INUIT AND SCIENTIFIC PERSPECTIVES ON THE RELATIONSHIP BETWEEN SEA ICE AND CLIMATE CHANGE: THE IDEAL COMPLEMENT?

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Abstract. Sea ice is influential in regulating energy exchanges between the ocean and the atmosphere, and has figured prominently in scientific studies of climate change and climate feedbacks. However, sea ice is also a vital component of everyday life in Inuit communities of the circumpolar Arctic. Therefore, it is important to understand the links between the potential impacts of climate change on Arctic sea ice extent, distribution, and thickness as well as the related consequences for northern coastal populations. This paper explores the relationship between sea ice and climate change from both scientific and Inuit perspectives. Based on an overview of diverse literature the experiences, methods, and goals which differentiate local and scientific sea ice knowledge are examined. These efforts are considered essential background upon which to develop more accurate assessments of community vulnerability to climate, and resulting sea ice, change. Inuit and scientific perspectives may indeed be the ideal complement when investigating the links between sea ice and climate change, but effective and appropriate conceptual bridges need to be built between the two types of expertise. The complementary nature of these knowledge systems may only be realized, in a practical sense, if significant effort is expended to: (i) understand sea ice from both Inuit and scientific perspectives, along with their underlying differences; (ii) investigate common interests or concerns; (iii) establish meaningful and reciprocal research partnerships with Inuit communities; (iv) engage in, and improve, collaborative research methods; and, (v) maintain ongoing dialogue.

1. Introduction

Dealing with climate variability has always been a reality for arctic societies, and yet the real and perceived consequences of a changing global climate have only begun to come to the forefront of scientific and public consciousness over the past few decades. Because sea ice plays a complex role in influencing ocean and atmospheric systems, considerable scientific attention has been focused on determining the potential feedback mechanisms (e.g. surface albedo, and thermohaline circulation) that may be triggered by climate/cryosphere interactions. Specifically, feedback mechanisms related to changes in sea ice extent, distribution, and thickness contribute to the projected amplification of warming trends – and thus environmental sensitivity – at high latitudes (Ledley, 1988; Ingram et al., 1989; Bintanja and Oerlemans, 1995; Curry et al., 1995; Lohmenn and Gerdes, 1998; Lemke et al., 2000; Holland and Bitz, 2003). While this type of research has raised the global profile of circumpolar regions, it has also sparked investigations into the human dimensions

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of climate change (Ford, 2000; Cruikshank, 2001; Fenge, 2001; Riedlinger and Berkes, 2001; Berkes, 2002; Berkes and Jolly, 2002; Fox, 2002; Huntington, 2002; Duerden, 2004). Comparatively little is known about the vitality of sea ice extent, distribution, and thickness to daily life in arctic communities, much less how community members perceive climate change as it relates to their local environs. Therefore, it is important to understand the links between potential climate change impacts and arctic sea ice patterns, as well as the related consequences for northern coastal populations. To realize such a comprehensive understanding of the relationship between sea ice and climate change, it is essential to characterize these notions from both scientific and Inuit perspectives.

This paper is the first step in a long process of drawing together different conceptions of sea ice conditions and dynamics. A literature review format is employed to assess current research presenting Inuit knowledge or observations of sea ice, along with scientific knowledge or observations of sea ice. Community-based research undertaken in Cape Dorset, Pangnirtung, and Igloolik, Nunavut (April, 2004 to June, 2005), can then expand on this review in the future, from a more practical standpoint. Literature was selected using keyword electronic index searches (journal and library) to identify research dealing with: (i) Inuit knowledge, observations, or uses of sea ice; (ii) Inuit observations of weather and/or climate change; (iii) sea ice and climate change; (iv) sea ice parameters in climate models; (v) scientific methods of monitoring sea ice change; and, (vi) linking Inuit/traditional/local knowledge with scientific knowledge.

This paper aims to provide a baseline understanding of Inuit and scientific perspectives on the relationship between sea ice and climate change. Therefore, Section 2 explores Inuit sea ice and weather associations and Section 3 presents some examples of Inuit observations of climate change. Section 4 synthesizes the scientific means of characterizing sea ice and climate system links. These sections are the background to an examination of the experiences, methods, and goals that differentiate local and scientific sea ice knowledge (Section 5). In distinguishing these two types of understanding, disparities and commonalities arise that can serve as complementary means of achieving a broader comprehension of sea ice/climate relationships. Section 6 highlights some of the challenges and opportunities for undertaking the interdisciplinary research necessary to facilitate improved linkages between scientists and Inuit communities. In building these connections more effective assessments of community vulnerability to climate, and resulting sea ice, change may be undertaken. This would contribute to the development of appropriate adaptive strategies for the populations most affected by climatic change.

2. Inuit Observations of Sea Ice – Links to Weather

Inuit are, among other indigenous groups in the circumpolar Arctic, year-round inhabitants of northern communities and environments. This paper focuses on Inuit knowledge and observations of sea ice, including sub-groups of Inuit which may be identified by another name according to the region within which they live, or a unique cultural grouping.[1] In this paper, literature discussing Inuit knowledge and observations of sea ice focus on the Inuit of northern Canada (i.e. Inuit in northern Labrador (Nunatsiavut), northern Québec (Nunavik), the Territory of Nunavut, and Inuvialuit in the Northwest Territories (NWT)) (Figure 1) and Alaska (i.e. Yupik and Inupiat).

Prior to presenting specific examples of Inuit knowledge relating sea ice properties with weather conditions or climate, a brief overview of indigenous knowledge characteristics and acquisition processes is provided. Traditional knowledge (TK) is one of many labels used to refer to the knowledge held by various Aboriginal peoples.[2] In the Canadian North the term *Inuit Qaujimajatuqangit* (IQ) is now commonly used to refer to Inuit knowledge and acquired ways of knowing (Thorpe et al., 2001; Aporta, 2002; Thorpe et al., 2002; McGrath, 2003; Wenzel, 2004). However, due to the multitude of interpretations this term can undergo depending on the Inuit community or Inuktitut (Inuit language) dialect, ‘Inuit knowledge’ will be used throughout this paper to refer to the expertise acquired by Inuit through extensive interaction with sea ice environments. Inuit knowledge is more encompassing of socio-cultural content (and importance) than TK or traditional ecological knowledge (TEK) alone (Wenzel, 2004), but this paper will only discuss the portion of Inuit knowledge (as published in current literature) dealing with the nuances of sea ice and weather/climate interactions. Furthermore, no matter what term is used to identify Inuit knowledge (or other forms of indigenous knowledge), it is just a label, and it is mainly used by academics and governments. Such labeling can be useful as a general reference to the epistemology, knowledge system, and characteristics often implied (or explicitly defined) with the use of ‘indigenous knowledge’, but in most cases the term used is: (i) an external (often Western) construct, and non-native term, created to identify another culture’s knowledge; (ii) not easily defined because the meaning varies from person to person and culture to culture; and, (iii) can reflect the knowledge that non-Aboriginal researchers think Aboriginal people possess, rather than the knowledge itself (McGregor, 2000). Despite numerous debates on which is the most appropriate term, definition, or method of applying indigenous knowledge, there is increasing consensus on the value of respecting – and learning from – the knowledge to which all these debates refer (Kuhn and Duerden, 1996; Nuttall, 1998; Burgess, 1999; Wenzel, 1999; Riedlinger and Berkes, 2001; Nichols et al., 2004).

The depth, specificity, and content of Inuit knowledge is highly variable depending on the individual, their upbringing and experiences, the community in which they live, and the environmental factors influencing harvesting practices. However, there are some general characteristics of knowledge acquisition which transcend individual, cultural, and regional differences within, and between, Inuit communities. First, Inuit knowledge, insight, and wisdom is gained through experience, incorporating a finely tuned awareness of – and respect for – the ever-changing relationship

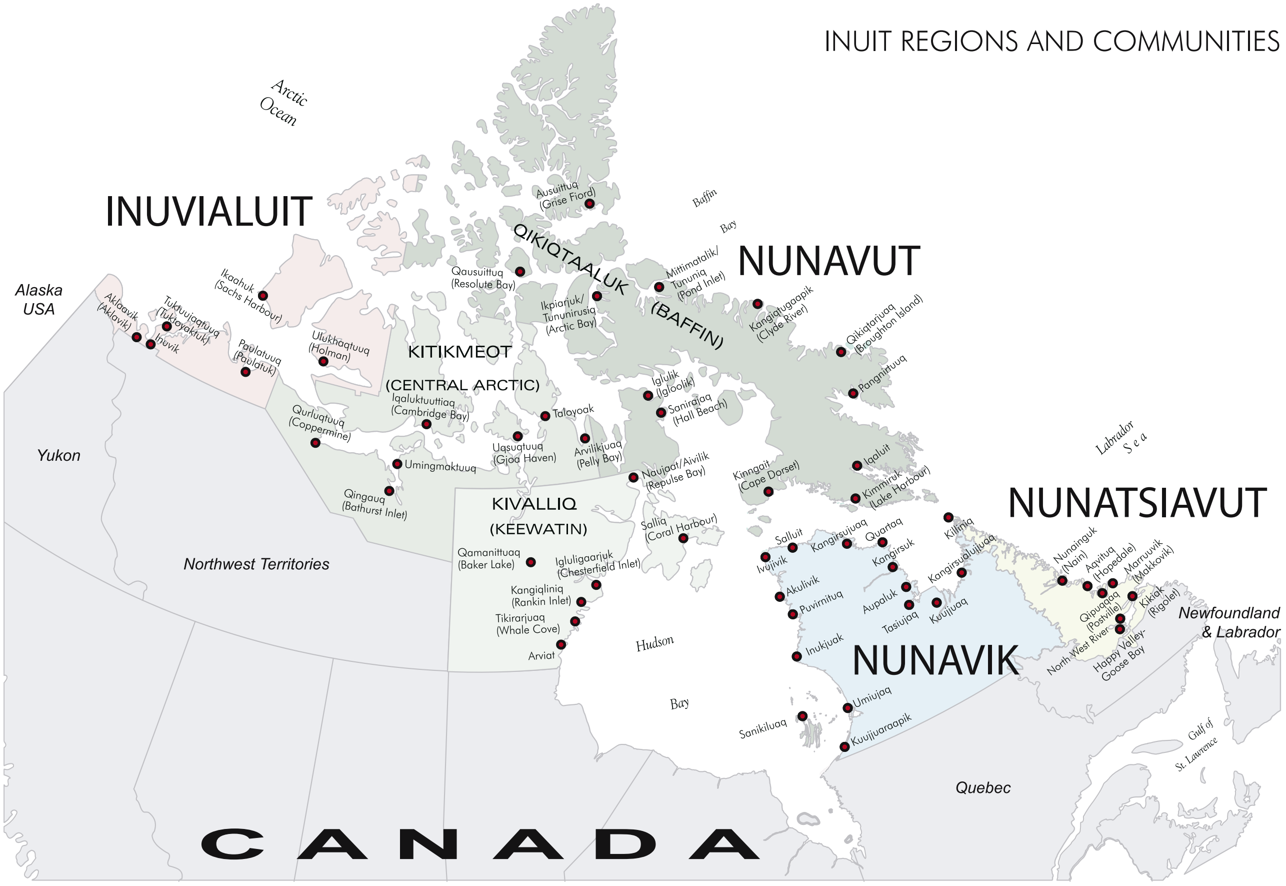


Figure 1. Map showing the Inuit regions, and communities, in Canada (courtesy of the Inuit Tapiriit Kanatami).

between Inuit and the land, the weather, wildlife, and the spiritual worlds (Nuttall, 1998; Thorpe et al., 2001). People who live close to nature, and derive sustenance from the land and sea (e.g. hunters, trappers, and fishers), build up an intimate and intuitive understanding of the environment over long periods of time (McDonald Fleming, 1992; Zamporo, 1996; Thorpe, 1998; Furgal et al., 2002a; Furgal et al., 2002b). Inherent in the experiential means of learning, repeated local observations and understanding place-specific characteristics are important for: (i) harvesting success; (ii) personal safety; (iii) reliability of information; and (iv) confidence in passing on information (e.g. Thorpe, 1998; Riedlinger and Berkes, 2001; Aporta, 2002; Furgal et al., 2002a; Oozeva et al., 2004). Second, Inuit knowledge, insight, and wisdom is shared through oral history, stories, myths, songs, lessons (and more recently, writings), and passed on over generations (Huntington, 1999; Thorpe et al., 2001; Furgal et al., 2002a; Nichols et al., 2004). This transmission of knowledge, and sharing of a worldview, involves a complexity of social, economic, and ecological relationships (Nuttall, 1998). It is a cumulative, and collective experience, whereby each generation incorporates adaptations that add to the knowledge base (McDonald Fleming, 1992; Zamporo, 1996; Thorpe, 1998; Huntington, 1999; Riedlinger and Berkes, 2001). Third, Inuit knowledge is continually expanding and changing depending on the person, as both personal experiences and teachings from others accumulate (Wenzel, 1999; Thorpe et al., 2001; Nichols et al., 2004). Inuit knowledge is dynamic and inclusive of new information or conditions which have proven influential or important over time (Bielawski, 1992; McDonald Fleming, 1992; Wenzel, 1999; Thorpe et al., 2001; Nichols et al., 2004). It is not just knowledge, but a way of life (Wenzel, 1999), part of a holistic experience incorporating physical, mental, emotional, and spiritual awareness (Zamporo, 1996; Thorpe, 1998). Therefore, Inuit knowledge is based on extensive, repeated observation and experience that is further verified, shared, and improved in a collective context. This implies both rigour and confidence in local understandings of complex systems. These general aspects of knowledge acquisition underlie the more specific presentation of Inuit sea ice knowledge, and links to weather conditions and patterns.

Despite growing community populations, shifting demographics, and the adoption of various aspects of southern lifestyles and technologies over the past fifty years, Inuit identity, knowledge, livelihoods, and survival are still strongly linked to the seasonal cycles of sea ice and wildlife harvesting (Wenzel, 1991; Pelly, 2001; Poirier and Brooke, 2000; Aporta, 2004; Robards and Alessa, 2004). Specialized skills such as reading the ocean ice or recognizing changing weather conditions may no longer be essential for survival,[3] but they are still highly valued (Stern, 1999). Subsistence harvesting can contribute economically and socially to household and community networks (e.g. Furgal et al., 2005), or simply instill a sense of personal fulfillment. Therefore, for those who are actively engaged in sea ice travel or harvesting, weather is a key driver in the ecological dynamics of subsistence resources as it impacts local access to, and availability of, marine mammals (Kofinas et al., 2002). Because local weather influences hunting and traveling conditions, Inuit have developed a rich tradition of understanding, interpreting, and forecasting weather patterns. Knowing about, and dealing with, weather forms an integral part of community life (Jolly et al., 2002; Oozeva et al., 2004). Hunters' knowledge includes an understanding of the reciprocal influences of winds, currents, and ice formation/dynamics (Nelson, 1969; Freeman, 1984; Krupnik, 2002). These will be briefly discussed before interpreting Inuit perspectives on the relationship between sea ice and climate change.

Sea ice is constantly shifting, making it extremely treacherous to navigate. Traversing moving ice requires an understanding of a vast array of interrelated factors such as: (i) crystalline formation; (ii) temperature; (iii) salinity; (iv) wind; (v) currents; and, (vi) shoreline and sea bed topography (Riewe, 1991; Jolly et al., 2002). Therefore, experienced hunters avoid taking unnecessary risks when traveling on the sea ice, demonstrating that they have sufficient sea ice knowledge along with a detailed understanding of the ocean and weather conditions that may cause sudden and dangerously changed ice conditions (Nelson, 1969; Freeman, 1984; Aporta, 2002). External indicators are important, as well as understanding the processes working invisibly underneath the ice cover (Aporta, 2002). By knowing the peculiarities of varying types of wind and current flows, for an assortment of wind/current combinations, Inuit can reliably forecast ice safety (Nelson, 1969; Krupnik, 2002). This allows hunters to travel in the desired direction to avoid dangerous circumstances (MacDonald, 1998). Some sea ice conditions are inherently more risky to traverse (e.g. moving ice, polynyas,[4] floe edge,[5] etc.), but often their importance as wildlife habitat and the desire or need for a successful hunt may be worth the risk to a confident and experienced hunter. Nevertheless, hunters are continually revising their personal guidelines for making correct (i.e. life-sparing) risk-versus-reward decisions (Norton, 2002; George et al., 2004). In such cases, localized knowledge of, and previous experience with, thin ice conditions, strong currents, animal behaviour, tidal stages, and navigational aids such as snowdrifts all contribute to enhancing the safety of sea ice travels (McDonald et al., 1997; MacDonald, 1998; Aporta 2002; Bennett and Rowley, 2004). Assessments of weather and ice conditions/stability can occur from the kitchen window, just outside the house, at the shoreline, or in the midst of traveling (Jolly et al., 2002; Oozeva et al., 2004). These assessments can also occur more collectively as the ice is constantly evaluated and discussed by hunters in town, on the move (Oozeva et al., 2004), or over shortwave radio (Aporta, 2004; George et al., 2004).

Providing a glimpse into the means with which Inuit predict movement and fragmentation of sea ice requires some consideration of wind forecasting techniques. The power of winds to affect sea ice conditions or movement is highly emphasized, and in so doing hunters tend to consider the effects of precipitation, temperature, or clouds as secondary, or of minor importance (Nelson, 1969; Aporta, 2002). Nelson (1969) noted that during winter months some Inuit are able to foresee weather with impressive accuracy, but also acknowledged that in summer their forecasts may not be as reliable. However, the accuracy of weather prediction will vary with the experience of the individual, the route they are traveling, the mode of travel, and the time of year. In addition, weather shifts have become more abrupt and weather patterns more unpredictable in the past few decades (refer to Section 3), making it more challenging to accurately interpret indicators or predict shifts in wind or weather conditions.

Understanding the wind-current-ice complex is especially important when hunters travel beyond the landfast ice,[6] whereby experienced hunters or travelers must learn the sophisticated wind direction identification and naming system relevant to their travel range (e.g. MacDonald, 1998; Oozeva et al., 2004). Wind direction, combined with knowledge of local shoreline topography, and tests of current direction and strength, are all crucial in determining:

(i) whether the ice is moving, and if so, in what direction;
(ii) the safety of ice (i.e. thickness and stability);
(iii) where leads and cracks will form, and the safety of crossing such openings;
(iv) what survival options are available in emergency conditions;
(v) where marine wildlife may be found and whether it is safe to hunt wildlife that has been located; and,
(vi) the moon phase, coupled with the strength of tides (Nelson, 1969; Freeman, 1984; Aporta, 2002; George et al., 2004).

Therefore, the times of early freeze-up, and late stages of break-up, are arguably the most critical in terms of assessing ice safety (Freeman, 1984). McDonald et al. (1997, 16) provide a succinct, useful textual and visual depiction of the Inuit conception of sea ice formation/decay stages, as related to currents, winds, and tides (Figure 2). Inuit from Sanikiluaq, Nunavut, on the Belcher Islands in Hudson Bay, consider five phases of ice formation as important to their use of, and travel on, the sea ice:

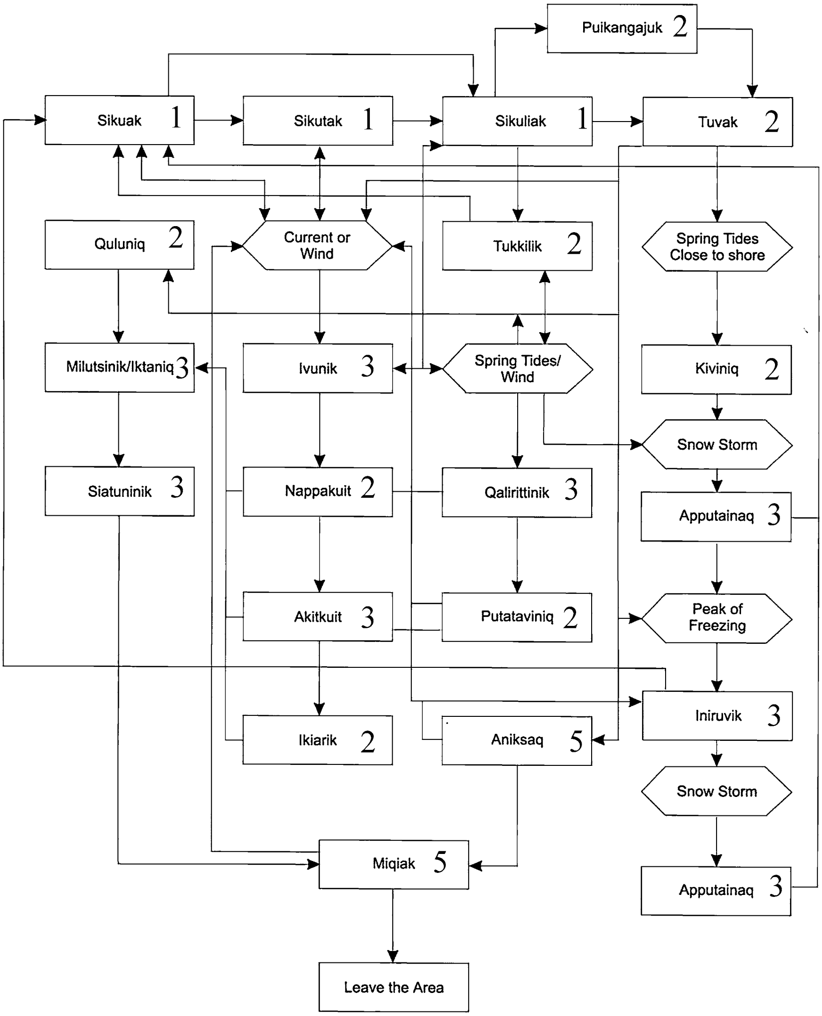
1. early ice formation – shoreline to land points in inlets, bays and peninsulas;
2. development of landfast ice;
3. development of floe edge ice;
4. spring cracks; and,
5. after break-up from spring to early summer (Figure 2) (McDonald et al., 1997).

In more northerly latitudes, the presence of multi-year sea ice during the summer can contribute to the safety of open water travel.[7]

Inuit hunters have essentially "decoded" sea ice behaviour through their understanding of lunar phases, tidal currents, and winds (Aporta, 2002, p. 352). The intricate and extensive Inuit knowledge of the sea ice environment cannot be described within the scope of this paper; however, the localized emphasis on linking ice conditions and movement with local weather patterns is critical.

3. Inuit Perspectives on Climate Change

Within the literature reviewed, it was challenging to find direct statements linking Inuit knowledge of sea ice to climatic conditions or trends (either by Inuit through interview passages or by researchers through their results). Rather, the relationships between sea ice and weather are reinforced as predominant Inuit concerns because these local interactions have important implications for hunting success and personal safety. However, environmental changes such as weather, and sea ice thickness or distribution, can also be linked to changes in climate (Riedlinger and Berkes, 2001; Nichols et al., 2004). Since some daily activities and safety in and around Inuit communities depend on local weather and ice conditions, Inuit formulate an indirect relationship between sea ice and climate.



Inuit have recently been observing changes in ice and weather patterns that they consider indicative of longer term climatic trends and increasing climate variability (McDonald et al., 1997; Ford, 2000; Riedlinger and Berkes, 2001; Fox, 2002; Furgal et al., 2002b; Huntington, 2002; Jolly et al., 2002; Kofinas et al., 2002; Krupnik, 2002; Nickels et al., 2002; Thorpe et al., 2002; Nichols et al., 2004). These experiences have expanded their characterization of the relationship between sea ice and climate change. Inuit seem to distinguish this relationship based on the outcome(s) it may have on their communities (e.g. alteration of travel routes, access to hunting grounds, marine mammal distribution and behaviour, weather or sea ice forecasting accuracy, etc.). Inuit perceptions of sea ice and climate change develop from place-based knowledge, and personal interaction with local marine environments. Some examples of climate-related changes experienced by Inuit in the North American Arctic are presented in this section (refer to Figure 1 for the location of Canadian Inuit communities).

For Inuit communities located around the perimeter of Hudson Bay,[8] many of the environmental indicators they normally employ to interpret weather patterns, forecast conditions, and predict seasonal events have no longer been accurately coinciding with existing weather systems (McDonald et al., 1997). By the early 1990s, weather changes were noted to be quicker, more unexpected, and difficult to predict in comparison to the 1940s (McDonald et al., 1997). These changes have had regionally varying impacts on the thickness of river and sea ice, as well as the timing of freeze-up and break-up. Snow conditions are notably poor, and are thus increasingly unsuited to making snow houses or emergency shelters while hunting (McDonald

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Figure 2. Inuit characterization of the effects of currents, spring tides, and wind on sea ice. Numbers in boxes refer to the stage of ice formation (described in Section 2.0). Source: McDonald et al. (1997, 16). Where: *Akitkuit* = new ice is allowed to form from ice broken up by strong currents or waves colliding against the floe edge; *Aniksaq* = large piece(s) of floating solid ice with no cracks, separated from the floe edge by strong currents or winds; *Apputainaq* = new cracks covered with snow, “false ice”; *Ikiarik* = forms when one piece of solid ice is pushed on top of another during a wind storm or spring tides; *Iniruvik* = “ice joints” occurring along the thinner edge of what was the floe edge, opening and closing continuously; *Ivunik* = rough, scrambled ice of varying thickness formed when moving ice collides with the floe edge and piles up; *Kiviniq* = the depression usually formed near shorelines, formed by the weight of high-tide water rising through cracks; *Milutsinik/Iktaniq* = formed at the floe edge when snow-soaked water freezes; *Miqiak* = “moulting ice: thick pack ice from north HB that often crowds areas so there is no open water in sight; *Nappakuit* = ice only 3–6 mm thick when broken by the forces of winds, currents, or waves; *Puikangajuk* = ice formed in polynyas during stormy weather or currents; *Putatiaviniq* = an older piece of ice, separated from other ice by currents, upon which *sikuliak* has formed; *Qalirittinik* = the result of strong currents and moving ice that causes thin pieces of ice to pile up on each other; *Quluniq* = deformed tukkiliit (plural of *tukkilik*) under the pressure of high and low tides; *Siatuninik* = pieces of ice moving as a group in the current; *Sikuak* = very thin layers of new ice formed on a calm day, often attaching to shoreline or other ice; *Sikuliak* = newly formed ice with no snow on top, thinner than old ice, but safe to walk/travel on; *Sikutak* = new ice that forms from *sikuak*; *Tukkilik* = thin ice that was formed in cracks occurring between islands when there is water under the ice; *Tuvak* = landfast ice that stays frozen in the bay and coastal areas and becomes solid ice attached to shorelines.

et al., 1997). Weather changes have altered ocean currents, which in turn affect access to food for marine animals, and access to wildlife for Inuit. Cold temperatures combined with weakened currents caused more frequent freezing of previously recurring polynyas (McDonald et al., 1997). This can contribute to the winterkill of marine birds (e.g. common eider), since several bird species are dependent on open water for access to food throughout the winter[9] (Nakashima, 1993; Richardson, 1993; Gilchrist and Robertson, 2000). Weaker currents are also suggested to be responsible for decreased numbers of polar bears, walrus, or beluga whales in certain areas of Hudson Bay (McDonald et al., 1997). Weakening currents were specifically mentioned around Sanikiluaq and Lake Harbour (now referred to as Kimmirut), Nunavut, and may be linked to either climatic change or to the damming of rivers draining into Hudson Bay for the purposes of hydro-electric development (Richardson, 1993). The changes may also influence the increasing distance of the floe edge noted from Inukjuak, Québec, where the longer distance to hunting grounds increases transportation time and cost (Richardson, 1993). While these environmental changes have significant impacts on nearby communities and may provide insights into potential future scenarios linked to climatic change, it is also important to determine the degree to which effects are a function of human-induced (e.g. hydro development in Québec) or geophysical (e.g. isostatic rebound) change.

Perhaps one of the most well-known accounts of Inuit observations of climate change, the International Institute for Sustainable Development (IISD) initiated a large project to document and film changes being experienced by the people of Sachs Harbour, in the Inuvialuit Settlement Region of the NWT (Ashford and Castleden, 2001). Here, it is (re)emphasized that observations of climate change are based on local knowledge of the weather (Ford, 2000; Jolly et al., 2002). Observations linked to climatic change have been noted since the 1990s, and were detected by hunters and experienced sea ice travelers based on deviations from a window of expected variability regarding: (i) the timing of freeze-up and break-up; (ii) seasonal temperatures; (iii) precipitation; and, (iv) wind strength and direction, among other indicators (Jolly et al., 2002). Changes relating to sea ice represented the largest group of community observations in Sachs Harbour. Overall they include changes to the seasonal extent and distribution of sea ice, timing of freeze-up and break-up, ice thickness, surface topography (e.g. pressure ridges, leads, and cracks), and the distribution/abundance of sea mammals (Jolly et al., 2002). Nichols et al. (2004) list several community observations that arose through semi-directed interviews conducted in Sachs Harbour, which indicate that, compared to the 1950s:

- there is less multi-year ice, and it is located further from the community;
- first-year ice is thinner;
- there is less sea ice overall;
- break-up is occurring earlier, and more rapidly;
- freeze-up is occurring later; and,
- winds are stronger, and windy days seem more frequent.

These variations are viewed as indicators of larger-scale changes that are already, and will continue to, affect peoples' travel routes and hunting practices (Jolly et al., 2002).

Yupik communities in Alaska have also been keenly observing changes in local weather and ice conditions.[10] Yupik concepts of the relationship between sea ice, marine mammals, and currents/winds demonstrate that they have developed full scenarios linking ice conditions and climate change. For example, the direction and strength of currents and/or winds can be related to the formation/location of leads, and thus to the relative abundance of walrus or bowhead whales (Krupnik, 2002). This allows hunters to effectively determine the anticipated degree of travel safety and hunting success (Krupnik, 2002). However, since the mid-1970s, some elders noted that the "rules for interpreting ice" had changed, whereby nearshore ice dynamics are no longer predictable in the manner to which they were accustomed (Norton, 2002, p. 142–143). For example, there are more frequent winter and early spring break-off events, and shortened sea ice seasons (Huntington, 2000a), causing increased instability in the nearshore ice. This affects whaling activities and success, and suggests that shorefast ice is more dynamic than in the past (George et al., 2004).

Based on a few examples from the literature reviewed there are several generalized changes relating to sea ice and climate that Inuit have been observing over the past two decades:

- Increased variability in weather events (McDonald et al., 1997; Riedlinger, 2001; Jolly et al., 2002; Kofinas et al., 2002);
- Fewer very cold days in early winter and fewer extended periods of extreme cold (Furgal et al., 2002b; Kofinas et al., 2002);
- Change in the pattern and rate of fall-to-winter transition (McDonald et al., 1997; Berkes and Jolly, 2001; Riedlinger, 2001; Furgal et al., 2002b; Jolly et al., 2002; Kofinas et al., 2002; Krupnik, 2002; Nichols et al., 2004);
- Increased number of summer storms/extreme events (especially the frequency of high wind events and lightning) (Jolly et al., 2002; Kofinas et al., 2002); and,
- Increased unpredictability, whereby changes are quick and the rate of change seems to be accelerating (McDonald et al., 1997; Berkes and Jolly, 2001; Furgal et al., 2002; Jolly et al., 2002; Norton, 2002; George et al., 2004).

It is noted that the increased variability of local weather changes is of great concern, but the unpredictable nature of such circumstances is most worrisome (Ford and Smit, 2004). The unreliability of previously effective forecasting techniques can undermine the relationships Inuit have formed with the sea ice environment and marine mammals, and can thus drastically affect their lifestyles and identities (Norton, 2002; George et al., 2004).

Attempts to characterize Inuit perspectives on climate change have focused predominantly on observations of change. When attempting to characterize the relationship between sea ice and climate change it is common for Inuit to communicate

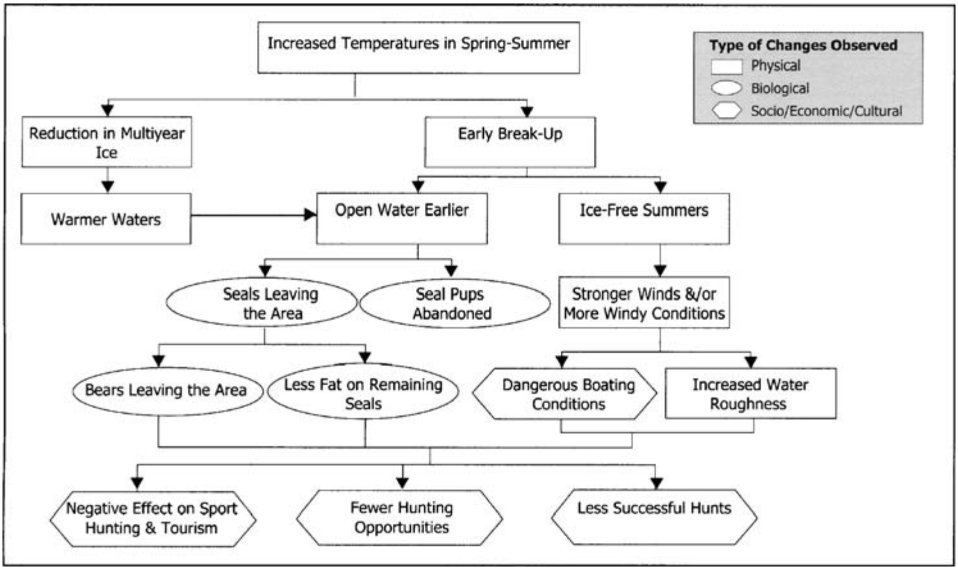


Figure 3. An example of Inuit perceptions of climate change influences on sea ice conditions and associated relationships – observations of seasonal change (spring and summer) in Sachs Harbour, NWT. *Source*: Nichols et al. (2004, 74).

the perceived influence of climate change on their: (i) harvesting practices; (ii) ability to forecast weather events; (iii) means of travel; and, (iv) ability to adapt to such changes (Figure 3). Because sea ice affects various aspects of Inuit life, it is difficult to isolate an Inuit perception of the relationship between sea ice and climate change alone (S. Fox Gearheard, 2003, personal communication). As such, it may not be the process of climate change itself that Inuit attempt to characterize. It seems that it is the manifestation of related changes that are deemed most important by Inuit, for example:

- floe edge history and position;
- melting seasons;
- freeze-up and break-up timing;
- water temperatures;
- snow conditions;
- changes in marine mammal movements/migration patterns; and,
- seal reproduction timing and success (Hunters and Trappers Association Meetings in Pangnirtung and Cape Dorset, Nunavut, 2003, personal communication).

As a result, it may be interpreted that it is the Inuit knowledge *of*, and experiences *with*, sea ice (and all related driving forces) that formulate a conceptual link between sea ice processes and climate change.

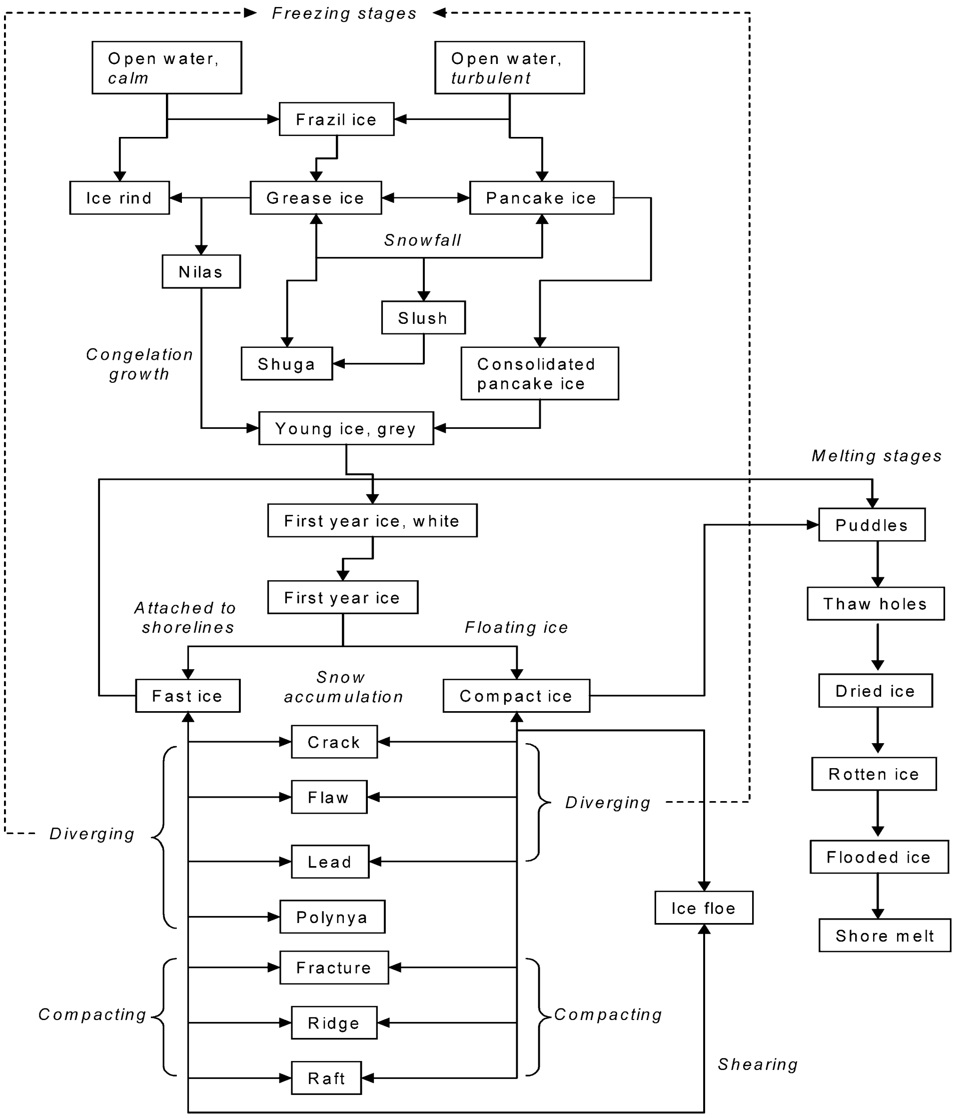
4. Scientific Perspectives on the Relationship Between Sea Ice and Climate Change

Scientists[11] are also concerned with the manifestations of climate change, as the underlying purpose of their studies is to help society understand, plan for, and adapt to climatic change. However, when characterizing the relationship between sea ice and climate change, they focus predominantly on the interactive functioning of sea ice-ocean-atmosphere systems.

Sea ice is influential in the climate system as it modifies the surface radiation balance through its high albedo, and alters atmosphere-ocean momentum, heat, and matter exchanges due to its insulating behaviour (Lemke et al., 2000; Grumet et al., 2001). By investigating the thermodynamics and dynamics of ocean ice formation and movement, scientists have characterized some of the physical – and internal – processes that influence changes in ice extent, distribution, and thickness. The key to thermodynamic characterizations of sea ice is to understand that sea ice is a mixture of ice, liquid brine (the concentration of salt in water), air bubbles, and solid salts. The interplay of these elements impacts the processes of ice formation, whereby the conduction of heat is influenced by the porosity (i.e. air bubble content) and salt content of ice (Figure 4) (Wadhams, 2000; Davis, 2000). Sea ice dynamics also determine the motion and growth/decay of sea ice (Figure 4), whereby stresses exuded by winds or currents may result in the formation of leads, pressure ridges, or polynyas (Davis, 2000).

The links between sea ice and climate have evolved mainly from the development of computer models used to evaluate/postulate the potential impacts of climate change on sea ice (e.g. Ingram et al., 1989; Mysak and Manak, 1989; Vinnikov et al., 1999; Lemke et al., 2000; Holloway and Sou, 2002; Saenko et al., 2002; Colman, 2003; Holland and Bitz, 2003). Numerical models are developed to re-create the complexities of nature using simulations of atmospheric and oceanic processes to represent climatic variables in a theoretical fashion. The climate system is thus divided into a three-dimensional global grid, whereby supercomputers are employed to solve mathematical representations of matter and energy exchanges between grid points (Demeritt, 2001a). Only when a sea ice model is fully integrated into a coupled atmosphere-ocean general circulation model (GCM) can it be referred to as a true climate model. GCMs are far more complex, computationally expensive, and time-consuming than simpler process simulations (e.g. stand-alone sea ice models or coupled ice-ocean-mixed layer models), and it must be recognized that sea ice/climate interactions tend to remain dependent on the type of sea ice model employed and degree of allowance for feedbacks (Laidler, 2004). Some ice-ocean-atmosphere relationships must be empirically derived to enhance model feasibility within current computing power, cost, and time constraints; therefore, different models may constitute different correlations that lead to varying results under climate change scenarios. Readers are referred to Vinnikov et al. (1999) and Walsh and Timlin (2003) for reviews of some of the most popular GCMs used in sea ice/climate change research efforts. In contrast, Demeritt (2001a) provides a valuable critique of decision-makers' reliance upon GCMs to provide a full and accurate view of climate change trends or future scenarios.

It may be tempting to take model results as representative of reality, especially when they provide quantitative estimates of the relationship between sea ice and climate change (e.g. sea ice extent, distribution, concentration, and thickness). Such results are indeed valuable in considering the potential range of *possible* impacts of climate change on arctic sea ice. However, the following issues are important to



consider when investigating scientific perspectives on the relationship between sea ice and climate change (based on GCMs):

(i) the type of model, including spatial/temporal resolution and methods of parameterization of particular processes;
(ii) the type of atmospheric forcing and degree of coupling allowed between sea ice, the ocean, and the atmosphere;
(iii) the baseline conditions employed for long-term model integrations (either simulated or prescribed);
(iv) the inclusion, and type, of sea ice dynamics incorporated in addition to the thermodynamics of sea ice; and,
(v) the degree to which particular feedbacks have been suppressed (Laidler, 2004).

Accounting for these modeling constraints allows for a more informed, theoretical understanding of the interplay between sea ice and climate, while also enhancing the palpability with which model results are interpreted and/or applied.

The development of interactive theories and models of sea ice/climate linkages has improved dramatically with advances in computing capability and

Figure 4. Scientific characterization of sea ice formation, decay, and dynamic processes. Based on: WMO (1970); Lock (1990), Wadhams (2000), Eicken (2003), Thomas and Dieckmann (2003). Where: (Freezing) – *Frazil ice*: fine spicules or plates of ice suspended in water during ice formation; *Grease ice*: an accumulation of frazil ice, when ice crystals coagulate forming a soupy layer on the surface; *Ice rind*: a brittle shiny crust of ice formed on a quiet surface by direct freezing or from grease ice, usually where there is lower salinity; *Nilas*: a thin elastic crust of ice (dark and light nilas according to thickness); *Pancake ice*: predominantly circular pieces of ice (around 3 cm to 3 m in diameter, less than 10 cm thickness) with raised edges; *Shuga*: accumulation of small spongy white ice lumps, formed from wind-driven accumulation of grease ice or slush; *Slush*: a viscous mixture of snow and water; *Consolidated pancake ice*: pancake ice frozen together; *Young ice (grey)*: transition stage between nilas and first-year ice (*grey and grey-white* according to thickness); *First-year ice (white)*: sea ice of not more than one winter's growth (categorized as *thin*, *medium*, or *thick*); *Fast ice*: see Endnote 6; *Compact ice*: floating ice with high concentration and no visible water. (Diverging Processes) – *Crack*: any fracture of fast ice, consolidated ice, or a single floe (separation of centimeters to meters); *Flaw*: narrow separation zone between drift ice and fast ice; *Lead*: a linear open water feature occurring in the ice pack between ice floes caused by ice break-up, and may be covered with new ice; *Polynya*: see Endnote 4. (Compacting Processes) – *Fracture*: any break or rupture – usually refreezing quickly – through compact, consolidated, or fast ice, or a single ice floe, resulting from deformation; *Ridge*: a line or wall of broken ice forced up by pressure, where the submerged portion is the keel and the exposed portion is the sail; *Raft*: ice deformation where one piece of ice overrides another. (Shearing Processes) – *Ice floe*: any relatively flat, discrete, piece of sea ice that varies in area from a few square metres to the area of a small town. (Melting) – *Thaw holes*: vertical holes in the sea ice formed when surface muddles melt through to underlying water; *Dried ice*: the surface of the sea ice after melt-water has drained through cracks and thaw holes; *Rotten ice*: sea ice which is in an advanced state of disintegration, appearing like a honeycomb; *Shore melt*: open water between the shore and the fast ice, formed by melting or due to river discharge. (- - - - - -) – divergence creating areas of open water will likely begin freezing again.

sophistication. Such developments have led to a general scientific characterization of the relationship between sea ice and climate as being composed of various potential feedbacks that could serve to dampen or exacerbate global warming trends (e.g. surface albedo/temperature and thermohaline circulation). The albedo-temperature feedback (or snow/ice-albedo feedback) is perhaps the most well-known possible climatic response to reduced sea ice extent or thickness. It is also one of the most popular reasons for hypotheses regarding the amplification of global warming at the poles (Bintanja and Oerlemans, 1995; Curry et al., 1995; Holland et al., 1997; Grumet et al., 2001). The basic chain of events would suggest a positive feedback whereby: (i) surface temperature rises; (ii) sea ice extent decreases; (iii) more open water allows an increased absorption of solar radiation; and, (iv) surface temperature increases further (Holland et al., 1997). The ice-albedo feedback mechanism may be present within the sea ice edge (i.e. changes in extent) or within the sea ice pack (i.e. changes in thickness without the disappearance of ice) (Curry et al., 1995). In other words, changes in multi-year pack ice, even without complete melting, can still have dramatic effects due to changes in the duration of snow cover, ice thickness, lead fraction, and melt pond characteristics that alter the surface albedo. The incorporation of sea ice dynamics into GCMs (e.g. lead formation) are deemed important in creating more representative sea ice responses to surface temperature changes (Ledley, 1988). Furthermore, an interactive atmosphere component ensures that potential sea ice-climate-thermohaline circulation (THC) feedbacks can be accounted for (Lohmenn and Gerdes, 1998). THC has important implications for salinity profiles and contributions to deep water formation in polar regions; it is often considered the “conveyor belt” of ocean currents at it spreads heat around the globe and influences climatic conditions worldwide (Copley, 2000; Vellinga and Wood, 2002). This deep water formation is believed to be largely controlled by variations in the sea ice margin, and especially by sea ice export to lower latitudes (Lemke et al., 2000). THC stability is a concern in climate modeling efforts since a major disruption in this global circulation driver could have significant impacts on regional climate simulations (Vellinga and Wood, 2002), not to mention on countries affected by altered circulation patterns and/or temperatures.

The arctic climate is periodically influenced by cyclical or quasi-cyclical forces such as El Nino-Southern Oscillation (ENSO) or the North Atlantic Oscillation (NAO) (Weller, 2000). Several satellite observation studies have attempted to link these driving forces (based on changes in atmospheric pressure gradients) to anomalous sea ice extents and concentrations (e.g. Mysak and Manak, 1989; Parkinson et al., 1999). One of the key questions that scientists continue to debate is whether or not recent changes in arctic sea ice result primarily from a temporary phase change of NAO or ENSO, or whether they are irreversible long-term trends related to a general global warming phenomenon produced by anthropogenic emissions of greenhouse gases (GHGs) (Wadhams, 2000). Scientists have observed sea ice through cruises, submarine sonar, ice cores, and most recently – and arguably most effectively – through satellite data (Johannessen et al., 1999; Wadhams, 2000). Overall, Northern Hemisphere results show a tendency towards declining sea ice extents, and decreasing thickness (Johannessen et al., 1999; Kerr, 1999; Copley, 2000); therefore, evidence is accumulating to indicate that climate change is affecting sea ice in a unidirectional manner not characterized by typical inter-annual, or even decadal, variability (Vinnikov et al., 1999). Nevertheless, it is important to emphasize that simultaneous positive and negative sea ice extent anomalies are also occurring on a regional basis (Grumet et al., 2001).

Despite some uncertainty in the absolute magnitude or statistical significance of changes, the scientific perspective on sea ice and climate change may be summarized as follows:

(i) the presence of sea ice acts as an insulating layer preventing heat loss from the ocean to the atmosphere and damping the effect of momentum transfer from ocean waves;
(ii) variations in the sea ice surface (i.e., snow covered, bare ice, melt ponds, or open water) affect radiative absorption, or surface albedo properties;
(iii) fluxes of latent heat impact the local atmosphere energy budget; and,
(iv) changes in sea ice thickness and dynamics affect ocean and atmospheric circulation (Davis, 2000).

Therefore, climate change may influence sea ice conditions in circumpolar regions, but sea ice will also have reciprocal effects on climatic systems locally, regionally, and globally.

5. Differentiating Inuit and Scientific Perspectives

Many studies presenting Inuit observations of climate change, uses of the sea ice, or Inuit knowledge of weather, climate, sea ice, and related factors have been conducted collaboratively. Within a community setting, researchers have spent weeks, months, or even years working with community members to learn from them and also to give voice to local concerns or expert opinions. However, with few exceptions,[12] the literature reviewed in this paper presents Inuit knowledge or observations of change through a filtered lens of the relevant scientific discipline. This is practical because: (i) it is the nature of research to interpret findings to come up with new theories, recommendations, or to provide voice to community concerns; (ii) not everything can or will be included in research data synthesis and analysis; and, (iii) researchers must comply with journal article length limitations. Therefore, presentation of a researcher's interpretation must be recognized, and not confused with a direct presentation of Inuit knowledge or perspectives (which may or may not actually occur). This is acknowledged prior to Sections 5 and 6, as the analysis of Inuit perspectives is based on secondary sources that in themselves are often social scientists' interpretations of Inuit knowledge. In contrast, evaluating sea ice and climate science literature is more direct as it is the author(s)' own experiences, experiments, and thoughts which are being presented and discussed. Thus, discussion of scientific perspectives is a direct interpretation of their findings, while discussion of Inuit perspectives is the author's interpretation of other researchers' presentations of Inuit perspectives.

Sections 2–4 have described several, markedly different, ways in which Inuit and scientists characterize the relationship between sea ice and climate change. Underlying the distinctions made between Inuit and scientific perspectives is the recognition of fundamentally different epistemologies. Scientific ways of knowing are reductionist by nature, aiming for objective isolation of experiments that elucidate causal relationships, consequences, or the intersection of variables (Freeman, 1992; Kuhn and Duerden, 1996; Nadasdy, 1999; Usher, 2000; Cruikshank, 2001). Remaining distanced from experiments is important to achieve replicability, comparability, and standardization across various contexts, free of actor interference. Although embedded assumptions and institutional influences do affect scientific practices, they are rarely acknowledged (Zamporo, 1996; Cruikshank, 2001). In contrast, Inuit knowledge (see Section 2) is part of a holistic understanding encompassing physical, mental, emotional, and spiritual awareness, and is thus inherently subjective (Kuhn and Duerden, 1996; Zamporo, 1996; Nadasdy, 1999; Berkes et al., 2000; Usher, 2000). Therefore, scientists tend to focus on understanding the physical processes involved in linking sea ice to climate change, while Inuit communities are more interested in understanding how changing ice conditions may affect their travel safety along with wildlife habitat and availability. Scientific perspectives tend to be based primarily on remotely acquired data, or modeled empirical relationships. Local Inuit perspectives derive from daily interactions with the sea ice environment and their dependence on weather and current conditions to ensure safe travel, reliable access to harvesting areas, and hunting success. The distinctive nature of these perspectives on sea ice and climate change phenomena inform the knowledge and practices of both scientific and Inuit communities, and may be summarized as originating from different: (i) experiences; (ii) methods; and, (iii) goals.

5.1. DIFFERENT EXPERIENCES

Perhaps the most outstanding difference between the sea ice/climate relationships characterized by Inuit and scientists relate to their life experiences.[13] Inuit *live* in the Arctic, thus they experience sea ice conditions and weather changes that affect their daily activities. In contrast, scientists *study* the sea ice environment, and *model* the links to weather or climatic variation. Such activities may or may not occur daily, and they are removed from personal experiences that physically affect pursuits outside of the work place.

For Inuit, sea ice and climate change maintain a practical significance linked to their personal safety, access to marine wildlife, ability to travel, and indeed to their cultural identity. Changes in ice and weather conditions have real implications for these practices, and can truly be a matter of survival should they get stranded on a moving ice floe due to an unpredictable storm or shift in ocean circulation. The implications for scientists have predominantly theoretical consequences. If modeling parameters do not adequately reflect the interaction between sea ice and climate they can be re-evaluated or re-calculated, but the scientist's life will not be threatened. Inaccurate model scenarios or calculation errors may impact a scientist's scholarly reputation or credibility, but are quite different from the perils of surviving on a drifting ice pack in hopes of being rescued.

Therefore, the differences in Inuit and scientific life experiences are strong influences in their divergent concepts of how sea ice and climate are linked (Berkes, 2002). While Inuit build relationships with the marine system through personal interactions and practical necessity, scientists remain distanced from sea ice as it is objectified and represented theoretically through remote observations or empirical simulations. This links to McGrath's (2003) distinction between Western culture as information-based, and Inuit culture as relationship-based. These different life experiences lead to the utilization of different methodologies for constructing a relationship between sea ice and climate change.

5.2. DIFFERENT METHODS

The differing modes of acquiring knowledge of sea ice and climate change derive from the experiential, *in situ* methodology used by Inuit communities and the remote observation and/or modeling approach taken by sea ice or climate scientists. Scientific sea ice data tend to be based on short-term, fragmentary records that rarely pre-date the twentieth century (Huntington, 2002). For example, satellite monitoring covers a broad spatial extent, but has only become widespread over the past few decades (Mysak and Manak, 1989; Johannessen, 1999; Parkinson, 1999; Huntington, 2002). Paleoenvironmental and archeological methods provide longer temporal coverage, but such data must be interpreted with caution (Riedlinger and Berkes, 2001; Huntington, 2002) because of the coarse temporal scale, the indicators used, and the method of data analysis. These types of scientific data are each valuable in their own right, but can be difficult to link to local scales or timeframes without adequate understanding of the spatial and temporal resolution of the data, and method of data manipulation.

Inuit knowledge of sea ice is constructed through years of personal interaction with, and inherent observation of, the marine environment. Comparable to the scientific practice of ground truthing, local experts not only account for the two-dimensional Cartesian mapping concepts promoted by satellite imagery (i.e., ice extent or percent surface coverage), but they enhance this 2-D characterization by incorporating a third and fourth sea ice dimension (Norton, 2002). In two dimensions, Inuit tend to characterize sea ice according to surface conditions and age composition. The third dimension accounts for the vertical nature of sea ice (i.e., thickness) that can be derived from surface indicators of stability and formation (Norton, 2002). The fourth dimension is a longitudinal representation that integrates a historical perspective by vesting sea ice with a seasonal "system memory" (Norton, 2002). Therefore, local weather and ice observations provide an account of seasonal patterns and local conditions that are not available in quantitatively-based data generated from satellite imagery, weather stations, or water survey measurements (Kofinas et al., 2002). Depth and temporal change assessment may be available through remote sensing analyses, but the coarse spatial scale and periodic image acquisition does not provide a comparable 'information package' to hunters requiring real-time evaluations of ice stability and safety. However, this is not to say that local "data" may be interpreted uncritically, for the detailed knowledge presented by Inuit communities is highly contextual (refer to Section 6).

Varying data collection methodologies have important implications for both the temporal and spatial scales accommodated in distinct perspectives on sea ice and climate change. Riedlinger and Berkes (2001) summarize these differences as follows:

- *weather station data* – short historical record (hourly), measurements at one point in space (1–1000 m)
- *satellite imagery* – large and small spatial scales, but relatively recent use
- *archival sources* (e.g. expedition records, whaling logs, Hudson Bay Company annals) – more historical depth, but spatially limited
- *proxy data* (e.g. ice cores and lake-sediment cores) – one locality but temporal scale spanning 100–10 000 years
- *traditional/local knowledge* – range of spatial scales (local and regional) with temporal scale spanning present, and living memory, to past (through historical recall and oral traditions that vary depending on the community and their knowledge-sharing processes)

Because Inuit tend to acquire their knowledge in an experiential manner, and usually in conjunction with efforts to navigate the sea ice or to hunt marine wildlife, their perspectives on the relationship between sea ice and climate change seem much broader than those of scientists. Inuit can relate what potential effects local weather events may have on ice conditions, as well as how such circumstances may affect the distribution, behaviour, or well-being of a variety of marine bird, fish, and mammal species. In contrast, scientists can offer more technical and detailed accounts of ice thermodynamics, dynamics, and physical interactions with global climate and circulation; however, it is difficult for such findings to be translated into local socio-economic implications. Not only are monitoring and modeling efforts often undertaken at scales that are too coarse to account for regional, much less local, variations in ice conditions (Copley, 2000; Demeritt, 2001a; Duerden, 2004; Nichols et al., 2004), to date they also tend to be conducted outside the context of the human dimensions of climate change. These variations in methodology are not to suggest that one is superior to the other, rather that disparate methods employed are inherently linked to the different goals pursued by scientific and Inuit communities.

5.3. DIFFERENT GOALS

The unique life experiences of, and methods used by, Inuit and scientists contribute to the pursuit of different goals in characterizing links between sea ice and climate change. Broadly summarized, Inuit communities value, and seek, sea ice knowledge that promotes personal safety, harvesting success, and reliable weather prediction. On the other hand, scientists are searching for a comprehensive understanding of the physical and internal processes of ice formation, decay, and motion, while also aiming to identify long term trends in sea ice extent, thickness, and distribution. Furthermore, scientists attempt to reliably model the interactions between sea ice-ocean-atmosphere systems to determine the potential impacts of global climate change.

Both groups aim to enhance the reliability of ice and weather forecasting, yet underlying the variation in goals is an inherently different focus. Modern scientific studies are unmistakably time-focused in their search for well-documented time series and uniformly organized data sets (e.g., annual temperature and ice series, ice charts, ice cores, etc.) (Krupnik, 2002). With this focus on temporality, scientists explore both average and extreme characteristics over time, based on yearly chronology and adherence to statistical reliability. Models are then used in attempts to better *explain* the relationship between sea ice and climate. In contrast, local Inuit knowledge focuses primarily on details that are specific to an in-depth characterization of the sea ice environment, whereby an assessment of reliability is derived from the age or experiences of the person making the observations/predictions (Kofinas et al., 2002; Krupnik, 2002; Norton, 2002; Oozeva et al., 2004). Furthermore, individual and collective conceptions of time, and consideration of events as normal or abnormal, will vary according to their social, ecological and economic relationships. Events or phenomena which have been incorporated into memory or actions are thus a function of various timescapes associated with Inuit experiences, and will influence local resilience to a particular change (Robards and Alessa, 2004). However, in general there is little emphasis placed on absolute dating or precise timing, and there is much more interest in extreme events rather than gradual changes.

Variations between the goals of Inuit and scientists are also reflected in the terminology they use. While the scientific exposition is notoriously hard for the layperson to comprehend (Figure 4) (Norton, 2002), Inuit ice vocabulary is perhaps even more challenging (e.g. Nelson, 1969; McDonald et al., 1997; Oozeva et al., 2004). Not only does Inuktitut terminology refer to ice states and processes, but also to human interaction with the sea ice (Nelson, 1969; Aporta, 2002). Thus language allows local ice users to pass along highly meaningful "environmental packages" motivated by the necessity to identify specific signals or shifts in ice/weather conditions (Krupnik, 2002). Compared to the technical terminology of scientific sea ice classification, the verb-based nature of languages like Inuktitut recognize the interaction between humans and the environment in the process of naming the ice environment (Aporta, 2002). Therefore, while scientific terms may have universal meaning to those who have access to the appropriate literature, local languages cannot be separated from the experiential processes in which they are derived. Unfortunately, Inuktitut sea ice words or concepts may increasingly lose their meaning/importance if people are not engaged in the terminology through daily interactions with the sea ice environment.

6. Discussion

Table I summarizes the key components serving to differentiate Inuit and scientific perspectives, as presented in Sections 5.1 to 5.3; however, it is also useful in sparking further discussion. The table format is used to ease interpretation and analysis, and is not intended to present a strictly dichotomous view of Inuit and scientific communities. In this discussion, the tabular presentation of differing perspectives (Table I) may be used as a guide to identify where increasing links and conceptual bridges need to be built between scientific and Inuit communities.

First, climate models are not universally accepted as the most appropriate scientific means of investigating climate change at a global scale. Debates exist within the scientific community surrounding the reliance of political decision-makers upon climate model results, and scientific consensus of global warming causes and effects. An insightful exchange between Demeritt (2001a,b) and Schneider (2001) highlights several key issues that should be considered when interpreting, or using, climate model results, including:

(a) scalar considerations and framing of climate change discussions (much modeling occurs on the global scale, while the regional scale was suggested as most important for policy-making);
(b) the focus on physical properties of GHGs;
(c) the objectivity of scientific methodologies and analyses;
(d) mathematical climate modeling as a primary means for understanding, analyzing, and predicting climatic change;
(e) policy decision-making based on climate model results;
(f) parameterization methods and goals in model development; and,
(g) evaluation of the legitimacy and credibility of climate modeling practices.

Therefore, while climate models can, and do, provide important insights into the physical processes of climate change, they only provide a partial window into the complex reality of climatic change (Demeritt, 2001a). Climate models provide

TABLE I

Summary of key components serving to differentiate Inuit and scientific perspectives on the relationship between sea ice and climate change (Sections 5.1–5.3)

Issue	Scientists	Inuit
Epistemology	**Reductionist**, aiming for **objectivity** and **generalization**	**Holistic**, highly **contextual**, aiming to understand local human-environment **relationships**
Sea ice	A **topic** of study	A **platform** to travel, hunt, and/or live on
Sea ice links to climate change	**Interest in the physical processes and feedbacks** relating to how sea ice can influence ocean/atmosphere energy exchanges, and thus climate	**Interest in how changing ice regimes will affect sea ice** as an important travel platform, the quality of wildlife habitat, wildlife availability, and personal safety
Sea ice observations	Predominantly based on **remotely acquired** data or point sampling	Acquired through **daily interaction** with sea ice, as well as weather, winds, currents, and tides that affect sea ice conditions, accessibility to wildlife, weather predictability, and travel safety
Importance of understanding links between sea ice and climate change	**Theoretical consequences** – inadequate modeling parameters may be re-evaluated or re-calculated; scientific reputation or credibility may be in jeopardy from mistakes or misinterpretations	**Practical consequences** – sea ice change can undermine personal safety, access to marine wildlife, the ability to travel, and notions of personal/cultural identity; survival may be in jeopardy from mistakes or misinterpretations
"The big picture"	**Technical** and **detailed** focus on physical processes and parameters of sea ice, and related interactions with global climate and circulation	**Broad** and **holistic** focus on all related components which may affect ice conditions, and subsequent influences on distribution, behaviour, or well-being of marine wildlife, as well as community members
Human position in climate change context	**External**	**Embedded**
Relationships with sea ice	**Distanced** from sea ice, relationship with an object of study through remote observations and/or theoretical and empirical simulations	**Personal** relationships with the marine system constructed out of personal interactions, beliefs, and practical necessity

(*Continued on next page*)

TABLE I
(*Continued*)

Issue	Scientists	Inuit
Life experience	***Study*** the sea ice environment, ***model*** ice links to weather or climate variation, typically in work-related activities	***Live*** in the Arctic, ***experience*** sea ice conditions and change daily, typically in subsistence-, commercial-, tradition-, or leisure-related activities
"Data" capture	**Short-term**, **fragmentary** records, predominantly based on satellite **remote sensing**, with some **paleoenvironmental**, **archeological**, and **point sampling** records	Years of **personal interaction** with, **observation** of, and **use** of the marine environment
Scale	Local, regional, and global (**mainly at coarse scales**), but generally short historical record or relatively recent use of technologies	Local (**mainly at fine scales**) and regional, spanning living memory to the past, through historical recall (varies greatly between communities)
Temporality	**Time-focused**, based on yearly chronology and statistical reliability; predominantly concerned with **averages** over time	**Experience-focused**, based on first-hand interaction with sea ice environments and reliability based on age or experiences of person making observations/predictions; predominantly concerned with **extreme events**
Goals	Comprehensive understanding of **physical and internal ice processes**, identification of long-term sea ice **trends**, and reliable **modeling** of future climates	Knowledge that promotes **personal safety**, **harvesting success**, and **reliable weather prediction**
Terminology	**Technical**, **specialized**, **jargon-laden**, notoriously hard for the layperson to comprehend; holds **universal meaning** for those with access to the appropriate literature	Refers to ice states, processes, and **human interaction** with sea ice, verb-based language structure recognizes **human/environment interactions** reflected in Inuktitut sea ice terminology; **highly contextual**

considerably less insight into the climate change impacts that may be felt in human lives and daily activities (Duerden, 2004; Nichols et al., 2004), which are the pre-eminent concerns of Inuit communities when seeking information on climate or sea ice change. The disparity between the scales at which physical data is gathered and scenarios are generated (broad scale), along with the distinct local geographies of widely dispersed communities (fine scale), magnifies the already uncertain results of climate models and their capability of predicting local implications of change (Duerden, 2004). Therefore, community-based studies incorporating or presenting Inuit knowledge can provide another partial window into the manifestations of climate change at a local level. If both Inuit and scientific perspectives can contribute to explaining phenomena observed beyond their respective cultures, then they can be considered equal contributions to human knowledge (Bielaswki, 1984). Perhaps increased interaction between scientists and Inuit can address some modeling limitations by improving linkages between different: (i) relationships with sea ice; (ii) “data” capture methods; (iii) scales; (iv) conceptualization of “the big picture”; and, (v) goals (Table I). In this sense both can add to the sources of general scientific explanation and be incorporated into the body of scientifically researched truth as discussed by Bielaswki (1984).

Second, the challenges of linking issues such as relationships with sea ice, human position in climate change context, and temporality (Table I) are substantial, especially considering that the validity of such different perspectives are ongoing dilemmas between natural and social scientists. Subjectivity has been used to contest the validity and credibility of social science research involving interviews and/or qualitative analysis (Collings, 1997), but similar arguments have also been presented in relation to the development of climate models and/or component parameterizations (Demeritt, 2001a). Climate models are continually, and rigorously, evaluated for accuracy and stability; however, a similar process has not been systematically developed for evaluating the consistency of Inuit knowledge. It is important to remember that not every Inuk[14] is equally knowledgeable about sea ice and weather or climate change, and that individual statements cannot be too quickly generalized to be representative of all Inuit (Wenzel, 1999). Knowledge will vary in quantity and quality between members of any given community, as it is constructed, created, changed, and modified in specific social contexts[15] (Nuttall, 1998; Ellerby, 2001), which can even by influenced by researchers themselves (Wenzel, 1999; Searles, 2001). Select Inuit within a community, often respected elders or active, experienced hunters will be renowned for a particular area of expertise (e.g. accuracy of sea ice navigation, hunting prowess, weather prediction reliability, etc.) and would thus be recommended as knowledgeable on a certain topic (Stern, 1999; Ellerby, 2001). But the selection of local experts is not conducted systematically, nor is this process reported in sufficient detail to enable comparisons with other studies (Baxter and Eyles, 1997; Davis and Wagner, 2003). For both Inuit and scientific observations or predictions of change, the validity of knowledge is based on that culture’s definition of reality, truth, and understanding (Bielawski, 1984). It is also dependent on which local groups were involved (i.e. influenced by gender and generational differences) and thus which local interests are represented (Nuttall, 1998). As a result, Inuit observations require the same level of independent "truthing" as other kinds of data (Huntington, 2000b), either from other community members, through participant observation (Wenzel, 1999), or through social science evaluations (Baxter and Eyles, 1997, 1999).

Davis and Wagner (2003) identify arctic researchers as being at the forefront of rigorous methodological development, and yet the majority only provide the "minimum" methodological descriptions by outlining their: (i) purpose; (ii) timeline; (iii) research instrument(s); and (iv) number of participants in a study. Improving the transparency of this process would allow for better interpretation of data quality or representation, and would also enable other researchers to learn from previous experiences or mistakes (Davis and Wagner, 2003). Not only data collection methods should be considered, but also what social scientists consider data in the first place (Searles, 2001). This is important when evaluating the quality and reliability of information shared. There are well established research methods and data validation procedures in the physical and natural sciences, and it is increasingly suggested that the social sciences need to move in a similar direction (Baxter and Eyles, 1997; Wenzel, 1999; Duerden, 2004). However, social scientists face the added challenge of avoiding decontextualization (Nuttall, 1998), as well as remaining reflexive and responsive to community interests and feedback. For example, documentation is an important means of increasing accessibility to Inuit knowledge, and rendering it parallel to other written information (i.e. the basis of scientific studies) (Huntington, 1998); however, the methods of documentation,[16] and their relative strengths and weaknesses, should be evaluated and disclosed (Huntington, 2000b). Criteria for evaluating qualitative research to ensure credibility, transferability, dependability, and confirmability are suggested as valuable starting points for assessing social science research that presents Inuit knowledge or observations (e.g. Lincoln and Guba, 1985; Baxter and Eyles, 1999). These could then be expanded or adapted to suit particular community or research needs. Furthermore, if such evaluations were undertaken more regularly natural or physical scientists may gain a greater appreciation for the reliability and/or specificity of Inuit knowledge.

Third, Schneider (2001) places the onus on social scientists, or Inuit communities for that matter, to produce numerical evidence to convince natural scientists – in conventional scientific language and journals – of observations or conclusions that may, or may not, corroborate conventional natural science methods, results, or analyses. However, do physical and natural scientists also not have a similar responsibility? The hurdles to gaining broader acceptance of Inuit knowledge may be attributed to inertia, and inflexibility (Huntington, 2000b). However, Inuit communities are also skeptical of the value of science (natural or social) (Nuttall, 1998; Wenzel, 1999; Furgal et al., 2005). Therefore, some responsibility must also fall on researchers to convince community members that their study is meaningful, and has implications at the local level. The inclusion of community considerations and interests is occurring in a changing northern research context which obliges social scientists to respond to concerns about the intrusive nature of research methodologies, lack of local involvement in research, poor communication with affected populations, short field seasons, inadequate acknowledgement of credit, and conflicts of data ownership (Bielawski, 1984; Nuttall, 1998; Wenzel, 1999; Duerden, 2004). Collaborative, cross-cultural research could be said to be evolving into a new social science paradigm as the changing social context of science may affect the practice of academic disciplines (Bielawski, 1984; Huntington, 1998; Wenzel, 1999; Duerden, 2004). Inuit can no longer be considered passive actors in climate scenarios (Duerden, 2004), nor "silent partners" in northern research (Wenzel, 1999). As discussed in the previous paragraph, more effort needs to be expended in rendering social science methods transparent, effective, and systematic, to enable some comparisons between social scientific studies, and also with natural or physical science results. Natural and physical scientists must also respond to this changing context as research licensing and permitting requirements include, and hold accountable, all disciplines of science. Duerden (2004) suggests that identifying the nature of climate change rests in the realm of physical science, while social scientists are better equipped to investigate how physical change will translate into influences on human activity and interaction in local communities.[17] This point could be expanded to suggest that social scientists have an important role to play in moving northern science towards interdisciplinarity (e.g. Ford and Smit, 2004). By elucidating the intersections between global and local knowledge social scientists can insist that local knowledge be taken seriously (e.g. Riedlinger and Berkes, 2001), and be given opportunities to challenge scientific perspectives (Cruikshank, 2001). Social scientists can highlight the strong links between the well-being of northern communities and their immediate environments, demonstrate the value of Inuit knowledge in addressing uncertainty, and reveal the complexity of community economies that renders translation of climate change into community-level impacts challenging (Duerden, 2004). Continued, and concerted efforts to reflect upon the social relations influencing scientific investigations are necessary, as well as how to break down disciplinary barriers among scientists (Demeritt, 2001a,b; Schneider, 2001), let alone between scientific and so-called lay communities (Duerden, 2004; Nichols et al., 2004). In so doing, the incorporation of rich cross-cultural perceptions can be considered a scientific advancement (Bielawski, 1984) as well as a benefit to northern communities.

Fourth, climate change raises many issues for communicating science to the broader community (Manning, 2003), and vice versa. In the case of sea ice, there is considerable knowledge and expertise held in Inuit communities, yet they find it challenging to identify the appropriate people to speak with, much less effectively communicate their concerns or observations (Hunters and Trappers Association Meeting in Pangnirtung, Nunavut, 2003, personal communication). It is imperative that the public better comprehend the notion of uncertainty as it relates to scientific climate change predictions and related impacts (Demeritt, 2001a,b;

Schneider, 2001; Manning, 2003), but it is equally important for the public to be able to communicate observations, and contribute to impact evaluations (e.g. Nichols et al., 2004). Among other constraints, impenetrable (Schneider, 2001) or unclear (Manning, 2003) natural/social scientific jargon compounded by nuanced, descriptive, and highly specialized Inuktitut terminology (Nichols et al., 2004) is a significant hindrance to cross-disciplinary and cross-cultural communication. Sea ice in particular comprises a myriad of topics or concepts fraught with possibilities of mistranslation, and it is unclear to what extent the two terminologies are even comparable (Nichols et al., 2004). And yet, improved communication methods and materials may facilitate the linking of many of the distinguishing factors noted in Table I. The physical sciences need to explore ways of communicating highly technical research results into accessible forms for the use of social scientists and community or governmental decision-makers. In turn, social or applied scientists' presentation of Inuit knowledge or observations must be expressed in terms understandable not only to peers, but also to the communities in which they work and the general public. While Dessai et al. (2004) are actually referring to the challenges of defining "danger" in the context of climate change, their generalized suggestions for bridging disparate discourses may aid in communicating notions of sea ice and climate change: (i) observe behaviour; (ii) ask the right questions; (iii) analyze social amplification/attenuation; and, (iv) engage in dialogue. However, it is also imperative to:

(a) observe and consider body language and community cultural dynamics;
(b) ask informed, appropriate, relevant questions, and be prepared to answer questions; and,
(c) incorporate the possibilities of social amplification or attenuation of the meaning of local observations, and/or what sea ice condition/change is deemed most critical in a particular community context.

Based on the above discussion nearly all the distinguishing characteristics between Inuit and scientific perspectives on sea ice and climate change need to be re-evaluated and re-considered on the basis of: (i) the end users of the sea ice/climate information accumulated; (ii) access to information; (iii) the delineation of expertise; and, (iv) communication of information. However, there are also some overarching themes of interest that can draw the two together. Both scientists and Inuit are concerned with, among other things:

(a) nearshore sea ice conditions;
(b) the position and stability of the floe edge;
(c) the influence of winds and currents on sea ice conditions or movement;
(d) freeze-up and break-up timing;
(e) sea ice thickness and distribution;
(f) the predictability of sea ice or weather changes; and,
(g) long-term changes in sea ice.

These common interests, along with different means of investigation and reasons for doing so, are what may render the two perspectives so complementary. Alaskan projects seem more advanced in their efforts to practically link Inuit and scientific sea ice expertise. Scientists and Inuit have worked closely together for the purposes of coastal sea ice watch (Norton, 2002) and investigations into major calving (break-off) events involving people (George et al., 2004). Different ways of understanding coastal sea ice dynamics were linked by common interest in, and corroboration of, evidence of extreme events, uni-directional change, rotating ice pan movement, distinguishing first- and multi-year ice, and the location – or cause – of ice fractures (Norton, 2002; George et al., 2004).[18] Additional examples of knowledge intersection methods and successes can be found within applied science contexts such as wildlife (co-)management (McDonald Fleming, 1992; Binder and Hanbidge, 1993; Nakashima, 1993; Richard and Pike, 1993; Collings, 1997; Ferguson and Messier, 1997; Rodon, 1998; Huntington, 1999; Gilchrist and Robertson, 2000; Moller et al., 2004), environmental impact assessment (Stevenson, 1996; Usher, 2000), and harvesting/dietary research (Wenzel, 1997; Thorpe, 1998; Poirier and Brooke, 2000). And while results are not always ideal, nor free of challenges, such studies provide learning opportunities that could be employed, or modified, to improve not only Inuit or traditional knowledge studies, but also interdisciplinary studies which aim to bridge the gaps between social and physical sciences. Cross-cultural working relationships can flourish when they are established upon common interest, mutual understanding, and ongoing dialogue.

7. Conclusions

It is precisely because Inuit and scientific perspectives on the relationship between sea ice and climate change differ (Table I), combined with their mutually strong interest in understanding sea ice processes and conditions, that they can be valuable to each other. The recurring issues of scale, reliability, and vested interests suggest that the experiences/methods/goals of Inuit and scientists can, and perhaps should, be bridged in some way. The physical processes involved in the complex cryosphere/climate system relationship must be understood in order to estimate potential global climate change impacts, as well as regional deviations from these global "norms". However, it will continue to be difficult for policy makers, informed by scientists (Demeritt, 2001a), to propose viable suggestions for adaptation if they do not know the importance of sea ice to local communities. Furthermore, if scientific information is not made accessible or understandable to community members and/or local decision-makers they will be less informed when developing their own adaptive strategies.

Inuit perspectives on the links between sea ice and climate, their long-term experiences and accumulated knowledge, and most importantly their permanent residency in arctic regions, make them important local experts to include when attempting to refine scientific models. Computer simulations lack the regional or local-scale aspects that may have some of the most important climatic consequences (Copley, 2000; Demeritt, 2001a; Duerden, 2004; Nichols et al., 2004). In particular, Riedlinger and Berkes (2001) suggest five convergence areas for arctic climate change research where local Inuit expertise could contribute to Western science by: (i) providing local scale expertise; (ii) expanding climate history and baseline data; (iii) helping formulate research hypotheses; (iv) providing insights into community adaptation; and, (v) reflecting cumulative, local monitoring systems. Increased cooperation and communication is necessitated because:

(a) climate models cannot provide the full story;
(b) complex systems need to be analyzed at multiple scales;
(c) validation of open (natural) systems is impossible (Berkes, 2002);
(d) arctic systems must increasingly be conceptualized in terms of human-environment relationships, not simply objects of study (Kofinas et al., 2002); and,
(e) local people should be involved in, and provided opportunities to contribute to, matters that affect them (Furgal et al., 2002b).

Furthermore, scientific tools and technologies such as satellite remote sensing and monitoring initiatives could be valuable to Inuit communities in the assessment of rapidly changing ice conditions. Vice versa, local Inuit expertise could improve local scale validation of remotely sensed sea ice data and provide fine scale linkages to socio-economic and biophysical variables (Nichols et al., 2004). Inuit are interested in, and want access to, scientific information but they also wish to have their own voices and expertise adequately accounted for in sea ice studies (Hunters and Trappers Association meeting in Igloolik, Nunavut, 2004, personal communication). Nichols et al. (2004) suggest that approaches to using Inuit and scientific knowledge in tandem may be developed through case studies. Through close interaction with community members, and strong community interest and commitment, Inuit expertise can be better represented as a valuable complement to scientific studies.

Admittedly, there are considerable practical and methodological challenges in attempting to intersect varying life experiences, methods, and goals. Nevertheless, possibilities for a positive enhancement of both perspectives on sea ice and climate change are proposed to outweigh the perceived barriers to such collaborative efforts. More collaborative research, representing both Inuit and scientific perspectives, may be achieved by:

1. engaging in a variety of participatory methodologies;[19]
2. investigating topics of interest to both Inuit and scientific communities;
3. starting early to establish the feasibility of, or mutual interest in, community-researcher collaboration;

4. involving community members in all research stages (from proposal to analysis) at a mutually desirable level; and,
5. maintaining ongoing communication.

The complementary nature of the two knowledge systems can only be adequately realized if each are considered equally valuable in their own right, and if new modes of communication and collaboration are further explored. This paper provides a baseline in understanding Inuit and scientific perspectives on the relationship between sea ice and climate change. The need for interdisciplinary researchers that specialize in interpreting/linking different ways of knowing is recognized, and thus more collaborative approaches to climate change research are encouraged (i.e. involving natural/physical scientists, social scientists, and Inuit community members). It is believed that intersecting these distinct, yet complementary, perspectives on sea ice will allow for more comprehensive assessments of community vulnerability and viable suggestions for adaptation to climatic change in high latitudes.

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Notes

1. The International Circumpolar Conference (ICC) definition of Inuit is used here, meaning indigenous members of the Inuit homeland – arctic and sub-arctic areas where, presently or traditionally, Inuit have Aboriginal rights and interests – including the: Inuit, Inuvialuit (Canada), Inupiat, Yupik (Alaska), Kalaallit (Greenland), and Yupik (Russia) (ICC, 1998).
2. In much contemporary literature traditional knowledge is interchangeable with other descriptions of Aboriginal knowledge and expertise such as traditional ecological knowledge (TEK) or indigenous knowledge (IK) (e.g. Stevenson, 1996; Collings, 1997; Duerden and Kuhn, 1998; Wenzel, 1999; McGregor, 2000; Riedlinger and Berkes, 2001).

3. Survival here refers to ultimate survival (i.e. the provision of food, clothing, heat, light, and equipment), but these skills can still be considered essential to surviving present-day sea ice travel for subsistence harvesting or personal leisure.
4. A polynya is considered to be any non-linear shaped opening that is enclosed by ice. They may form from latent heat (i.e. near coastal areas of islands and created by wind or current displacement) or sensible heat (i.e. from upwelling warm water), both of which prevent solid ice formation (WMO, 1970; Wadhams, 2000; Thomas and Dieckmann, 2003).
5. Commonly known as the floe edge, the more specific term would be 'ice edge'. This term refers to the demarcation (or boundary) at any time between the ice-free ocean (or sea) and ice-covered ocean (or sea), whether fast or drifting ice. This delineation is highly dependent on the scale of investigation (WMO, 1970; Thomas and Dieckmann, 2003).
6. Commonly known as landfast ice, but specifically referred to as 'fast ice', this ice is literally stuck 'fast' to the continent (or other fixed objects such as islands, grounded icebergs, and peninsulas). It may be formed by the freezing of sea water, or by the freezing of floating ice of any age which attaches to the shore. It may be more than one year old, and would then be prefixed with the appropriate age category (e.g. second-year, multi-year, etc.) (WMO, 1970; Thomas and Dieckmann, 2003).
7. In other words, the greater the amount of ice, the calmer the open water as the ice creates shelter from the wind, and thus the safer the conditions for boating (Jolly et al., 2002).
8. The Inuit communities involved McDonald et al.'s (1997) Traditional Ecological Knowledge and Management Systems (TEKMS) study in the Hudson Bay bioregion comprise those in Nunavut (Lake Harbour, Cape Dorset, Coral Harbour, Repulse Bay, Chesterfield Inlet, Rankin Inlet, Whale Cove, Arviat, and Sanikiluaq) and Nunavik (Kangiqsujuaq, Salluit, Ivujivik, Akulivik, Povungnituk, Inukjuak, and Umiujaq). However, the most detailed observations and analysis from Inuit communities occurred on the Belcher Islands, in Sanikiluaq.
9. This is of great local importance to communities such as Sanikiluaq, but it must be noted that the presence of marine birds throughout the winter only occurs in the southern regions of the Arctic (i.e. where areas of persistent open water occur in the winter months).
10. Refer to Oozeva et al. (2004) for local accounts of weather observations and related techniques that were documented in detail for the period of 2000/2001.
11. The reference to scientists in this paper means those who work directly with sea ice and/or climate phenomena to better understand their intrinsic and combined functioning (e.g. climatologists, oceanographers, climate modelers, remote sensing specialists). While there are other scientists within natural, applied, or social science disciplines (e.g. biologists, zoologists, ecologists, anthropologists, archaeologists, geographers) with an interest in sea ice and/or climate change, and overlapping interests with Inuit community members, only those with a specific sea ice or climate system focus are included within the scope of this paper.
12. McDonald et al. (1997), Thorpe et al., (2001), Thorpe et al., (2002), and Oozeva et al. (2004) are a few examples where community members are included in publication authorship, although there may be other Inuit authors which are not explicitly stated or are included generally as a community group (e.g. Kofinas et al., 2002).
13. These different life experiences could be argued to condition the different epistemological foundations for the ways in which Inuit and scientists approach, and characterize, sea ice and climate change. As a result, the variation in methods used by Inuit and scientists, and their goals for observation or investigation, are a function of their experiences and relative epistemologies.
14. Inuk is the singular form of Inuit, in other words meaning one individual.
15. This is especially true nowadays with increasingly altered lifestyles and shifts away from hunting, trapping, or fishing for survival (Stern, 1999; Searles, 2001).

16. Some of the most common methods used for Inuit knowledge documentation include: semi-directed interviews, participant observation, questionnaires, workshops, and collaborative/experiential field work.
17. The way that physical environmental changes are experienced will vary according to local filters such as the demography and economy of a community and the population's view of reality or expectation of change (Duerden, 2004).
18. Despite different means of arriving at their conclusions, Inuit and scientists found common ground in many different areas of sea ice investigation. Where gaps remained for each group individually, multiple workshop and field work sessions enabled contributions from each side to clarify issues that were previously unknown, or confusing, to the other. Both Inuit and scientists struggled at times to accept different ways of understanding the same phenomena, but the mutual learning experience greatly enhanced the overall comprehension of shorefast ice dynamics and their influence on whaling success and travel safety in the Beaufort Sea near Barrow, Alaska (Norton, 2002; George et al., 2004).
19. Some of the participatory methodologies that are currently being used for collaborative research and/or decision-making include (in alphabetical order):

    (a) community monitoring (e.g. Gilchrist and Robertson, 2000; Kofinas et al., 2002; Krupnik, 2002; Oozeva et al., 2004);
    (b) experiential travel and learning (e.g. Nelson, 1969; Gilchrist and Robertson, 2000; Aporta, 2002; Furgal et al., 2002a; Aporta, 2004; George et al., 2004);
    (c) focus groups (e.g. Furgal et al., 2002b);
    (d) jointly directed research projects (e.g. McDonald et al., 1997; Thorpe et al., 2002);
    (e) map biographies or participatory mapping (e.g. Nakashima, 1993; Ferguson and Messier, 1997; Huntington, 1999; Fox, 2002; Aporta, 2004);
    (f) narratives (e.g. Nakashima, 1993; Oozeva et al., 2004);
    (g) participant observation (e.g. Nelson, 1969; Fox, 2002; Furgal et al., 2002a; Jolly et al., 2002);
    (h) participatory rural appraisal (e.g. Ford, 2000);
    (i) participatory action research (e.g. Thorpe et al., 1998);
    (j) structured or semi-directed interviews (e.g. Nakashima, 1993; Ferguson and Messier, 1997; Huntington, 1999; Ford, 2000; Gilchrist and Robertson, 2000; Aporta, 2002; Fox, 2002; Furgal et al., 2002a; Furgal et al., 2002b; Jolly et al., 2002; Thorpe et al., 2002; Aporta, 2004; George et al., 2004; Nichols et al., 2004);
    (k) videography (e.g. Ford, 2000; Fox, 2002; Jolly et al., 2002); and,
    (l) workshops for research planning, implementation, or reporting (e.g. McDonald et al., 1997; Ford, 2000; Jolly et al., 2002; Nickels et al., 2002; Norton, 2002; George et al., 2004; Nichols et al., 2004).

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