’ conditions from ‘recent’ conditions.

Having stated this, it is not feasible to focus on absolute directions in reporting wind-related results and analysis. However, it is useful to discuss influences of winds on sea ice in relation to the general direction from which they originate. While referring to particular directions, interviewees often mentioned winds coming from the mainland in comparison with winds coming from the open water. Generally, the more northerly winds constitute winds coming from the mainland (that is Baffin Island) and the more southerly winds originate from the open waters of Hudson Strait. So, for the purposes of the remaining discussion, the directions between west and east towards the north are ‘from the mainland’, and the directions between west and east towards the south are ‘from open waters’ (Fig. 12).

Influences of wind on ice conditions or movement

In this section concerning the influences of winds on ice conditions/movement, Table 5 and Fig. 12 should be consulted as references for Inuktitut terminology and links between processes.

Table 4. Summary of predominant directional and seasonal winds around Cape Dorset, and their related influences on sea ice.

Direction	Season	Ice influence	Number of sources
West	• Autumn • Predominant	• Break up the ice • Less = MYI closer to town	3
NW	• Predominant		2
North	• Autumn and winter • Predominant	• Promotes freezing • More = MYI far from town	8
NE	• Predominant • Autumn	• Nice weather • Promotes freezing	3
East		• More = MYI far from town	1
SE	• Autumn		1
South	• Autumn • Winter • At full and new moons	• Break up the ice • Prevents freezing • Less = MYI closer to town • Lots of ice near town	7
SW	• Spring • Autumn	• Less = ice stays longer • More = ice will leave sooner • More = breaks off the ice	2

Where: MYI = Multi-year ice.
Sources: AA1, AE1, AN1, AP1, EE2, EM1, EP1, KS1, MJ1, MK1, NP1, OO1, PP1, QP1, QT1, SK1.

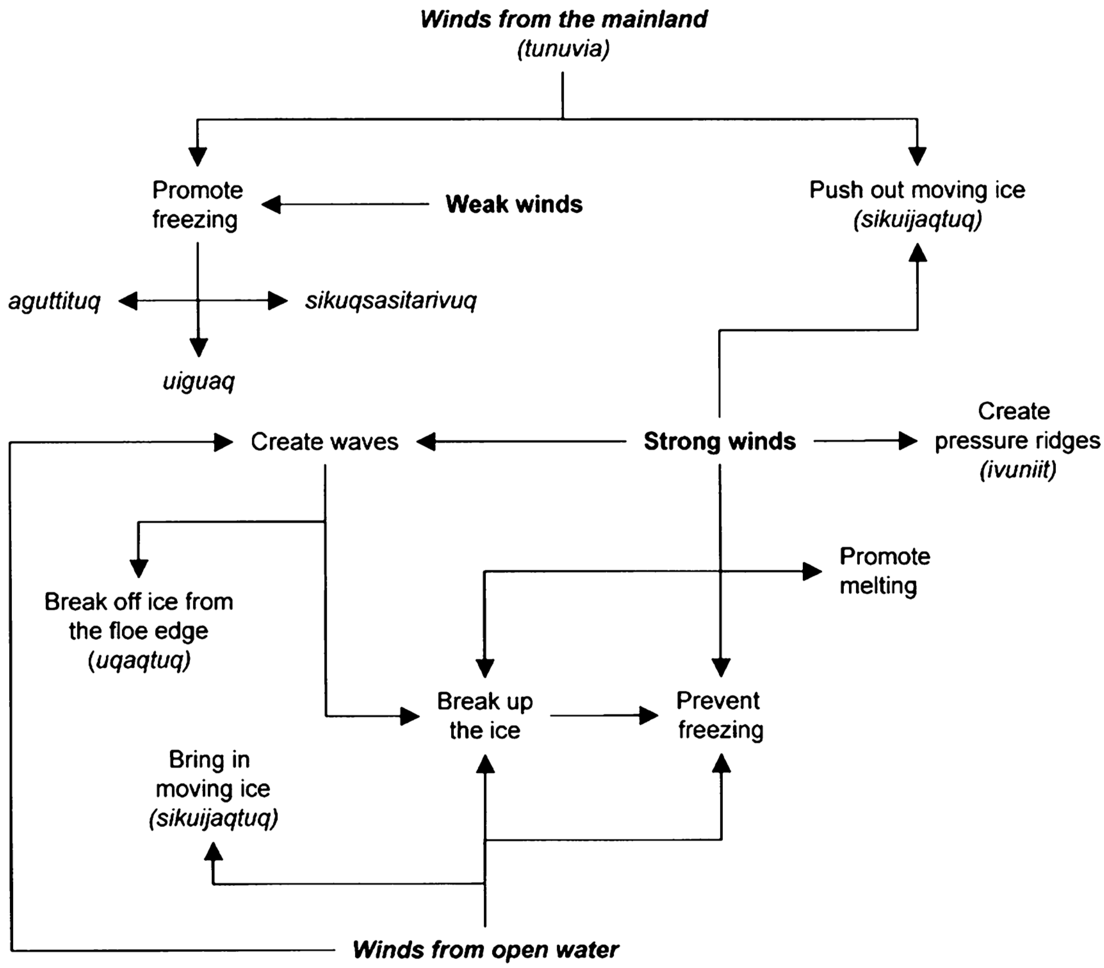

Fig. 12. Conceptual model of the influences of winds on sea ice formation, movement, or decay based on interviews conducted in Cape Dorset.

Table 5. Inuktitut terminology, descriptions, and brief definitions for sea ice conditions associated wind influences (in approximate order as shown in Fig. 12).

Term	Description	Brief definition
	Sea ice as influenced by winds	
tunivia	Weather	weather/wind that comes from the mainland
agguttituq	Action, ice formation	ice forming in the direction of the wind
uiguaq	Ice condition, ice edge	new ice that forms at the floe edge
sikuqsasitarivuq	Autumn ice condition, near shore	ice forming outward from the edge of the land
sikuijaqtuq	Action, moving ice	ice moving with the wind
uqaqtuq	Action, ice edge	when uqaq is occurring
ivuniit	Ice feature, rough ice	pressure ridges

> When it's time for the ice to freeze, it will usually freeze from the north side, from the mainland side going down. But if it's been windy from the south side for a bit of time, the ice usually won't freeze up for a while. Like [I] said, winds are part of breaking [the] ice (Alasuaq 2004).

Winds from the mainland tend to bring pleasant (and cold) weather (AA1; PP1), and if sustained within mild to moderate speeds they promote the freezing of sea ice in the autumn (AE1; EP1) (Fig. 12). Therefore, with *tunuvia*, weather coming from the mainland, the ice will begin to form outward from the edge of the land (*sikuqsasitarivuq*) (OO1). Winds from the mainland can also drive moving or multi-year ice (MYI) away from the community, allowing for conditions that are more conducive to boat travel (AN1).

In contrast, winds coming from the open water are said to have greater influence on ice conditions (SS1), usually in a destructive manner (Fig. 12). In any season, winds coming from the open water are likely to break up the sea ice (*uqaq* or *aukaaq*) by causing increased wave action, or by pushing moving ice into the *sinaaq* (AA1; AE1; AN1; EP1; Solomonie 2004 (KS1); JM1; MJ1; MK1; MS1). Such turbulence prevents freezing in the autumn (AA1; AE1) and promotes break-up in the spring (AE1). Winds from the open water also bring moving ice close to town, and can keep it there (Mangitak 2004 (EM1); AN1).

> [S]ometimes the ice has broken off from [another] area, it will go right up to around Cape Dorset, and sometimes it will be stuck up [here] for a while. A lot of our hunters will say that there is no floe edge close by because of the ice that has broken off and kind of settled up [here] for either a few days, or weeks at a time (Saila 2004).

Light winds, or calm conditions promote ice formation (EM1; EP1; MK1), whereby the term *aguttituq* describes ice forming in the direction of the wind (Figure 12) (MK1). In contrast, strong winds from any direction can affect ice stability. Ice deformation can be caused when winds push ice on top of other ice, causing it to pile and refreeze into rough ice (*ivuniit*, likened to pressure ridges) (AA1; AN1).

> Another ice is called *ivuniit* . . . it's like a bulldozer coming from the water side pushing [thick ice] to the islands or the mainland. When it's windy from the south side that happens, or around current areas . . . (Alasuaq 2004).

Winds also create wave action, which prevents ice from forming (AP1; MK1), and may cause the *sinaaq* to open up or break off (KS1; SS1). Seasonally, a windy autumn means that broken pieces of ice will freeze together, rendering spring ice travel dangerous because the ice might break off little by little (Fig. 12) (MJ1). Windy conditions seem more prevalent in the spring (EM1) and they promote ice melting, causing faster ice deterioration than the influence of sun or rain (MJ1). Winds also cause ice movement (SK1), whereby *sikuijaqtuq* refers to ice moving with the wind (Fig. 12) (OO1). Furthermore, sustained strong winds will cause the formation of *naggutiit* in the sea ice (NP1).

Tidal cycles and currents

Currents play an important role in the unique ice conditions around Cape Dorset. The strength of the currents is related to different water depths, under which shallower water promotes the faster movement of water, keeping many areas ice-free year-round (AN1; EP1; JM1) (Fig. 13). For example, an *aquanaq* is described as a shallow area (likened to a reef) that creates stronger currents and can prevent ice from freezing solid (EM1). Due to relatively shallow waters around Cape Dorset, tidal variations are large (SS1). The cycle of high and low tides determine the direction of currents, as they go back and forth typically in a north/south alternating pattern (AA1; EE2; MK1; OO1). The water is described as moving towards the north (up/in) at high tide, and towards the south (down/out) at low tide, approximately every 12 hours. Beyond the daily high and low tide cycles, the monthly new and full moons are especially influential on current strength (i.e. peak high and low tides), and thus ice conditions (Fig. 13) (AN1; EE1; EE2; MS1; NP1; Pootoogook 2005 (PP2); SS1; QT2; SK1).

Current and tidal influences on ice conditions or movement

In this section concerning the influences of currents on ice conditions/movement, Table 6 and Fig. 13 should be consulted as references for Inuktitut terminology and links between processes.

Generally, the stronger the currents the harder it is for ice to form (Fig. 13). Hudson Strait currents are significant

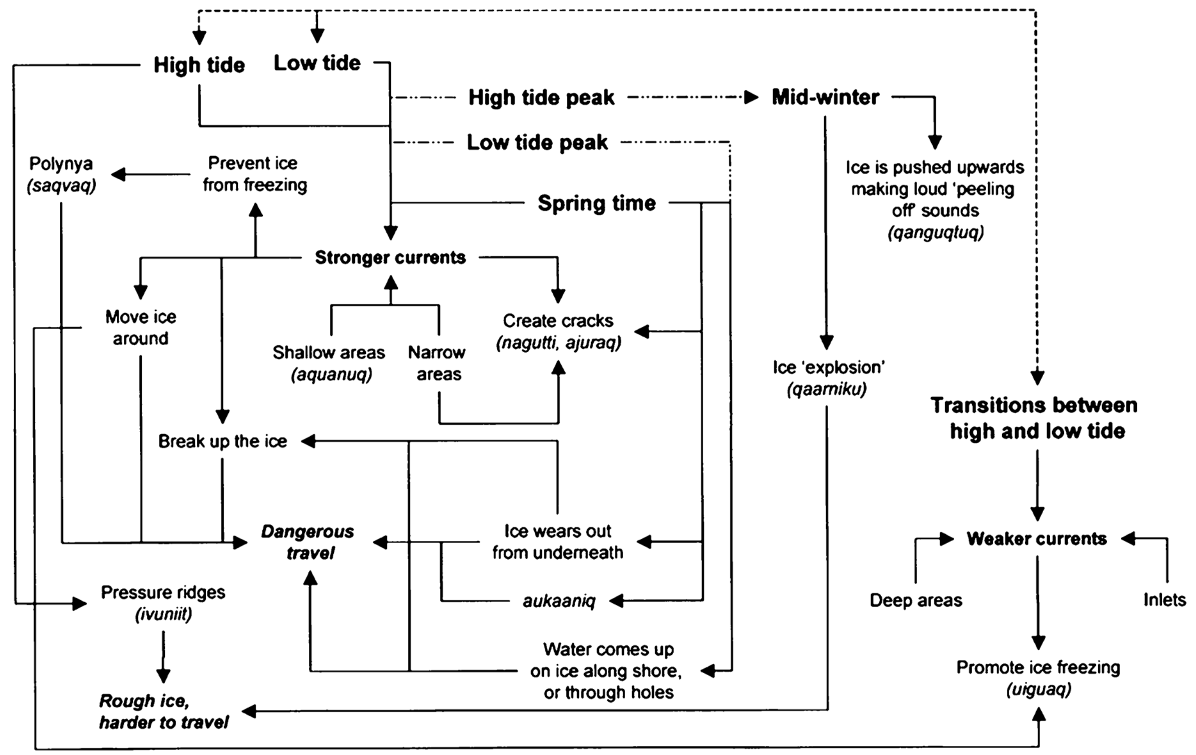

Fig. 13. Conceptual model depicting the influences of currents and tides on sea ice formation, movement, or decay based on interviews conducted in Cape Dorset. Where: a solid line = general process direction, a dashed line = daily cycle, a dashed and dotted line = monthly cycle.

contributors to the maintenance of the *sinaaq* close to town throughout the winter, and the annual creation of *saqvait* (plural of *saqvaq*, likened to polynyas) (AA1; EM1; EP1; MS1; OO1; PP1; PP2; QT1; SK1). Ice is more likely to form in inlets, but not usually up to the points of land as that is where currents tend to be strongest (EP1, PP1, PP2, QT1) (Figure 15).

> The ice will form mainly around the edges, because it's all currents on [the West] side. Mainly around the edges . . . in between these two islands it doesn't usually ice in between there. So mainly close to the mainland here, it will form only mainly in inlets because there's too much currents . . . It doesn't go, even most places it doesn't go right up to the points, just the little inlets will be ice (Petaulassie 2004a).

Between islands the currents are also very strong, as they are funnelled through narrower areas (PP2; SS1). This funnelling action results in thinner ice or more frequent formation of *naggutiit* (EP1; SS1) (Fig. 13). In addition, strong currents cause *ivuniit* to form along the coastline, along the *sinaaq*, or in areas where tidal cycles cause ice to collide or break off (AA1; AN1; MK1) (Fig. 13).

The Inuktitut term for polynya, *saqvaq*, actually refers to areas 'where there are currents' (not necessarily areas that never freeze over). It is well understood around Cape

Table 6. Inuktitut terminology, descriptions, and brief definitions for sea ice conditions associated current/tidal influences (in approximate order as shown in Fig. 13).

Term	Description	Brief definition
	Sea ice as influenced by currents	
aquanaq	Underwater topography	a shallow area, like a reef, that creates strong currents
saqvaq	Open water within sea ice	an area with strong currents that does not usually freeze in the winter (polynya)
nagguti	Ice feature, tidal crack	a crack that forms in the winter and re-freezes
ajuraq	Spring ice feature, crack/lead	tidal crack that does not re-freeze, open water remains within it
ivuniit	Ice feature, rough ice	pressure ridges
aukaaniq	Early spring ice condition	patches of sea ice that melt/open up earlier than other areas
qaarniku	Action, mid-winter	'ice explosion'
qanguqtuq	Action, mid-winter	'peeling off' sounds made when a strong tide pushes ice upwards
aniqsai	Ice feature, moving ice	floating ice that moves with the currents
uiguaq	Ice condition, ice edge	new ice that forms at the floe edge

Table 7. Inuktitut terminology, descriptions, and brief definitions for moving ice.

Term	Description	Brief Definition
		Moving ice
aniqsai	Ice feature, moving ice	floating ice that moves with the currents
asaluaan	Ice feature. moving ice	ball-shaped ice (rounded) in open water
aulaniq	Ice feature. moving ice	general term for moving ice
marruluin	Ice feature, moving ice	broken ice from other areas, as identified by ocean or shoreline debris on the ice
puktaan	Ice feature, moving ice	small pieces of ice moving in open water
qaikuin	Autumn ice condition, in open water	chunks of ice that form in open water and move with the currents
qapvaq	Ice feature, multi-year ice	Large moving ice floes that come from areas far away, usually from the north
qunni	Ice feature, moving ice	ice that will not crack, floating in open water
savittuq	Ice feature, moving ice	a small piece of ice that broke off and is floating away
sikurasaan	Ice feature, moving ice	small pieces of ice gathered in an area, moving as one

Dorset that areas of strong currents prevent ice formation, and keep certain areas ice-free throughout the winter, although they are surrounded by *tuvaq*. However, along with the varying strength of currents during a month, varying degrees of ice cover may form over a *saqvaq*. A notoriously dangerous area for *saqvait*, or thin ice conditions, is Saqvaq Inlet (Chorkbak Inlet on the map) (Fig. 14a). Areas of open water were indicated throughout the inlet, and between the myriad of islands in the area. Therefore, this inlet tends to be avoided when travelling to Kimmirut (a neighbouring community to the southeast of Cape Dorset). There is one small area near the mouth of the inlet that does freeze over at times (*nunniq*), and thus becomes passable (PP2). But elders warn that this area is still very dangerous if the person is not familiar with conditions around the inlet (PP2). *Saqvait* are also scattered throughout the region, predominantly between islands and in narrow areas where currents are perpetually strong. Interviewees indicated several important *saqvait* near Cape Dorset, known as both dangerous for sea ice travel and as popular for seal hunting (Fig. 14b). To identify a particular *saqvaq*, the closest place name on the land is used, and added to the term *saqvaq* (QT1).

The monthly new and full moons create peak tidal stages where stronger currents contribute to: i) ice thinning; ii) more dangerous sea ice travel; iii) the opening or creation of *naggutiit*; iv) the opening or formation of *saqvait*; and, v) ice break-off events (AN1; EE2; MS2; NP1; PP1; PP2; QT2; SK1; SS1) (Fig. 13).

> [E]specially when it's full moon season, that's when the currents start moving a lot, that's when [certain] areas are no longer safe to be travelling through, full moon season. And the new moon season is same as, almost like a full moon, 'cause the tide is not as low as it would be when it's regular low tide (Saila 2004).

Seasonally, in mid-winter a full moon can create such tidal pressure under the ice that an explosion of sorts (*qaarniku*) may occur, but not on a regular basis (EE1). Also, at the end of a very strong (high) tide, currents can lift up ice that was frozen to the ground, making loud 'peeling off' sounds (a process referred to as *qanguqtuq*), likened to the sound of loud snoring (Fig. 13) (AA1; Manning 2005b (JM2)). Furthermore, full moon effects in the spring contribute to enhanced ice thinning from underneath the ice surface, and cause water to come up through holes in the ice (EE2). Currents may also be stronger in the spring, which can expedite melt processes and/or break-up (AN1).

Currents also influence sea ice movement. Usually movement delays ice formation in the autumn (QT1), but currents may also promote freezing if they deposit ice in areas with weaker currents, in which they can freeze (JM1; MJ1; MK1; QT1) (Fig. 13).

> [W]hen it comes to icing in the fall time, currents have something to do with ice forming in some areas, where it would not ice right away the current has moved a chunk of ice into that area and now it's permanent in that area. The currents have something to do with ice forming in areas where it wouldn't have frozen right away because there's currents in the area. But sometimes the currents take ice to [where] it will stick . . . That's why some areas are a lot thicker than [other] areas (Tapaungai 2004).

Currents can take frozen piled ice to another area where it will stay (*sikuliaqta*), if the winds are not strong (MK1). Furthermore, in the spring currents can speed up the melting processes, and create *aukaaniit* (Figs. 10, 13). In addition, floating ice tends to follow the currents, as associated with the tidal cycle (EM1). A few key terms associated with moving ice (*aulaniq*) are provided in Table 7. Specifically, *qapvaq* (likened to multi-year ice) is associated with hampering sea ice or boat travel.

> [Q]apvaq, they're big, like Hudson Strait polar ice, they're really clear white blue colours . . . when people see that say 'oh oh, we're going to get trapped'. Because when they start to see that *qapvaq* [it] means a big area of ice like that can move into your area and block off all the shoreline. That has happened here, we got stranded out right here one time, with *qapvaq*. And then it stayed there over almost two weeks (Manning 2005b).

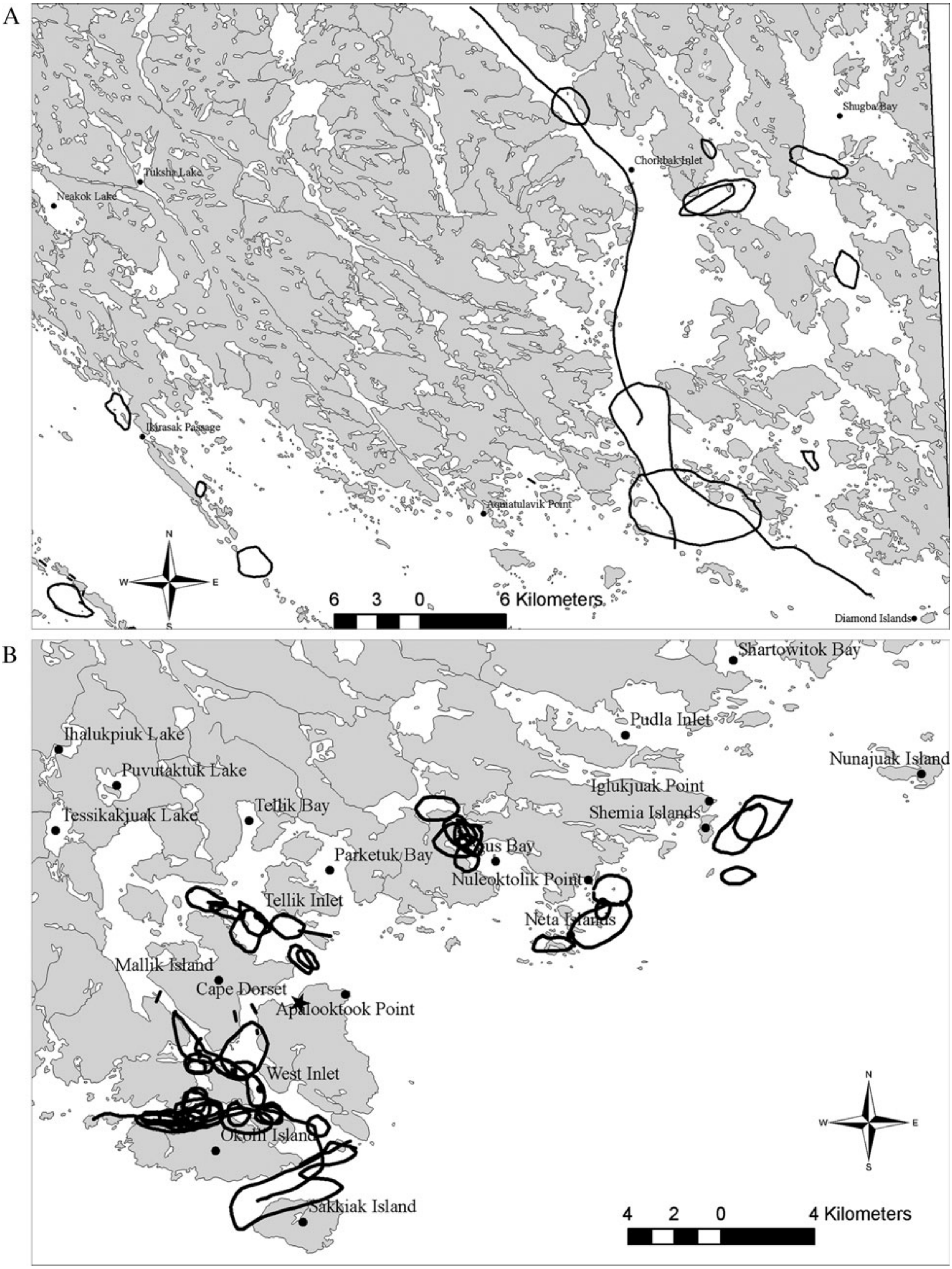

Fig. 14. Maps showing prominent *saqvait* around: a) the Chorkbak Inlet area; and, b) the Cape Dorset area. These are dangerous if the person is not familiar with the conditions around these *saqvait*. Sources: AA1; AN1; EE1; EP1; JM1; MJ1; MK2; MS1; MS2; OM2; PP1; PP2; QP1; QT1; SK1.

Both currents and winds clearly influence sea ice movement, formation, decay, and distribution. In addition, their strength or direction varies with weather, lunar, and seasonal cycles, enhancing the complexity of understanding local sea ice freezing and melting processes. These dynamic influences are also continually considered when travelling or hunting on the sea ice, as they can greatly enhance the danger of sea ice navigation.

Discussion and conclusions

In using sea ice extensively for travel and hunting purposes, Inuit elders and hunters in Cape Dorset have developed a detailed and nuanced understanding of freezing and melting processes. Specific Inuktitut terms are used to describe various ice conditions and transition stages that occur throughout the annual sea ice cycle of formation and decay. These also link to the floe edge, tidal cracks, and polynyas, as influenced by wind and current conditions. Such characterisations of freeze/thaw and dynamic processes provide a unique glimpse into the localised conditions and marine geography of the sea ice surrounding Cape Dorset, and extending along the northern Hudson Strait coastline. This local scale understanding is critical for Inuit elders and hunters in evaluating ice conditions related to travel safety and marine wildlife hunting/habitat (Laidler and Elee 2006). Beyond community-based applications, these results also have the potential to inform future research efforts on: i) local/regional sea ice monitoring; ii) the relationship between Inuit knowledge, language, and the environment; and, iii) addressing community interests through targeted studies.

First, sea ice monitoring is often undertaken at coarse spatial scales (>25 km^2 resolution), using passive-microwave (radar) satellite sensors (with hemispheric to regional coverage) (Mysak and Manak 1989; Wang and others 1994; Mysak and others 1996; Parkinson and others 1999; Parkinson 2000; Heide-Jorgensen and Laidre 2004). These data provide a useful overview of ice conditions (presence vs. absence, ice concentration, ice extent), and permit extensive spatial coverage for temporal trend analysis. However, Cape Dorset is included within the regional delineation of Hudson Bay (Mysak and Manak 1989; Wang and others 1994; Mysak and others 1996; Parkinson and others 1999; Parkinson 2000), and the trends in ice coverage and freeze/thaw processes do not adequately capture the dynamics and ice movement in Hudson Strait. Heide-Jorgensen and Laidre (2004) provide a subset analysis of the fraction of open water present in sea ice around Baffin Island, which is useful in evaluating regional sea ice trends for south Baffin Island. In addition, Gagnon and Gough (2005) present a regional analysis of Hudson Bay freeze-up and break-up trends (not including Hudson Strait) and Gough and Houser (2005) analyse Hudson Strait sea ice formation and retreat along with the length of the ice-free and ice-covered seasons. These last two studies employed Canadian Ice Service sea ice chart data, which is derived from a combination of satellite imagery, image interpretation, and ship- and aircraft-based observations (EC, 2003). These studies provide increased spatial resolution, but still this data is not easily translated into meaningful information that can be used at a community level to evaluate ice conditions within the regional vicinity used for travel and harvesting purposes. A few notable exceptions include: i) Higgins' (1968) local characterisation of Cape Dorset ice conditions and freeze/thaw processes/timing based on *in situ* observations and measurements; and, ii) Environment Canada's local ice monitoring programme (which was cut in the mid-1980s along with federal budget reductions and increased automation of weather forecasts)(E. Bell, personal communication, 2005). Both of these exceptions are temporally constrained, and are thus not of direct relevance to contemporary sea ice conditions and uses. But active hunters are continually observing and monitoring the ice as an inherent part of travelling and hunting safely on the sea ice. Inuit hunters and elders rely on their own experience and expertise to determine the local safety and stability of ice conditions (Aporta 2002; Gearheard and others 2006; Laidler and Elee 2006; Meier and others 2006). And it is this local scale that is most difficult to capture remotely, or with sporadic scientific field campaigns (and point measurements). Therefore, Inuit expertise has the potential to inform scientific studies of locally important sea ice features/processes often lamented as lacking due to inadequate sensor resolution or inability to conduct frequent and extensive ground verification. Hunters are the experts on these localised ice conditions, and they feel that if they are not consulted in related studies or monitoring activities, that scientists are missing a great deal of important information (Laidler 2006b). Nevertheless, community members have also expressed interest in learning more about scientific research findings, and gaining access to satellite images that represent areas of interest in the Hudson Strait region (Laidler 2006b). This would allow community members better to assess areas they cannot see prior to travelling and, with two-way communication, could help scientists to refine monitoring programmes or image interpretation based on local observations. There may thus be new opportunities for collaboration under which local monitoring programmes, such as described in Tremblay and others (2006), could be implemented to complement regional-scale satellite image acquisitions (for example Meier and others 2006) or ice chart analysis (for example Gough and Houser 2005).

Second, research on the relationship between Inuit knowledge, language, and the environment has evolved through land use studies undertaken as part of the land claims process in Nunavut (Freeman 1976), and more recently in investigating Inuit oral history, placenames, navigational skills, and astronomy (MacDonald 1998; Aporta 2003; Aporta 2004; Bennett and Rowley 2004; Aporta 2005; Henshaw 2006). Specifically in relation to sea ice knowledge and terminology, it becomes evident that the use of the sea ice, Inuktitut terminology, and cumulative personal/shared experiences combine to contribute to the development of a hunter's sea ice expertise (Freeman 1984; Riewe 1991; McDonald and others 1997; Aporta 2002; Gearheard and others 2006). These elements of engagement and language are inextricably linked, and cannot be divorced from one another. As Henshaw (2006: 52) describes: '. . . Inuit ways of knowing their world come to life through an active engagement with their surrounding environment, informed by experience, observation, and language.' She suggests that place-names (toponyms) represent one cultural manifestation through which Inuit express such an engagement. We suggest that sea ice terminology is another such manifestation, in which Inuit express their engagement with the dynamic sea ice environment through detailed descriptions of seasonal sea ice processes and features. Sea ice terms not only evoke a picture of particular ice types (through the literal and descriptive nature of Inuktitut), the quotations used throughout this paper highlight the expression of sea ice dynamism, seasonality, danger, and utility, especially for those familiar with the context in which terms are being used. Henshaw (2006) also found that embedded within some place-names are climate sensitive features such as sea ice conditions, or ocean currents. Therefore, we propose that combining sea ice terminology and dynamic descriptions with extensive place names research such as Henshaw has undertaken, can provide an enriched understanding of relationships between *Sikusilarmiut* (people of Cape Dorset, *Sikusilaaq*), their (changing) uses of the land and sea, physical terrestrial and marine geographies, and the evolution of local Inuktitut dialects. Like Henshaw (2006), it is acknowledged that mapping and terminology documentation cannot do justice to the dynamic nature and use of both the sea ice environment and the Inuktitut language, but it is a valuable starting point. Terminology lexicons and maps may enable improved communication with those who are unfamiliar with the language and/or the local environment (for example some Inuit youth, researchers, and government officials). By documenting sea ice terminology, it is also hoped that this work can contribute to broader efforts to preserve languages and knowledge of the north (Dorais and Krupnik 2005), an aspect of great concern to the elders and hunters who were part of this project.

Finally, an improved understanding of locally important sea ice conditions could help create targets around which to develop future research. One example that arose in interviews and meetings was the importance that community members placed on knowledge documentation as a means of enabling their expertise to be represented in writing, and on maps (Laidler 2006b). They felt that this would help them to be taken more seriously by youth involved in the formal education system, and by scientists working in their community (Laidler 2007). Great educational potential was seen in the recording of terminology and sea ice conditions/uses/hazards. With this baseline material, there is potential to develop interactive educational tools through a combination of Geographic Information System (GIS) and Global Positioning System (GPS) data, Inuktitut terminology and descriptions, photos of sea ice conditions, audio and video footage of interviews, sea ice trips, and focus groups, along with written transcripts and reports. Interactive multimedia, especially where maps and GPS or remote sensing technology have been incorporated with audiovisual material, have proved especially effective at engaging Inuit youth in a form of learning that is a compromise between the long-term experiential *in situ* learning of more traditional times, and the formal text-based learning of the southern-style education system predominantly in place in Nunavut (Fox 2003; Aporta 2005; Gearheard 2005; NRI 2006). Furthermore, multimedia elements can more effectively portray the dynamics of the sea ice environment (for example, animated sea ice motion on maps), along with the interpersonal relationships and social learning that are necessary in the context of sea ice use (for example, watching a video of a local elder describing a sea ice condition).

A second example would be a research emphasis on local marine birds and mammals that are important for community subsistence and commercial harvesting, along with being tourist attractions. The importance of incorporating Inuit knowledge into wildlife research or co-management practices has already been demonstrated in other Nunavut communities (for example Wenzel 1991; Nakashima 1993; McDonald and others 1997; Kilabuk 1998; NWMB 2000; Furgal and others 2002; Peter and others 2002). The results presented here inform related research being undertaken better to understand Inuit expertise on the linkages between specific sea ice conditions and wildlife habitat, behaviour, and health. In addition, local tourism revolves not only around the presence of cultural heritage, art, arctic wildlife, and vast expanses of impressive land-, sea-, and skyscapes (Milne and others 1995; Doubleday and others 2004; Laird 2004), but also the ability to access those locations. Sea ice can provide an important platform that facilitates, or hinders, access to such sites. As such, tourists may gain an enhanced cultural experience, and perhaps added personal safety, by travelling with experienced guides and having some community-specific sea ice background information available to them.

A third example relates to community interests in climate (and related sea ice) change. Incorporating Inuit expertise on localized ice conditions could complement scientific research on similar topics at coarser scales (Riedlinger and Berkes 2001; Fox 2002; Gearheard and others 2006; Henshaw 2006; Laidler 2006a; Laidler and Elee 2006), and could provide an enhanced perspective on how such changes may affect socio-economics and the sustainability of northern lifestyles and culture (Riedlinger 1999; Riedlinger 2001; Duerden 2004; Ford and others 2006a; Ford and others 2006b; Gearheard and others 2006; Nickels and others 2006). For climate change vulnerability research that promotes the characterisation of current exposure and adaptation from both physical and social perspectives (Ford and Smit 2004), local Inuit experts have much to contribute. Yet, there is little of this community-specific knowledge available in the literature. In Cape Dorset, the location of, and dynamics along, the tidal zone, the *sinaaq* (floe edge), *naggutiit* (tidal cracks), and *saqvait* (polynyas) are of particular importance. Such local characterisations could be used to help contextualize changes that are currently being experienced by community members (Laidler and Elee 2006), or as indicators to target future monitoring or change assessment research to reflect community interest. Additionally, there are instances where community members are unsure of how long-term or seasonal sea ice variations affect specific ice conditions/movement. In these cases, targeted remote sensing or point instrumental measurements could aid in explaining phenomena that are difficult to observe through tactile or visual means (for example ocean current strength/direction changes, lunar effects, atmospheric oscillations, ocean temperature, air temperature, wind strength/direction, long-term trends). Therefore, researcher-community interactions and collaborations are essential to the success of such multidimensional research, which can begin to be fostered through baseline documentation research such as undertaken in Cape Dorset. Having a better grasp on how community members use, monitor, and evaluate ice conditions, makes it is easier to identify areas of overlapping interest with other researchers or community experts.

Through this discussion, an attempt has been made to highlight a few of the ways that community-based sea ice research can contribute to a broader context of northern research or community initiatives. Community members want to work with researchers, and to have their expertise considered alongside scientific expertise, especially where addressing local interests or concerns (Laidler 2006b). Working together is essential to understanding the potential implications of sea ice change for northern peoples and environments, but working together must start by mutual understanding. Therefore, it is hoped that this paper can provide a starting point for future cross-scalar investigations that would incorporate marine environmental trends, wildlife and human health, socio-economic implications, and socio-cultural perceptions/connections as interrelated with the sea ice environment around Cape Dorset.

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Note. All interviews referred to below took place in Cape Dorset and were conducted by the first author with the second author translating or facilitating. All originals (and transcripts) are archived at the local Community Learning Centre (Nunavut Arctic College).

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