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Arctic adaptive : responsive design in the Canadian north

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ARCTIC ADAPTIVE:

RESPONSIVE DESIGN IN THE CANADIAN NORTH

by

Erin Ann Hampson

Bachelor of Architectural Science, Ryerson University, 2006

A thesis

presented to Ryerson University

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requirements of the degree of

Master of Architecture

in the Program of

Architecture

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Abstract

Since the industrial revolution, architecture has become increasingly disconnected from its surrounding environment and the existence of regional vernacular architecture is dwindling. (Fathy,1986; Ozkan, 1985) Modern technology coupled with globalization has resulted in universal architecture based on formal aesthetic and economy rather than local climatic factors.(Fathy,1986; Frampton,1983)

The lack of regionally responsive design is nowhere more evident than in the Canadian Arctic. (Dawson, 1997) Despite its immense cultural, economic and environmental importance to Canada and the world, Arctic communities have struggled with inadequate buildings and infrastructures since the creation of permanent settlements in the 1950's. (Bone, 2008; Dawson, 1997)

Through the synthesis of modern technology and principles learned from nature and vernacular architecture this thesis explores new possibilities for a regionally responsive architecture in the Canadian Arctic; focusing on the building skin and its relationship between both indoor and outdoor environments.

Acknowledgements

This thesis would not have been possible without the support and encouragement of many people.

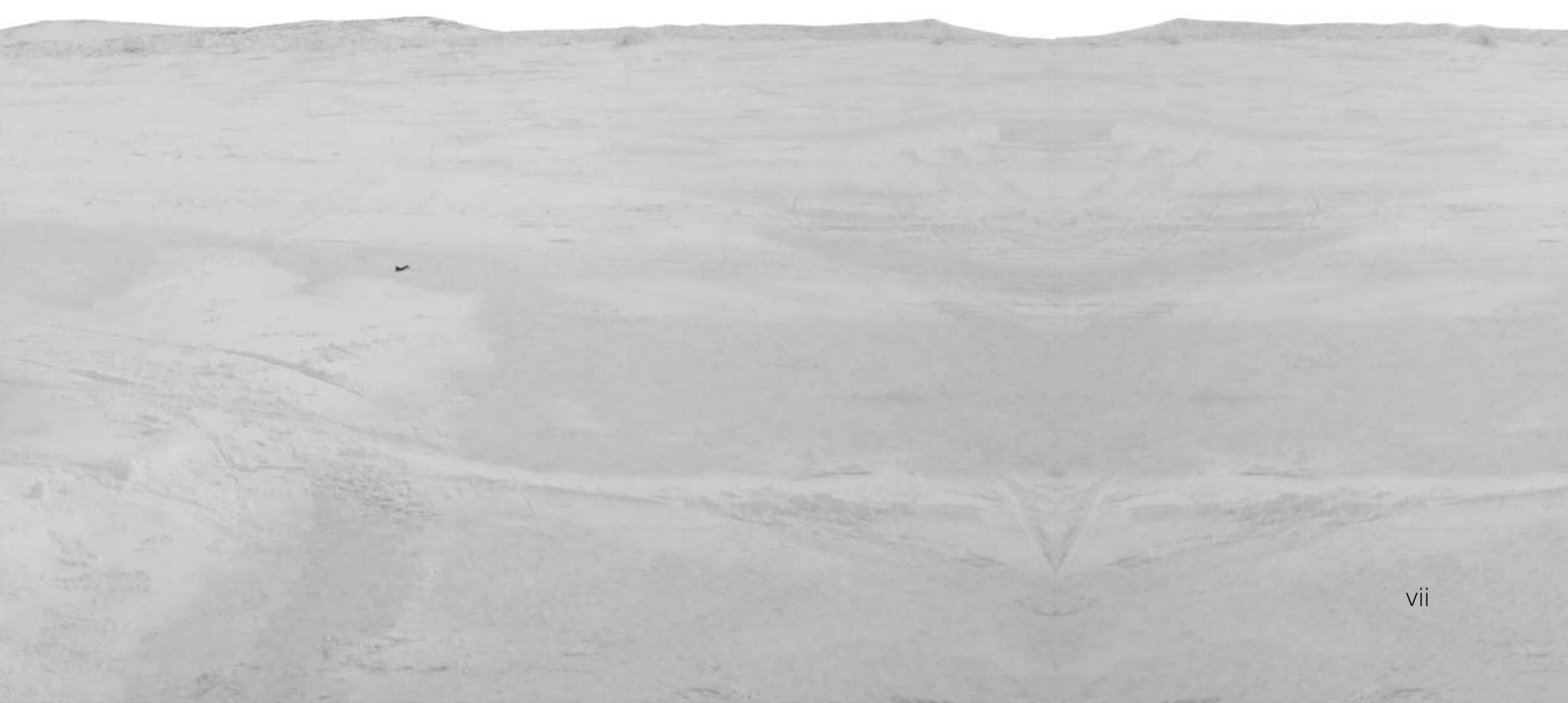
First and foremost I would like to thank Colin Ripley for his guidance as my thesis supervisor. Your insight and expertise both challenged and enriched this project. Thank you to the Department of Architectural Science at Ryerson University, Golden Key International Honour Society, and CUPE Local 3904 for educational grants that allowed me the opportunity to conduct field research in Iqaluit; the experience was one I will never forget and was truly integral to the success of this thesis. I would also like to thank the staff at Carrefour Nunavut for connecting me with amazing people and cultural activities during my stay in Iqaluit.

In addition I would like to thank Janet Armstrong for sharing her experiences on Arctic living as well as Dr. Diana Brecher for her guidance throughout the year.

My gratitude also extends to family and friends who went the extra mile in showing their support, especially Kailyn, whose bright smiles were just the encouragement I needed. Mark, I cannot thank you enough for your patience, love, and understanding throughout the thesis process. Last but not least, I would like to thank my classmates for their input, motivation and support; and for ensuring the many long hours in studio were always fun and interesting.

Dedication

To Mark.



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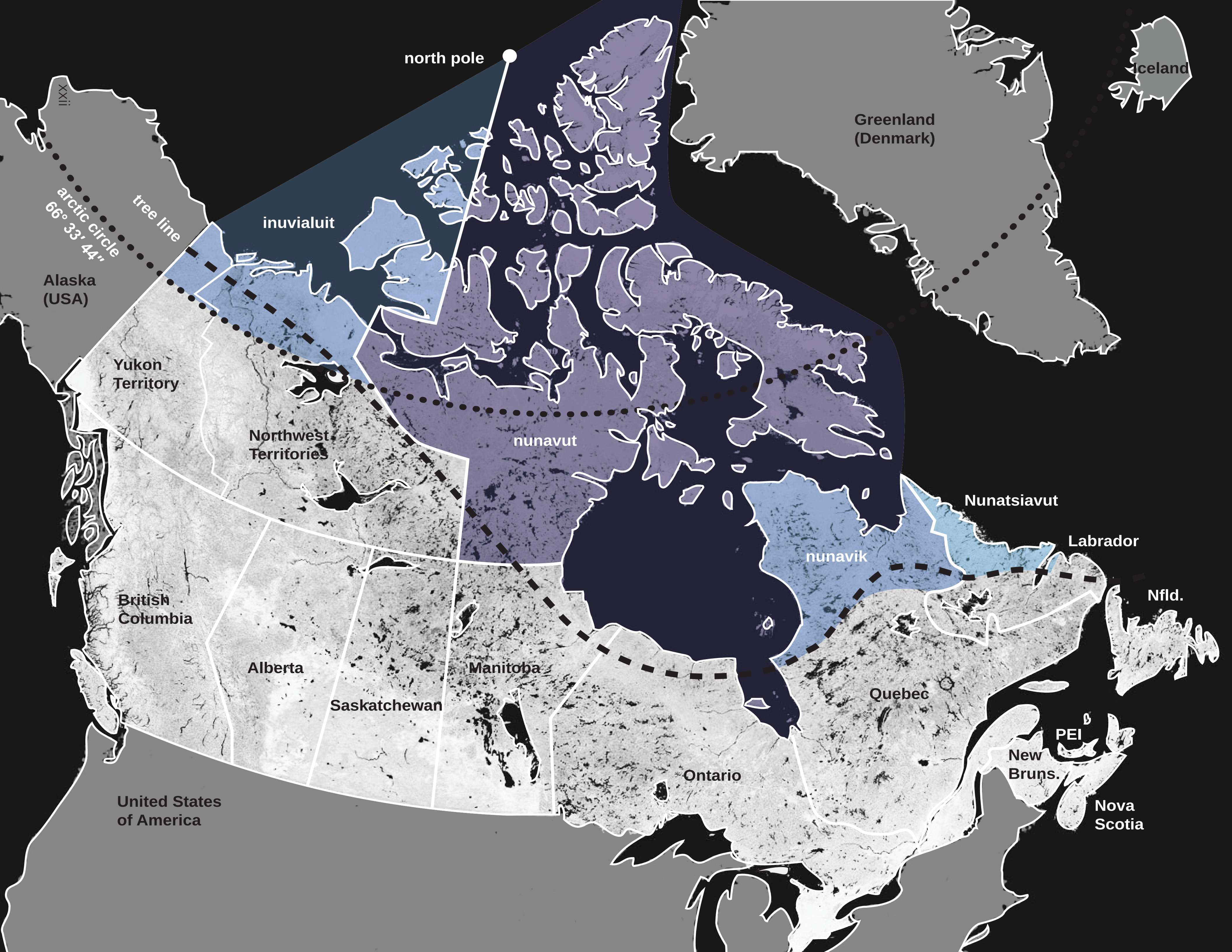
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Ontario
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of America

01 Introduction

In an era of globalization and ever increasing dependence on energy and resources, the existence of regional architecture is dwindling. (Ozkan, 1985) Since the industrial revolution, architecture has become increasingly disconnected from its surrounding environment. (Fathy, 1986) From Mexico City to Moscow glass, concrete and steel have conquered the built landscape. Modern technology coupled with globalization has resulted in universal architecture based on formal aesthetic and economy rather than local climatic factors. (Fathy, 1986; Frampton,1983) Building materials are imported from around the globe despite their embodied energy footprint and lack of climatic suitability. Interior environments are artificially created through mechanical means and function independent of the outdoor climate. Building envelopes remain static throughout the year regardless of daily and seasonal climatic variation. (Fathy, 1986) This standardized approach leads to building material and energy inefficiencies as well as a "sameness" that does not respond to a region's unique cultural, environmental and economic characteristics. (Frampton, 1983)

The lack of regionally responsive design is nowhere more evident than in the Canadian Arctic. (Dawson, 1997) Despite its immense cultural, economic and environmental importance to Canada and the world, Arctic communities have struggled with inadequate buildings and infrastructures since the creation of permanent settlements in the 1950's. (Bone, 2008; Dawson, 1997)

Fig. 01: (opposite page) Map of Canada showing the Arctic region and its aboriginal subregions: Inuvialuit, Nunavut, Nunavik and Nunatsiavut.

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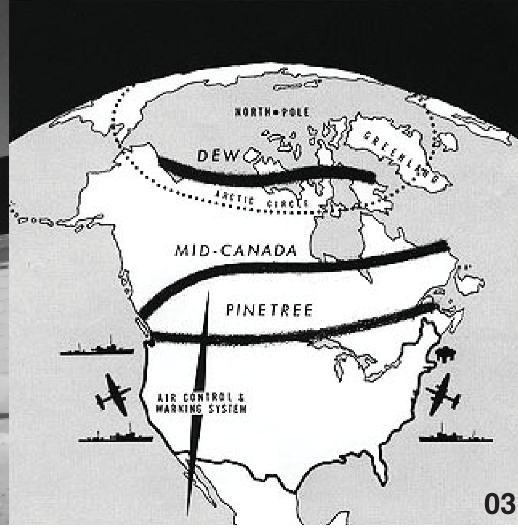

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1.1 Arctic Settlement

Traditionally, aboriginal populations enjoyed a semi-nomadic existence, moving between land and sea with the seasonal migration of subsistence land and marine mammals. (Stern, 2010) Dwellings consisted of the iconic Arctic vernacular structures such as the snow house (*iglu*) and skin tent (*tupik*). (Dawson, 1997) Constructed from local materials such as snow or animal pelts these dwellings were conducive to a semi-nomadic lifestyle, allowing ease of flexibility and mobility. (Ibid, 1997)

In the early twentieth century the increase of whaling and fur trapping industries in the Canadian Arctic. Europeans, Americans and southern Canadians established trading posts and whaling stations from the Alaskan coast to Baffin Island and Hudson Bay. Many Inuit groups lived near or had regular contact with these trading posts to take advantage of this new economic system. (Bone, 2009; Wachowich, 2004) During the 1950's the Canadian government used these stations as a basis for forming communities. Permanent settlement was encouraged as a means to distribute health care, education and other social services to the Inuit. (Bone, 2009)

However, settlements were designed without their consultation and served government administrative and economic purposes rather than the needs of the Inuit. (Bone, 2009; Stern, 2010) Housing was often poorly insulated, high maintenance and programmatically

Fig. 02:
The Hudson's Bay Company trading post buildings still exist in Iqaluit, Nunavut

Fig. 03:
Map of the early warning radar systems.

Fig. 04:
A DEW Line station in the Canadian Arctic.

Fig. 05:
The Iqaluit airport, a remnant of the town`s military past.

foreign to their Inuit residents leading to greater societal issues such as overcrowding and health problems, many of which still exist in Arctic communities today. (Dawson, 1997)

The mid twentieth century also saw the militarization of the Canadian Arctic. During World War II Allied forces used its strategic location to connect supply routes from North America to battle zones overseas. The American government spearheaded most of these military endeavours creating air bases, radar sites, highways and other necessary infrastructures in order to refuel and restock supply missions to Europe and Japan. Many existing Arctic communities had their beginnings as military bases, such as Frobisher Bay (now Iqaluit), Hall Beach, and Fort Chimo (now Kuujjuaq). (Bone, 2009; Stern, 2010)

These transportation links also allowed the Subarctic and Arctic hinterlands to become better connected to global markets. Resource-rich towns could now supply raw materials to the population centres in Canada and the United States. (Bone, 2009) As with the fur and whale trading posts, Aboriginal settlement near military bases was common and increased access to modern consumer products, building materials, southern foods and social services. (Bone, 2009; Stern, 2010)

The Cold War brought the issue of Arctic sovereignty to the forefront of national interest. The threat of a Russian attack across the Arctic

and the unauthorized traverse of American oil tankers through the Northwest Passage further compounded Canada's concern in protecting its northernmost boundary. (Bone, 2009) With the United States, three early-warning radar systems were constructed in Canada as precautions against a cross-polar attack: the Pinetree Line across southern Canada, the Mid-Canada line along the 55th parallel and the Distant Early Warning Line (DEW Line) north of the Arctic circle along the 70th parallel. (Waldron, 2009) The DEW Line was the last to become operational in 1957. (Fig. 03) (Lajeunesse, 2007)

In addition, the government relocated Inuit from Port Harrison (Inukjuak), Quebec and Pond Inlet, Northwest Territories to the high Arctic to form the communities of Grise Fiord and Resolute Bay, Northwest Territories (now Nunavut). This relocation served to substantiate Canada's territorial claim to this region through its occupation by Canadian citizens. (Stern, 2010)

Today, settlements are small, isolated communities located primarily along the coastlines of the Arctic Ocean and Hudson Bay. (Bone, 2009; Bone, 2008) Over half of the region's population is of aboriginal descent and include the Athapaskan Na'dene and the Inuit cultures of Labrador, Ungava, Baffin Island, Iglulik, Caribou (Qairnirmiut, Harvaqtuurmiut, Hauniqtuurmiut, Paallirmiut, and Ahiarmiut), Netsilik, Copper (Inuinnait), and Inuvialuit. (Bone, 2009; Bone, 2008; Collignon, 2006) In recent years the North's population has experienced

Fig. 06:
A gas pipeline weaves itself through the Arctic landscape.

Fig. 07:
The Diavik open pit diamond mine, NT.

Fig. 08:
The unique cultures and landscapes of the Canadian Arctic.

Fig. 09:
An icebreaker cuts through the Northwest Passage.

unprecedented growth; a result of high natural birth rates among aboriginal populations and an influx of workers and professionals due to increased economic activity. (Bone, 2009, Bone, 2008)

1.2 Economy

Historically the Arctic has been a resource frontier for gold, diamonds, oil and gas, lead, zinc and fish stocks. (Bone, 2008) In recent years, rising temperatures due to global warming have made resource exploration and development in the North increasingly viable. (Hassol, 2004) It is also predicted that the Northwest Passage will be fully navigable year-round by as soon as 2015 due to the melting of the sea ice pack. (Hassol, 2004; Nickels et al., 2006; Nuttall, 1998; Wonders, 2003)

The potential for resource exploration and extraction has brought the issue of Arctic sovereignty back to the forefront of national interests as circumpolar countries such as Russia, the United States, Denmark (Greenland) and Canada vie for the precious natural resources that lie within the Arctic's uncharted territory. (Bone, 2009)

1.3 Environment

The Arctic is home to unique ecosystems not found anywhere else in the world. These include physiographic elements such as pingos, thermokarst and patterned ground caused by the repeated freeze and thaw of the active layer of permafrost ground. (Bone, 2008)


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Polar bears, narwhal, lichen are but a few of the many unique fauna and flora found only in this part of the world. (Bone, 2008) However, current research shows that the Arctic has been experiencing temperature increases at twice the average global rate due to climate change. (Hassol, 2004) The climate and species of the Arctic have been identified as being particularly vulnerable to climate change phenomena. The rapid rise in temperature has caused a chain-reaction of environmental change in this region that is adversely affecting animal, plant and human life. (Bone, 2008, Hassol, 2004)

Despite these recent changes, the Arctic is symbolic of our "True North Strong and Free" and remains integral to our identity as Canadians. (Bone, 2008) How the future of northern expansion and development will be orchestrated is unknown, but opportunities are present to ensure the protection of the people, cultures, ecosystems, and resources through sustainable development. Architecture can play a role through responsive regional design.

This thesis explores how architecture can begin to address some of the key issues of building in the North through the synthesis of modern technology and principles learned from nature and vernacular architecture to achieve a regionally responsive architecture; focusing on the building skin and its relationship between the indoor and outdoor environment.

Fig. 10:
Coastal erosion is already wreaking havoc in Alaska.

Fig. 11:
Peary caribou are unique to the Canadian Arctic. Climate change is affecting their migration routes and ability to forage for food in the winter.

Fig. 12:
The polar bear has become the symbol of climate change. The Canadian government is taking steps to protect this threatened species.

Fig. 13:
The iconic work of Lawren Harris of the famous Group of Seven. The Arctic represents a key aspect of our cultural identity as Canadians

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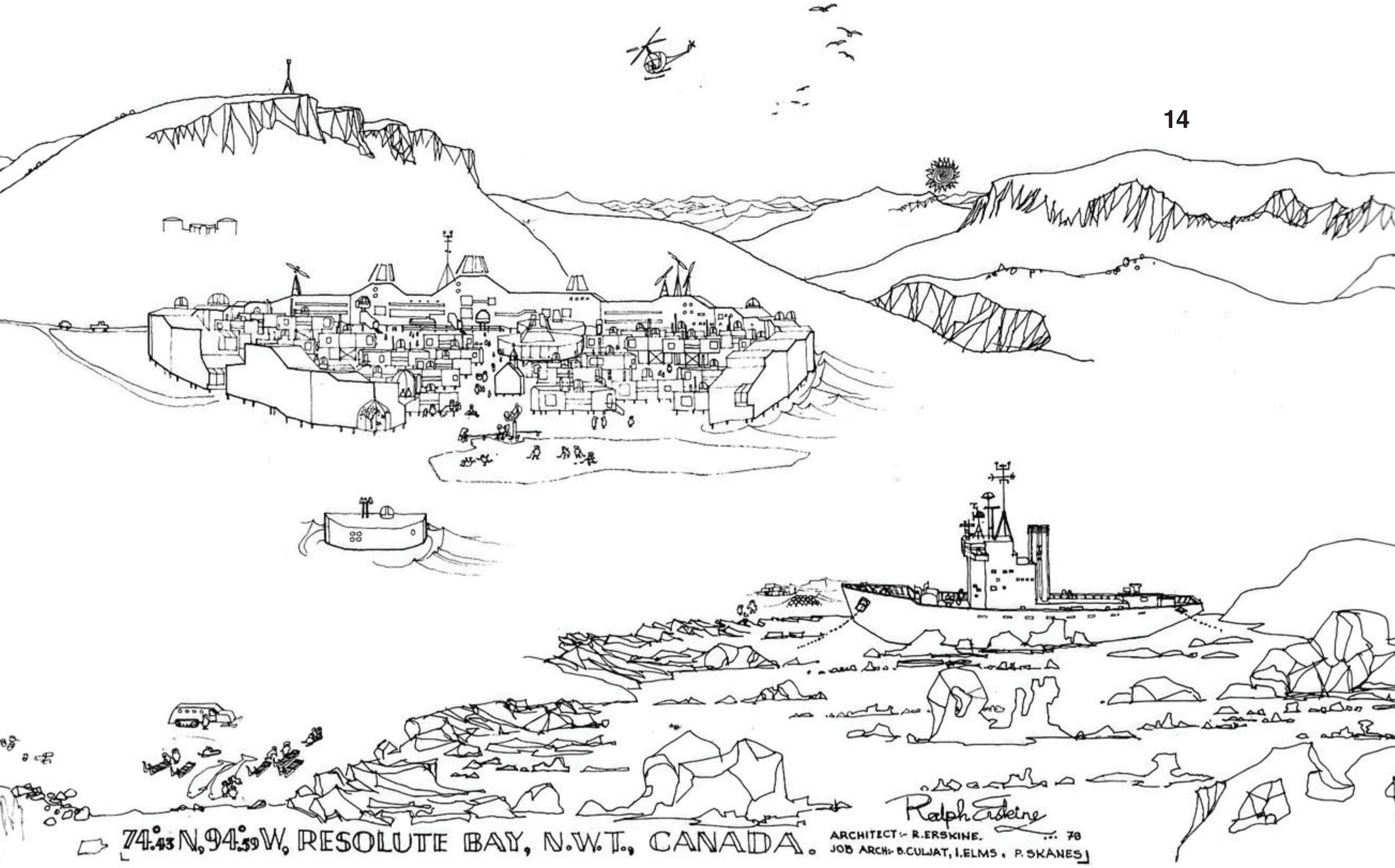
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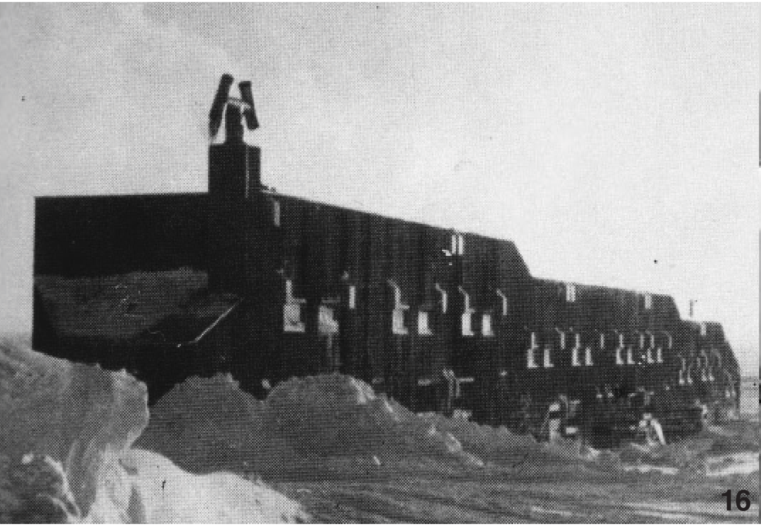
02 A History of Modern Arctic Construction

Since the creation of permanent settlements in the 1950's, Canadian Arctic communities have struggled with inadequate buildings and typologies. (Dawson, 1997) The extreme Arctic climate, unique cultures and logistical constraints are often poorly understood by those designing for this region. (Dawson, 1997; Strub, 1996; Waldron, 2009) The results are structural failure, rapid material degradation, poor indoor air quality and energy inefficiencies that tend to exacerbate the social issues that have plagued Arctic communities since the creation of permanent settlements. (Dawson, 1997; Stern, 2010; Strub, 1996) The following is a catalogue of Arctic architecture, from the mid-twentieth century to present day.

2.1 Frontier Futurism

The design of Arctic communities and architecture in the 1950's and 1960's expressed the Cold War and space-age attitudes of the time. (Waldron, 2009) A community master plan was commissioned by the Canadian government for Frobisher Bay, currently known as Iqaluit. (Ibid, 2009) The Frobisher Development Group Committee (FBDC) proposed an enormous high density, mixed-use, low-rise megastructure. The self-contained structure turned its back on the surrounding landscape internalizing its public functions in a central enclosed courtyard. This development exemplifies how foreign interpretations of a region can translate into well-meaning but socially or culturally inappropriate architecture. The megastructure design

Fig. 14-15:
Sketches by Ralph Erskine of his master plan for Resolute, NU (1973)



was meant to compliment the vastness of the surrounding landscape and block out what was viewed as an inhospitable climate. (Waldron, 2009) This is in contrast to the Inuit view as the Arctic as their home which was reflected in the small-scale and intimate dwelling clusters of traditional Inuit communities. (Dawson, 1997) Although the master plan was eventually cancelled three buildings were constructed that currently exist as the Astro Hill Complex in Iqaluit. (Waldron, 2009)

Ralph Erskine was also commissioned to design a master plan for the new townsite of Resolute, Nunavut in 1973. Erskine was an architect who was known for his expertise in cold climate design. (Collymore, 1982) Erskine's community plan contained housing, offices, workshops and various institutional and recreational buildings. (Ibid, 1982) This was one of the first attempts to engage the local Inuit population in the design process. (Ibid, 1982)

The overall plan considered the Arctic environment in its design, resulting in a large, horseshoe shaped multi-functional building to protect the interior space from the often harsh Arctic winds. The central space was reserved for single-family housing and institutional buildings. (Ibid, 1982) Although an attempt was made to consider Inuit culture and the environment, the overall plan was still based around megastructures and the design aesthetic of individual buildings lacked cultural meaning. Only the housing terrace was fully built, as political and economical factors caused the cancellation of

Fig. 16:
The only constructed building of Ralph Erskine`s master plan for Resolute, NU.

Fig. 17:
Nakasuk elementary school, Iqaluit, NU. Designed by Gesellius Lindgren Saarinen, 1970's.

Fig. 18:
Inuksuk high school, Iqaluit, NU also utilizes a pre-fabricated building system.

Fig. 19:
The Iqaluit, NU airport. It was constructed using pre-fabricated components.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the rest of the project. (Ibid, 1982) The building site currently sits abandoned. (Dawson, 1997)

Nakasuk elementary school and Inuksuk high school in Iqaluit are also examples of a megastructural aesthetic. (See Figs. 17-18) Built by Northwest Territories Housing Corporation they incorporate pre-fabricated panels were designed for rapid installation, cost-effectiveness and to shut out the Arctic climate. (Quirouette, 1980; Waldron, 2009)The schools are large, awkward masses in the landscape and the small port-hole windows create an interior space with poor access to natural ventilation and daylight. In contrast with vernacular architecture, the two schools do not integrate well into the surrounding landscape and fail to address the local climate. (Ibid, 2009)

2.2 Architecture of Efficiency

Due to the remote location of Arctic communities and the lack of local modern building materials many buildings are designed around issues of transportation and manufacturing costs. Many buildings including institutional, civic and residential functions consist of pre-fabricated or temporary structures, Quonsets and hangars that are more appropriate for military and scientific endeavors. (Waldron, 2009) Although cost and time efficient, these buildings lack social and cultural relevance and often result in a bland aesthetic. (Dawson, 1997)

2.3 Euro-Canadian Design

Housing supplied by government to newly formed settlements in the 1950's reflected the values and beliefs of Euro-Canadian culture prevalent in southern Canada. (Dawson, 1997) Inuit adapted to these new forms of housing as they were viewed as modern and prestigious. They also provided a dryer interior environment than traditional dwellings such as the snow house or skin tent. (Collignon, 2006) Houses were designed in a cost efficient rectilinear shape earning them the nickname of "matchbox" houses. (Dawson, 1997) They were designed to sit above-ground on metal stilts anchored into the permafrost in order to prevent snow from drifting against them. Raised construction also prevented heat generated within the home from warming the permafrost ground which could cause the building foundations to shift and potentially fail. (Strub, 1996)

The primary structural and exterior surface material of these houses was wood as it was inexpensive to manufacture and transport to the Arctic. (Dawson, 1997) Although wood was the most economical building material, its performance within the arctic climate was poorly understood. Houses often suffered from rapid deterioration and required frequent and expensive maintenance its aesthetic, thermal and structural properties. (Dawson, 1997; Strub, 1996)

The interior layout aligned with Euro-Canadian ideals about appropriate households comprising of nuclear families with separate living and

Fig. 20:
One of the few remaining government issued houses from the 1950`s in Iqaluit, NU.

Fig. 21:
A typical government supplied house from the 1970`s.

Fig. 22:
A bland modular hotel building in a Canadian Arctic community.

Fig. 23: Contemporary modular housing in Iqaluit, NU.

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sleeping areas. (Dawson, 1997; Stern, 2010) This is in contrast to traditional buildings that consisted of a central multi-functional, multi-person living space that fostered intimacy and easy nonverbal communication among household members. The breakdown of functions into multiple, segregated spaces in modern frame houses disrupted this traditional social structure. (Bone, 2009; Collignon, 2006; Stern, 2010) Housing designed by non-aboriginal architects did not anticipate the kinds of activities and family structures of Inuit families. New houses did not allocate spaces for processing game or repairing hunting equipment, often resulting in the misappropriation of rooms such as the kitchen or bathroom for such activities. (Collignon, 2006; Strub, 1996) Instead of building culturally appropriate housing, the Canadian government released a booklet entitled “Living in the New Houses” describing the conduct of domestic life in government supplied houses based on the societal values and gender roles of Euro-Canadian households. (Dawson, 1997)

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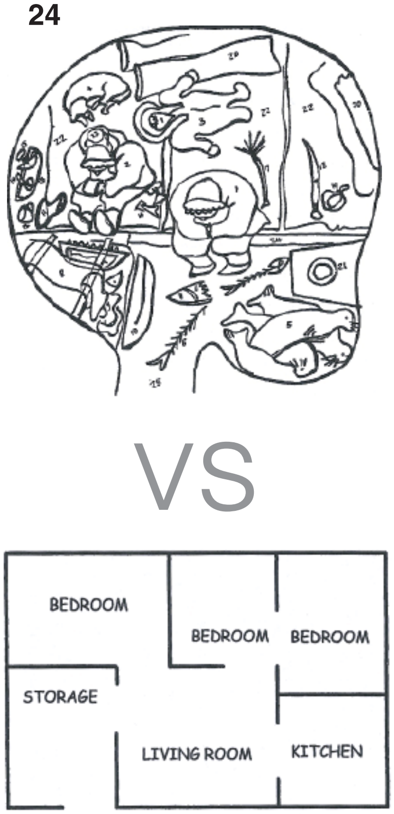

Fig. 24:
Diagrams of the open, multi-purpose interior of traditional Inuit housing versus the segregated, dedicated spaces of Euro-Canadian housing design.

2.4 Inuit Culture as Artifact

The Canadian government made several attempts at providing culturally meaningful housing for the Inuit. (Dawson, 1997) Prototypes for a Styrofoam “snow house” were tested in Cape Dorset, Northwest Territories in 1956. (Ibid, 1997) The prototype was constructed out of 6” translucent Styrofoam bricks, held together by an adhesive sealant instead of the traditional material of snow blocks. Advantages of the

design included a low construction cost, simple construction, high insulation values and excellent transmission of daylight. (Ibid, 1997) Unfortunately the Styrofoam blocks were easily degraded by the harsh Arctic winds and long-term exposure to ultra-violet light. These prototypes were in use from 1956 - 1959. (Ibid, 1997)

Another attempt at incorporating Inuit culture was the government designed double-walled canvas tent. (Ibid, 1997) This housing form was meant to resemble the traditional spring and summer skin tent dwelling. An inner and outer layer of canvas was affixed to a wooden structural frame. The space between each layer was filled with an aerocor fiberglass insulation. Unfortunately this design was more expensive than the government-approved budget and also suffered degradation due to constant exposure to sunlight. (Ibid, 1997)

Contemporary attempts to address Inuit culture have often resulted in caricatures of traditional building forms. St. Jude's Cathedral (Fig. 26) in Iqaluit, currently under reconstruction, and Our Lady of Victory Roman Catholic Church in Inuvik are literal representations of an Inuit snow house. The churches dome shapes are purely symbolic and failing to address the function and material qualities of the traditional form they mimic. The dome of the snow house was a direct response to the Arctic winter climate and the use of snow as a building material. These churches are copies of this iconic dwelling emphasizing the dome shape rather than climatic responsiveness or cultural relevance. (Dawson, 1997)

Fig. 25:
Our Lady of Victory Church, Inuvik, NT. Built 1958.

Fig. 26:
Rendering of new St. Jude`s Cathedral in Iqaluit, NU. It is being reconstructed to its previous form after the original building was lost to arson.

2.5 Contemporary Design

Today, construction in the Arctic is based primarily on cost-effectiveness and climatic conditions such as wind and snow loads. (Strub, 1996) This results in the construction of rectilinear forms clad in wood or vinyl siding that are neither aesthetically pleasing or culturally meaningful. (Ibid, 1996)

A recent case in point is the North by North housing project by Avi Friedman (2007). Pre-fabricated housing modules were designed for the community of Iqaluit. The project is successful at addressing the technical requirements of construction in the extreme Arctic climate and integrates well into the existing built fabric. Issues of material transportation and construction were also well addressed. (Ibid, 2007) At the level of cultural expression, however, the project falls short. Colours drawn from traditional Inuit art applied to the exterior façade fail to mask the boxy pre-fabricated structural form beneath. Furthermore, the design does not incorporate sustainable design strategies to deal with on-site energy production, water filtration or air purification.

There has been some effort in recent times to break away from the cookie-cutter aesthetic of modular pre-fabricated structures in favour of the principle of mass customization. McMinn and Polo (2005) praise projects such as the Kugluktuk Recreation Complex in Kugluktuk, Nunavut and the Kiilinick High School in Cambridge Bay, Nunavut,

Fig. 27:
Fake parapets lack aesthetic appeal and lack regional cultural appropriateness in this Iqaluit subdivision. (2011)

Fig. 28:
The bland facades of a new housing subdivision in Iqaluit, NU. (2011)

both by Pin/Taylor Architects, for their attempt at address many of the social, cultural and economic issues faced by Arctic communities.

The Kugluktuk Recreation Centre, built in 1998, also considers various elements of the Arctic climate in its design. (Ibid, 2005) The exterior form of the building is shaped to deflect strong winds, maximize daylight and control snow drifting. (Fig. 32) This building works with local climatic conditions rather than trying to shut them out. (Ibid, 2005)

Another contemporary building that successfully addresses the local culture and technical requirements of building in the North is the Nunavut Legislature by Le Groupe ARCOP with Full Circle Architects, 1999. (Arcop, 2011) The exterior form deflects strong winds and the dark blue wood cladding was chosen for its high performance against wind and sun exposure. (Ibid, 2011) The curved wood poles that frame each entrance represent traditional Inuit sleds. (Ibid, 2011)

Although many of the interior materials were chosen for cost-effectiveness, high quality and culturally relevant finishes were integrated into the main council chambers. (Ibid, 2011)The round interior of the chambers is modeled after an Inuit meeting place, or *qaggiq*. (Ibid, 2011) Seal skin is utilized on the council seats and public benches while the main door handles are constructed out of whalebone. (Ibid, 2011)

Fig. 29:
Avi Friedman's modular housing complex in Iqaluit, NU. Individual units are demarcated architecturally, however there is little consideration for climatic conditions in its design.

Fig. 30:
Exterior view of the Nunavut Legislature. Le Groupe ARCOP with Full Circle Architects,1999.

Fig. 31:
Council chambers of the Nunavut Legislature. Le Groupe ARCOP with Full Circle Architects,1999.

Fig. 32:
The Kugluktuk Recreation Centre in Kugluktuk, NU by Pin/ Taylor Architects, 1998. Its form is a direct response to the Arctic climatic conditions.

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Through building form and cultural references, these contemporary designs begin to successfully address local culture and climatic conditions. (McMinn and Polo, 2005; Arcop, 2011) The following chapter looks at how to build upon these design practices through the synthesis of modern technology and principles learned from regional vernacular architecture.

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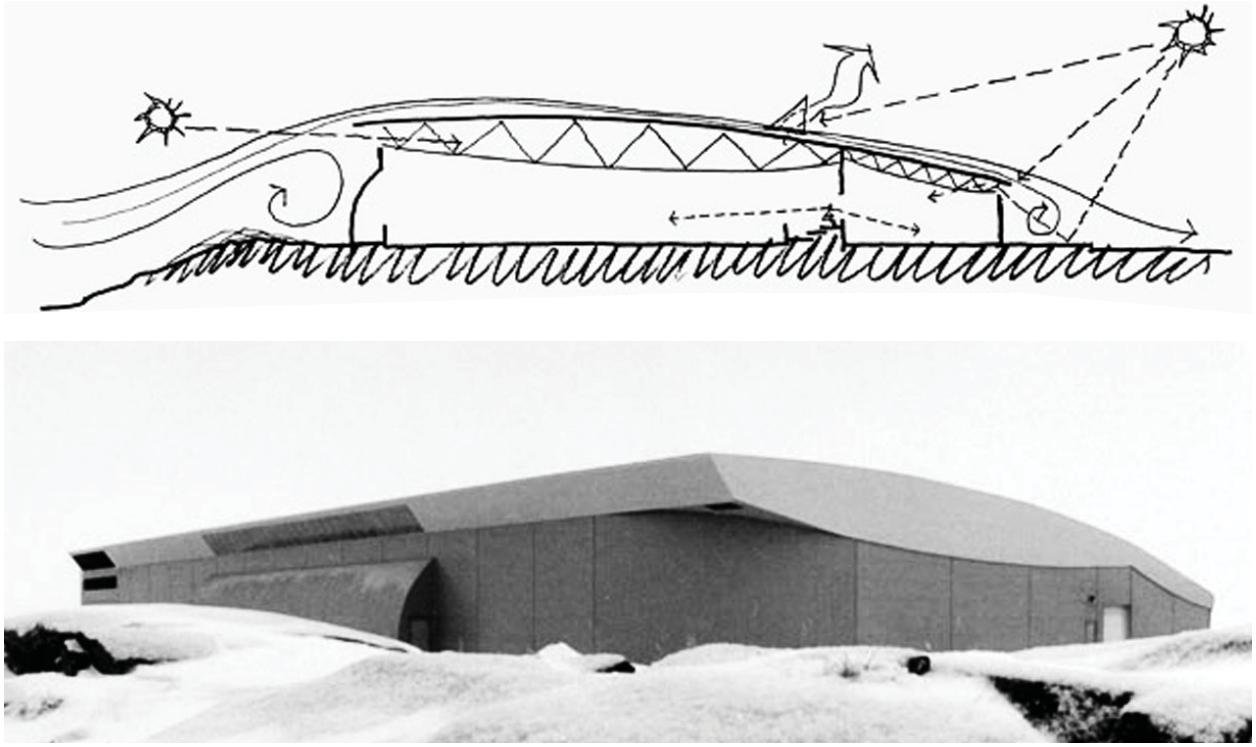


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03 Towards an Adaptive Architecture

3.1 Vernacular Architecture

All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of living in the cultures that produce them. (Oliver, 1997)

In an era of globalization, urbanization, climate change and rapid technological development, many forms of traditional architecture and regional identity are disappearing from around the world. (Ozkan, 1985) Although often romanticized and considered incongruous with today's modern culture, vernacular architecture remains relevant in contemporary architectural discourse. (Asquith, 2006)

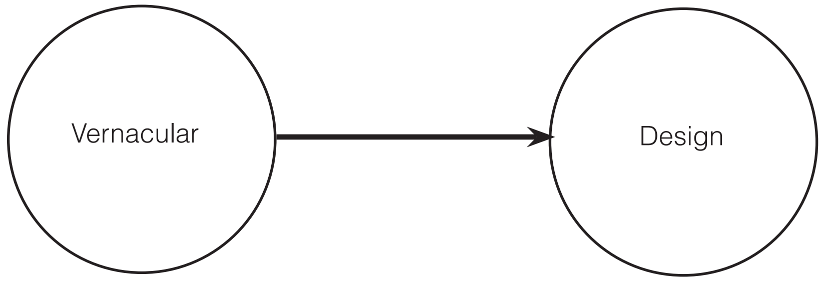
Fig. 33
Image of a snow house, the iconic traditional winter dwelling in the Canadian Arctic

Fig. 34
The whalebone structure of an Inuit sod house.

Fig. 35
An Inuit skin tent. This particular image shows the use of caribou hide for the outer skin.

Paul Oliver, one of the pioneering researchers in the field of vernacular architecture, (Ibid, 2006) espoused that traditional buildings should reveal methods and principles for responding to a particular region's social, cultural and climatic characteristics. Vernacular architecture needs to be seen as a constantly evolving entity, reacting to the changes in the communities that shaped its form. (Ibid, 2006) The author reinterprets this concept as being an "adaptive architecture"; an architecture that is resilient, constantly reinventing itself with the changing social, cultural, and environmental milieu in which it is situated.

To create a contemporary regional architecture the principles and processes of vernacular architecture must be understood. (Rappoport,



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2006) offers two methods for analysing vernacular architecture, a "learning through copying" method (Fig. 36) and "learning through analysis" (Fig. 37) which describes a process of studying related socio-cultural influences to break down the underlying principles and mechanisms of vernacular design.

Fig. 36:
Process for learning from the vernacular by copying, Amos Rappoport. (2006)

In accordance with the writings of Marcel Vellinga (2006), contemporary architecture should not be restricted to the forms and materials of the vernacular. The "learning through copying" method is only relevant in cases of historical preservation.

One must also be aware of other issues related to the direct copying of vernacular architecture. Nezar Al Sayaad (2002) warns of a resulting "fake" architecture: literal translations of traditional buildings that are untrue to their contemporary contexts. Modern buildings become superficial representations of traditional forms, with materials and spaces unrelated to existing climatic and cultural conditions. The iglu churches of Iqaluit and Inuvik are clear examples of such a fake architecture. (Dawson, 1997)

Vellinga's colleague, Lindsay Asquith (2006), also describes a methodology for the analysis of vernacular architecture but focuses solely on sociological analysis such as spatial use and activity patterns. Climatic responsiveness, material use and construction methods can also be studied in traditional building forms. (Ibid, 2006)

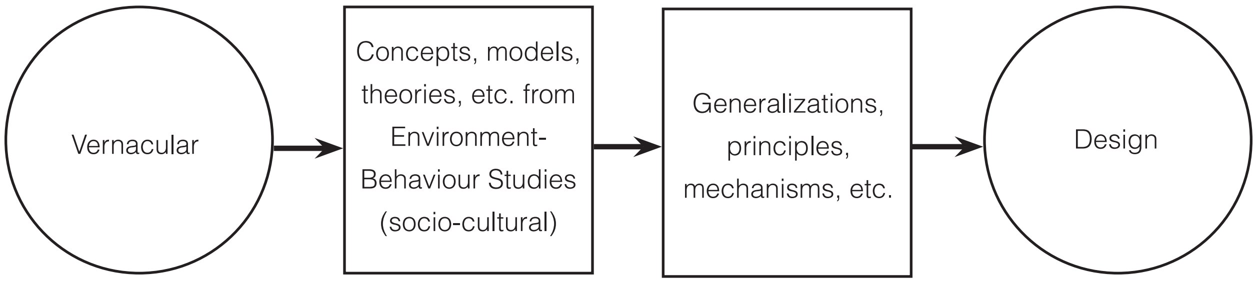

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Fig. 37:
Process for learning from the vernacular through analysis, Amos Rappoport. (2006)

The work of the late Hassan Fathy best exemplifies contemporary regional design based on the principles of traditional architecture. Throughout his career Fathy espoused the use of climatically appropriate materials and forms as an ethical obligation of the architect. (Ozkan, 1985)

> *But a 3 x 3m glass wall in a building exposed to solar radiation on a warm, clear tropical day will let in approximately 2000 kilocalories per hour. To maintain the microclimate of a building thus exposed within the human comfort zone, two tons of refrigeration capacity are required. Any architect who makes a solar furnace of his building and compensates for this by installing a huge cooling machine is approaching the problem inappropriately and we can measure the inappropriateness of his attempted solution by the excess number of kilocalories he uselessly introduces into the building. Furthermore, the vast majority of the inhabitants of the Tropics are industrially underdeveloped and cannot afford the luxury of high-technology building materials or energy-intensive systems for cooling.* (Fathy,1986)

Although much of his work was designed for hot climates, the main argument can be universally applied to regional design. (Ozkan, 1985)

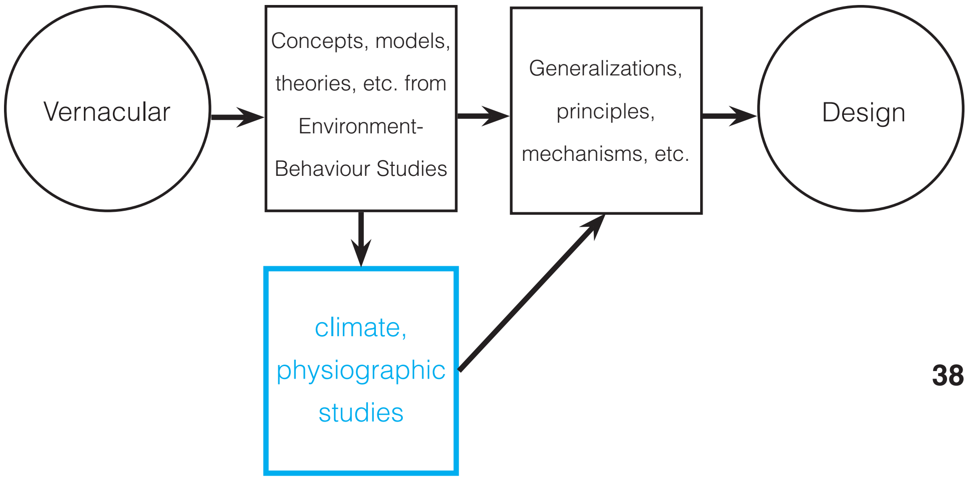


Fig. 38:
Learning by copying, Amos Rappoport (2006) with modification by the author.

The two major factions of vernacular architecture, the socio-cultural analysis espoused by Vellinga (2006) and Asquith (2006) and climatic analysis championed by Fathy (1985) can be described through the modification of Rappaport's (2006) "learning through analysis" diagram. (Fig. 38) The modified diagram also argues that the design process is not linear; designs must be validated against the principles from which they are derived.

3.2 Technology and Biomimetic Design

The use of appropriate materials is paramount in the achievement of an adaptive architecture. Historically,

> *Dwellings are built to serve a variety of functions, but one of the most important is to create living conditions that are acceptable to their occupiers, particularly in relation to the prevailing climates. Buildings do not control climate, which, apart from the wind or sun shadow that they cast, remains largely unaffected.* (Oliver, 2003)

Responsive architectural systems are at the forefront of technological innovation. Although they still cannot change weather patterns, new technological developments allow buildings to have a more dynamic response to climate. Pioneers such as Tristan d'Estree Sterk (Orambra, 2011) and Chuck Hoberman (Hoberman Associates, 2011) are known for their research and application of intelligent,

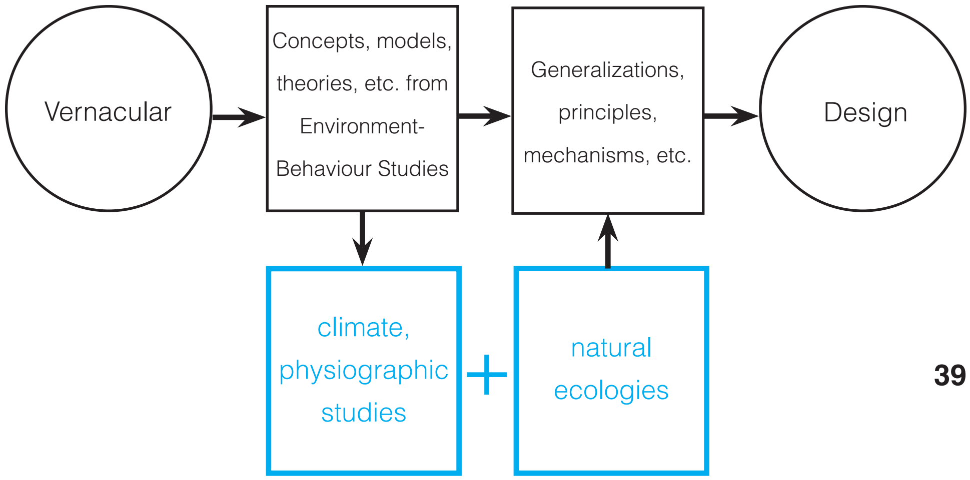
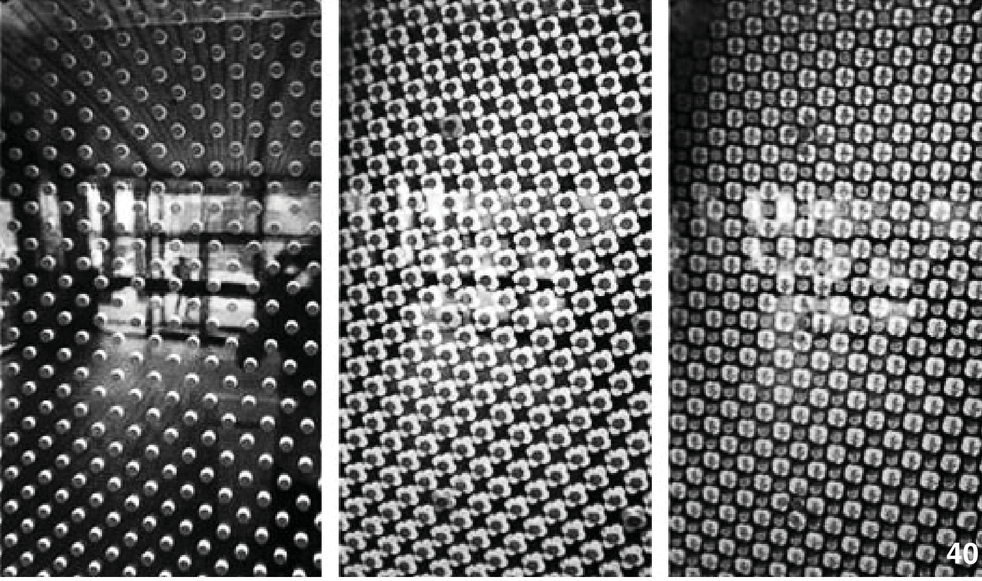


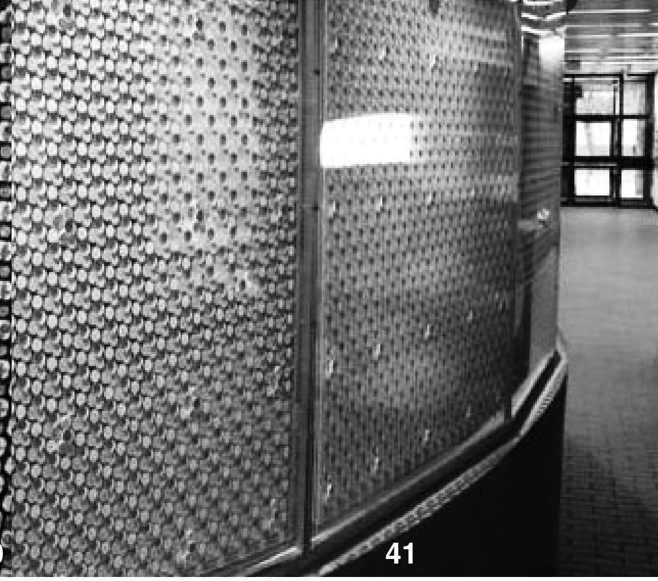
Fig. 39:
Learning by copying, Amos Rappoport (2006) with modification by the author.

robotic and transformable structures. Innovations such as phase and shape changing materials, kinetic structures, nanotechnology, smart materials, sensors and actuators offer new possibilities for responsive architectural solutions. (Hoberman Associates, 2011; Orambra, 2011)

For example, Hoberman Associates' "Adaptive Fritting" is a responsive building shading system. (Hoberman Associates, 2009) Similar to a traditional fritted glass, Adaptive Fritting utilizes a printed pattern to regulate solar gain and daylight variability. The difference between Adaptive Fritting and traditional fritting is the integration of a motorized control that can allow the fritted pattern to become more opaque or more transparent depending on the user's needs. The motor shifts panes of fritted glass to create overlapping or separated patterns to achieve this effect. (Ibid, 2009) This project exemplifies how technological innovation can result in an architecture that is responsive to its environment.

The inspiration for many responsive technologies are systems found in nature. Biomimetic architecture learns from the climate-adaptive processes of plants and animals and applies them to building design. The Thirst Pavilion by Cloud 9 Architects of Barcelona best exemplifies this bio-inspired approach. This pavilion was a temporary structure for Expo 2008 in Zaragoza Spain. (McCann, 2008) The building consisted of a fiberglass and ETFE (ethylene-tetra-fluoro-ethylene) skin that was able to "sweat" in hot weather. The ETFE would emit salt





water over the exterior of the building that would rapidly evaporate in high temperatures. This would help the building cool itself similar to how the human body regulates heat. Layers of salt would crystallize on the outside of the building that would be washed away with rain and collected for re-use in the cooling system. (Ibid, 2008)

3.3 Adaptive Design in the Canadian Arctic

With specific reference to the Canadian Arctic there is only one design handbook for modern high-latitude design. Harold Strub's (1996) *Bare Poles* is a thorough investigation of the people, terrain, and climate of northern Canada. Strub looks at the social, cultural, economic and climatic issues and constraints related to construction in the Arctic and describes ideal programmatic elements that should be considered in building design. Although traditional architecture is mentioned, a connection is not made between the modern construction methods he espouses and the principles of Arctic vernacular architecture. (Ibid, 2006)

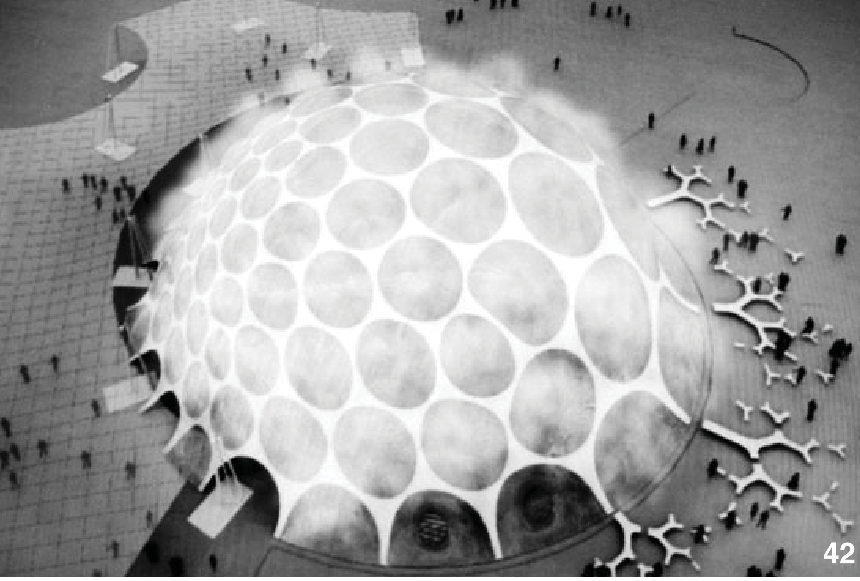
Since the publication of this book the Arctic region has experienced shifting demographics, increasing population numbers and greater economic prosperity, as well as being affected by global climate change. (Bone, 2009, Hassol, 2004) New materials and systems are now available that can lend alternative building solutions.

Fig. 40:
Various opacity levels of Adaptive Fritting technology.

Fig. 41:
Adaptive Fritting exhibition at the Harvard Graduate School of Design.

Fig. 42:
Aerial view of Cloud 9's Thirst Pavilion, Expo 2008, Zaragoza, Spain.

Fig. 43:
Close-up of the ETFE exterior of Cloud 9's Thirst Pavilion, Expo 2008, Zaragoza, Spain.



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The following chapters look to both vernacular dwellings and organic systems in the Arctic for design principles that can be applied to a responsive architecture in the Canadian Arctic.


01

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04 Learning from Tradition

In essence vernacular architecture is architecture that responds to its local climate and resource availability. (Fathy, 1986) The following analysis of Arctic vernacular architecture will help to identify key climatic considerations and design principles when building for an Arctic climate.

One of the major characteristics of Arctic vernacular dwellings is that they are temporary. (Dawson, 1997, Strub, 1996) Due to the extreme change in climate throughout the year, different dwellings were constructed to suit specific seasonal weather: the snow house during late autumn, winter and early spring, the skin tent during late spring summer and early autumn. (Ibid, 1997; Ibid, 1996)

Other general characteristics include the use and re-use of local materials, material form and efficiency, ease of construction, flexibility and mobility. (Ibid, 1997; Ibid, 1996)

4.1 Snow House, *Iglu*

The snow house is the iconic symbol of traditional Inuit architecture and was the primary form of dwelling during the winter and early spring. (Dawson, 1997; Stern, 2010; Strub, 1996) Its relatively simple construction and use of snow as a building material allowed Inuit families to remain mobile allowing families to migrate with their food sources. (Dawson, 1997; Strub, 1996)

Fig. 44:
(opposite page) Iglu building in Sylvia Grinnell Territorial Park, Iqaluit, Nunavut. April 18, 2011.

4.1.1 Site

Snow houses are often sited near existing snow drifts and clustered together to retain heat and shield themselves from the harsh Arctic winds. Fig. 45 shows how snow houses could be built with interconnected tunnels to maintain internal circulation when clustered together. (Dawson, 1997)

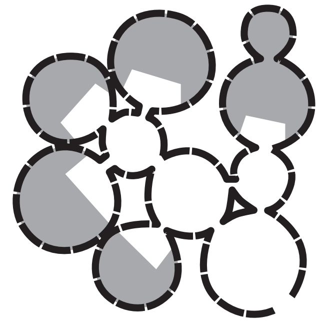

Fig. 45:
A plan showing the clustering of snow houses. The grey areas represent raised sleeping platforms.

4.1.2 Spatial Syntax

The interior of a typical iglu consists of an entrance tunnel, central storage corridor and large multi-purpose area. (Ibid, 1997) The central multi-functional space was the basis of traditional communal living. (Stern, 2010)

Each function relates to the interior temperature generated by the form of the structure. (Dawson, 1997) The entrance tunnel acts as a cold trap, unsuitable for domestic activities. The central corridor is warmer and therefore more suitable for storing items without being prone to freezing. The main dome is designed to trap body heat and heat produced from oil lamps (*qulliq*) as it rises. This is where all domestic activities take place such as cooking, eating, working, playing and sleeping. (Ibid, 1997) A small hole is cut above the entrance in the dome for ventilation. An elevated platform allows occupants to dwell within the zone of trapped warm air. (Ibid, 1997) Large snow structures (*qaggiq*), sometimes up to 40' in diameter, were used as community meeting spaces. (Stern, 2010)

Fig. 46:
The multi-purpose interior of a snow house.

4.1.3 Structure

The structure of an iglu is very strong. Blocks of snow are stacked in a spiral to create a domed enclosure, acting as both structure and building envelope. (Dawson, 1997; Strub, 1996) The dome shape helps to distribute compressive forces downwards and is highly resistant to wind and snow loads. (Dawson, 1997; Strub, 1996) Snow houses incorporate the available local material and utilise it in a way that maximizes it's structural and thermal properties. (Dawson, 1997; Strub, 1996)

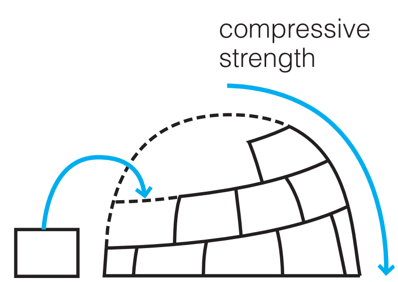

Fig. 47:
An elevation showing the stacking technique of snow blocks.

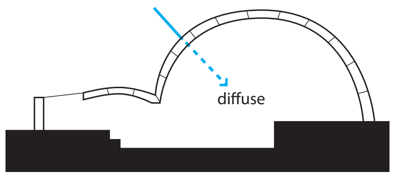

Fig. 48:
Section of a snow house showing the diffuse dispersion of daylight through snow blocks.

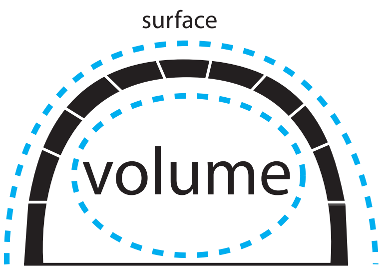

Fig. 49:
Section diagram showing surface to volume ratio of efficient material use.

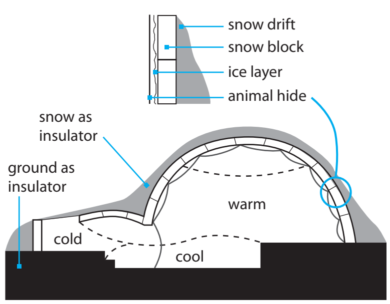

Fig. 50:
A section showing thermal performance of a snow house.

4.1.4 Natural Light

Interior light is most often provided through the burning of oil lamps (*qulliq*), however diffuse light does enter the iglu through the blocks of snow. Sometimes a window of clear ice is placed within the side of the main living dome to capture what little daylight exists during the winter months. (Dawson, 1997) The snow house can act as a beacon in the dark as interior light filters through the translucent snow blocks. (Ibid, 1997)

4.1.5 Economy

The snow house is a highly efficient structure. In its most basic form it requires only the snow from the surrounding landscape and a knowledgeable builder to provide a solid, warm enclosure. (Dawson, 1997; Stern, 2010) Domes are also the most materially efficient form, allowing for a large interior volume to be created with a minimal amount of surface material. (Strub, 1996) The snow blocks are also easy to procure and modify. Blocks are cut of the same size and modified as needed during the construction of the iglu. Iglus are highly flexible as snow blocks can be modified with the use of a simple knife (*sulung*). (Dawson, 1997)

4.1.6 Thermal Performance

Iglus are perfectly designed for the harsh Arctic winters. Its domed shape traps heat in the interior and deflects strong winds outdoors. (Dawson, 1997; Strub, 1996) Snow is highly insulating as it contains pockets of trapped air. Extra snow was often piled around the sides of an iglu as additional insulation. (Dawson, 1997) The heat created from human habitation and cooking and causes the inside surface of the iglu to slightly melt and re-freeze. This causes a layer of ice to form that effectively seals the interior of the iglu from the frigid outdoors. Sometimes caribou or seal skins were hung in the interior to further warm the dwelling. (Ibid, 1997)

4.2 Skin Tent, *Tupik*

4.2.1 Site

The skin tent is associated with the summer season. (Dawson, 1997; Strub, 1996; Stern, 2010) They are located on the open land and sometimes taking advantage of naturally occurring depressions or recesses left over from previously abandoned dwelling sites. (Ibid, 1997) This shows that skin tents were often built to integrate with the existing landscape.

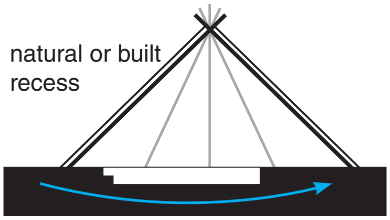

Fig. 55:
Section showing the skin tent constructed over an existing recess.

4.2.2 Spatial Syntax

The interior layout is similar to that of an iglu in that it contains a large multi-functional living area. (Ibid, 1997) Sometimes a sleeping platform was integrated, similar to the snow house, to take advantage of warmer temperatures near the top of the tent enclosure. (Ibid, 1997) Skin tents could also be clustered and interconnected similar to the snow house. (Ibid, 1997)

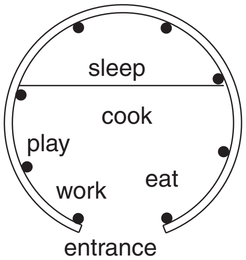

Fig. 56:
The multi-purpose interior of a skin tent.

4.2.3 Structure

The structure consists of found whalebones or driftwood anchored by stones. Whalebone structures were more common in coastal communities while driftwood was abundant in communities near river sources that would bring wood from southern locations. (Ibid, 1997) Layers of seal or caribou skin are then wrapped around the exterior, working in tensile strength. (Ibid, 1997)

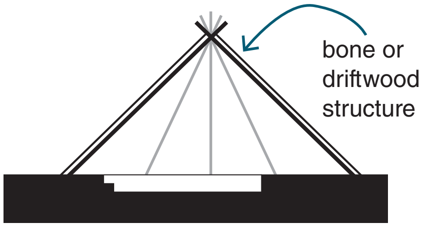

Fig. 57:
Section showing the structure of a skin tent.

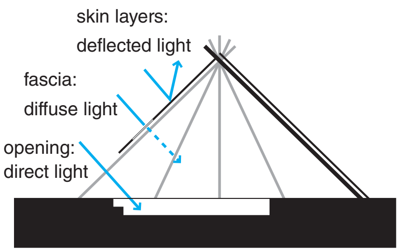

Fig. 58:
Section showing the varying light permeance of a skin tent.

4.2.4 Natural Light

Arctic summers consist of near to twenty four hours of daylight. The amount of natural daylight that permeates can be modified through various openings in the tent. Sometimes the translucent fascia layer of the seal or caribou skin is incorporated as a window. (Ibid, 1997)

4.2.5 Economy

The skin tent is highly efficient as it utilizes local materials, is easy to construct, mobile and reusable. (Ibid, 1997) Animal pelts are also a highly flexible material, allowing for modifications to the skin tent to be made with ease. (Ibid, 1997)

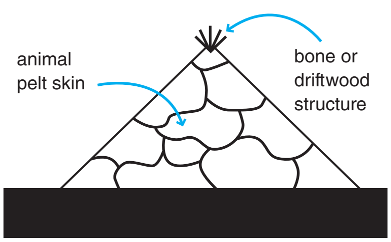

Fig. 59:
Elevation showing the use of local materials in a skin tent.

4.2.6 Thermal Performance

The thermal properties of the tent come from the amount of skin layers applied. The skin is naturally waterproof and wind proof. Thermal performance can be adjusted to the weather by simply adding or removing layers of skin. (Ibid, 1997)

The study of Arctic vernacular dwellings show us how local climatic conditions were addressed through the use of local material and innovation. These simple building forms teach us how to achieve material efficiency and flexibility, appropriate seasonal insulation and light variation throughout the year. (Dawson, 1997; Strub, 1996)

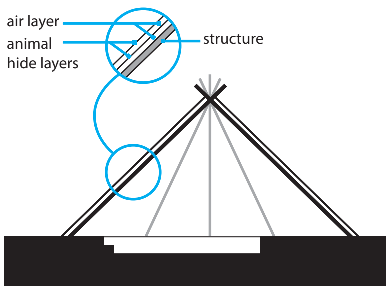

Fig. 60:
Section showing the structural and thermal layers of a skin tent.

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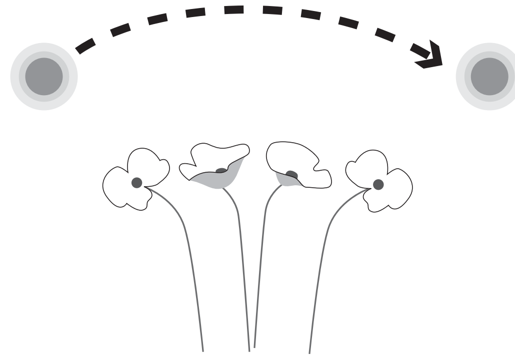

sun tracking

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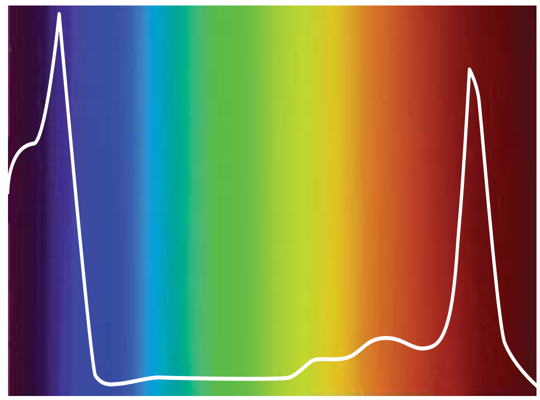

photosynthesis absorption spectrum

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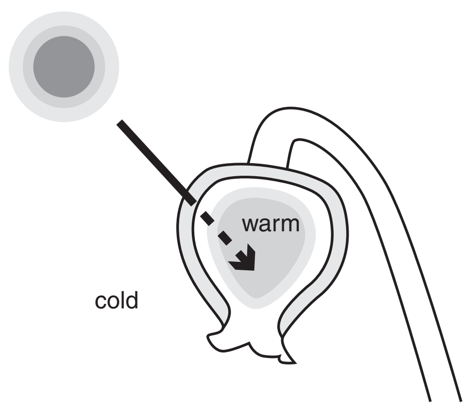

greenhouse effect

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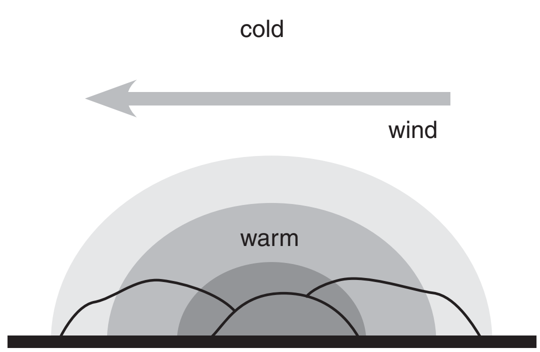

cluster and ground warmth

05 Learning from Nature

Arctic plants and animals use adaptive measures to survive the harsh Arctic climate. (University of Guelph, n.d.) By analysing these processes, climate-responsive principles can be learned and applied to building design in the Arctic.

Fig. 61
Image of the Arctic poppy. The diagram shows how it rotates in coordination with the sun's movements across the sky.

Fig. 62
Image of Arctic blueberry. The diagram shows how red absorbs more solar energy than other colours on the spectrum.

Fig. 63
Image of bog rosemary. The diagram shows how the flower utilizes the greenhouse effect.

Fig. 64
Image of Nunavut purple saxifrage. The diagram shows how the plant clusters low to the ground to retain heat.

5.1 Arctic Flora

Arctic plants are primarily concerned with temperature regulation and heat retention. (Ibid, n.d.) For example, the Arctic poppy (*Papaver radicatum*) (Fig. 61) rotates its petals with the orientation of the sun in order to maximize solar orientation. The absorption of solar energy allows the Arctic poppy to maintain warmer temperatures for longer periods of time. (Ibid, n.d.)

Solar energy is also utilized by the Arctic blueberry (*Vaccinium uliginosum)* (Fig. 62). It's leaves turn red in the autumn in order to absorb sun light across a broader spectrum. (Ibid, n.d.)

The bog rosemary (*Andromeda polifolia)*, however, utilizes the greenhouse effect in order to retain a warm temperature. The sun's rays permeate the outer petal, warming the air inside the hollow flower. (Fig. 63) (Ibid, n.d.)

The Nunavut purple saxifrage (*Saxifraga oppositifolia*) blooms low to the ground to avoid the harsh Arctic wind. The temperature near the soil can be between 5°C and 10°C warmer. Plants also cluster together to retain heat. (Fig. 64) (Ibid, n.d.)

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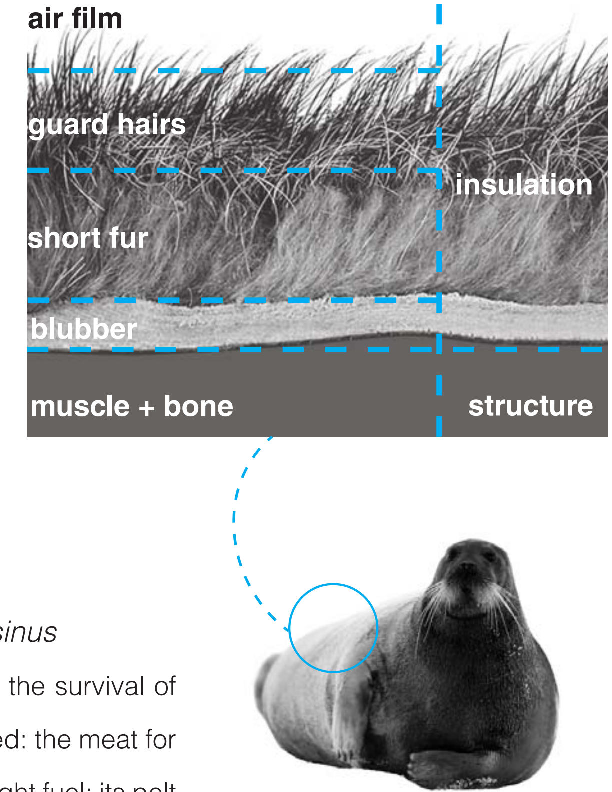

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5.2 Arctic Fauna

5.2.1 Northern Fur Seal *Callorhinus ursinus*

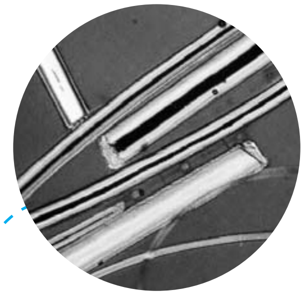
The ring seal is one of the most important species to the survival of traditional Inuit families. Every part of the seal was used: the meat for sustenance; its blubber and oil for cooking, heat and light fuel; its pelt for clothing and shelter; and its bones for tools, jewelry and traditional games. (Strub, 2010)

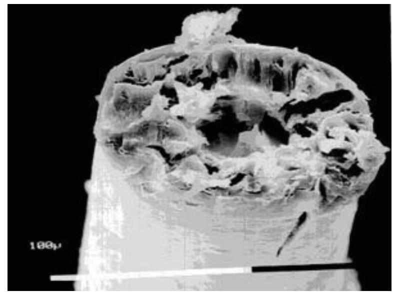
The ring seal's primary defense against the cold Arctic climate is it's blubber. This layer of fat acts as a thermal regulator throughout the year. During the winter, seals maintain a thicker layer of fat to provide more insulation against the extreme cold. The layer of blubber becomes thinner during the warmer summer months. (Mahan, 2010) The principle of variation of insulation throughout the year can be applied to architecture.

Another physiological aspect of the ring seal is it's fur. The seal contains two layers of fur, an outer layer of oily, course guard hair and an inner layer of densely packed fur. The oils on the outer layer allow the seal to be waterproof while swimming and retain air pockets for increased insulation while on land. (Ibid, 2010) The concept of thermal layering is something that can also be applied to architecture.

Fig. 65
Sections through seal skin that show the seasonal variation in blubber thickness.

Fig. 66
Section through seal skin showing its various component layers and their function.





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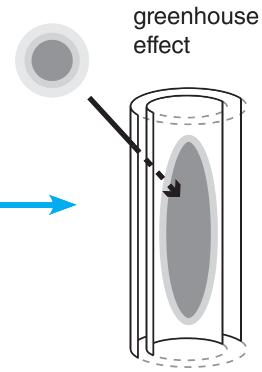

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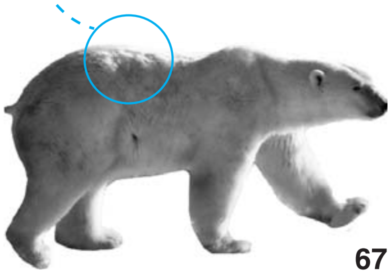

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Fig. 67
Close-up of the hollow guard hairs of polar bear fur. Image taken under polarized light.

Fig. 68
Close-up of hollow interior of polar bear fur.

Fig. 69
Section through a polar bear fur strand describing how it utilizes the greenhouse effect.

5.2.2 **Polar Bear** *Ursus maritimus*

A polar bear survives by utilizing similar strategies to the ring seal. It is able to regulate its temperature throughout each season with a varying layer of fat around its body similar to the ring seal. (National Wildlife Federation, 2011)

The fur of a polar bear is also very efficient in cold temperatures. It is similar to the fur of a ring seal in that there is a longer, course layer of oily outer fur and a thicker, more dense layer closer to the body. (Ibid, 2011) The outer guard hair is hollow, reminiscent of tiny glass tubes. It acts as an air trap, similar to the seal, by creating a layer of air around its body which acts as an additional layer of insulation. (Ibid, 2011) Natural oils found in the guard hairs form a waterproof layer. The guard hair also utilizes the greenhouse effect: the sun penetrates the outer layer of hair and warms its hollow interior. The interior is rough in texture, trapping the air inside. The texture also acts as a prism, scattering light, allowing the polar bear to appear white in colour, even while wet. (Ibid, 2011)

Similar to the ring seal, the principles utilized by the polar bear such as thermal layering and variable insulation can be applied to architecture.

The following chapter discusses how principles learned from Arctic flora and fauna as well as vernacular dwellings can be applied to contemporary architecture in the Canadian Arctic.


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06 Arctic Design Handbook

The following design handbook looks at how to address some of the major issues of high-latitude construction utilizing principles learned from Arctic vernacular architecture, flora and fauna combined with modern technologies. The following designs are but a few examples of the many possibilities that exist for a new adaptive architecture.

6.1 Thermal Variation

Although the Arctic is a vast place it does hold some common physical and climatic characteristics. (Bone, 2009; Bone, 2008) The arctic is characterized by two primary seasons; a short, cool summer (*aujaq*) and a long, cold winter (*ukiuk*). (Bone, 2009; Bone, 2008; Stuckenberger, 2007) Unfortunately many existing buildings in Arctic communities only address this seasonal variation in temperature through mechanically derived temperature controls. (Strub, 1996)

The average temperatures for various Arctic communities can be found in Appendix A. They show the extreme variation in temperature throughout the year that must be considered when designing in the Arctic.

Fig. 70
Image of the Arctic tundra in the summer.

Fig. 71
Image of the Arctic tundra in the winter.

Unlike the temperate climates of Southern Canada, Arctic communities experience long bouts of extreme cold. Issues of heat loss, the expansion and contraction of building materials, ice damage and freeze/thaw cycles are exacerbated and must be thoroughly considered in envelope design. (Ibid, 1996) Unfortunately many

existing buildings in Arctic communities only address this seasonal variation in temperature through mechanically derived temperature controls. (Ibid, 1996)

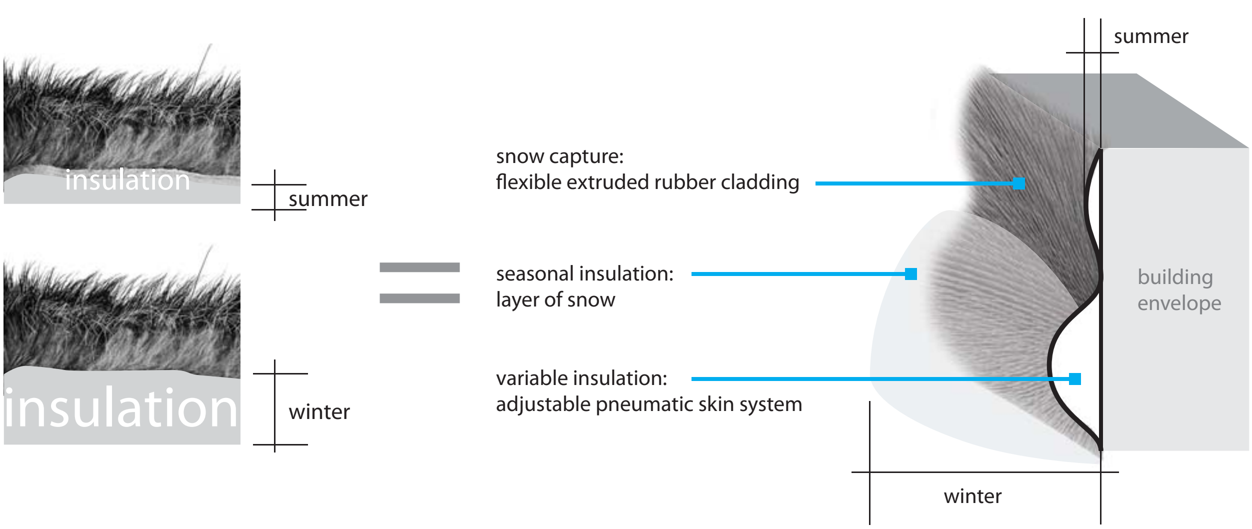
What if building skins could adapt to the seasonal temperature variations of the Arctic climate? By taking the principle of thermal variation from polar bear and seal skin, a new type of variable thermal building skin is created. (Fig. 76) A pneumatic envelope system can expand and contract throughout the seasons to provide increased insulation in the winter and less in the summer.

The exterior flexible membrane can contain rubber extrusions similar to the animal fur to capture a layer of snow in the winter for added thermal performance.

Fig. 72
Image of a construction site in Iqaluit, NU and it's static layer of insulation. (2011)

Fig. 73
Image of typical building facades in the Arctic. They do not change or adapt to seasonal climatic variation.

Fig. 76:



6.2 Ground

The ground is also a major issue to be considered in Arctic building construction. (Strub, 1996) This is due to the existence of permafrost soil. Permafrost is ground that is continuously frozen year-round. (Bone, 2008; Strub, 1996) The depth of permafrost varies depending on where it is located. In Canada's high north permafrost may penetrate hundreds of metres into the ground and only around ten metres at southern permafrost boundaries. (Bone, 2008; Strub, 1996)

Fig. 74
Image of steel pile foundations. This is a typical construction practice in the Canadian Arctic.

Fig. 75
Image of a concrete foundation on a new housing project in Iqaluit, NU. Concrete is typically never utilized in this region due to the extreme freeze/thaw actions of the ground. (2011)

Fig. 76: (bottom left)
Diagram showing how seal and polar bear fur can be translated into an architectural application.

The Arctic contains primarily continuous permafrost and some areas of discontinuous permafrost. Continuous permafrost contains ground that is over 80% frozen and occurs where the annual mean temperature is approximately -7° Celsius. Discontinuous permafrost is classified as ground that is 30%-80% frozen and occurs in areas where the annual mean temperature is approximately -5° Celsius to -7° Celsius. (Bone, 2008; Williams, 1986)

Permafrost contains two layers, an active, upper layer that melts each summer, and a permanently frozen lower layer. Infrastructure, buildings and other structures in the Arctic typically rely on permafrost for a stable foundation for steel piles where bedrock is not available. This allows wind to blow freely under the structure so as to avoid unwanted snow drifting. (Bone, 2008, Williams, 1986)

Recently, the rising temperatures associated with global climate

change has caused the melting of permafrost, increasing the depth of its active layer. The melting of permafrost also releases carbon dioxide, a greenhouse gas, into the atmosphere. (Bone, 2008; Strub, 1996)

In order to stabilize shifting foundations the design strategy in Fig. 80b proposes coating steel piles with a protocell technology. Once applied, the protocells absorb CO_2 from the atmosphere and crystallize into solid calcium carbonate. The idea is that they would eventually form a secondary structure to support the building. As more carbon dioxide is released, more structure is created. The protocells can regenerate to continue the absorption and crystallization process. The resulting limestone is an additional benefit as it can be harvested as a building material. (Devlin, 2009)

Another design looks at the concept of utilizing the ground as a thermal insulator as precedent in both the snow house and purple saxifrage can be applied to architecture. Insulation and a flexible flooring membrane hug the existing landscape. (Fig. 79)

This design proposes that buildings are formed with the existing landscape, rather than altering it. The design proposes that a rigid insulation be sprayed or formed into place to act as both structure and insulation, similar to the snow blocks of an iglu. A semi-rigid membrane can then be applied on top to act as a floor. This layer is similar to the animal pelts often used in the snow house interior.

Fig. 77
Close-up of a steel pile foundation in Iqaluit, NU (2011)

Fig. 78
Steel pile foundation under construction in Iqaluit, NU. (2011) These piles are anchored to bedrock.

Fig. 79
Diagram showing how principles learned from the Inuit snow house and the purple saxifrage can be applied to an architectural application.

Fig. 80a
Diagram showing the active layer of permafrost in the Arctic ground and how it can cause structural instability as it melts.

Fig. 80b
Diagram showing how protocell technology can create a supporting structure against melting permafrost soil. The protocells turn into calcium carbonate crystals with the absorption of CO_2

Fig. 79:

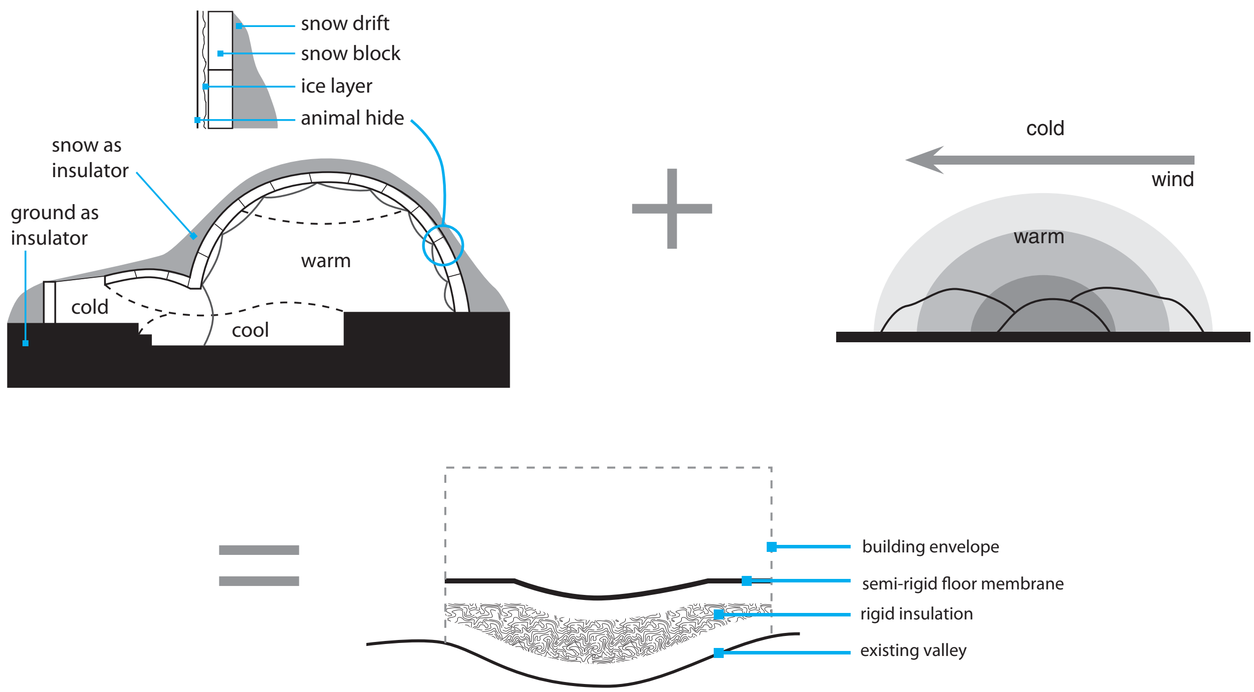


Fig. 80a:

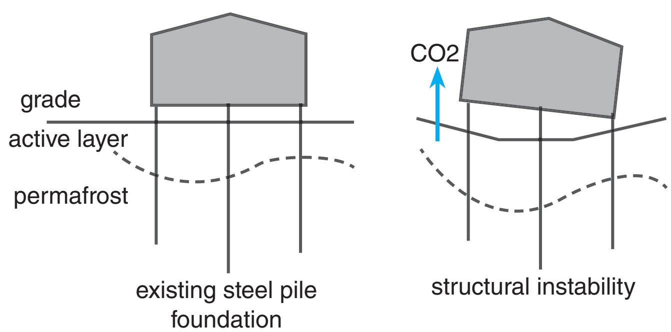
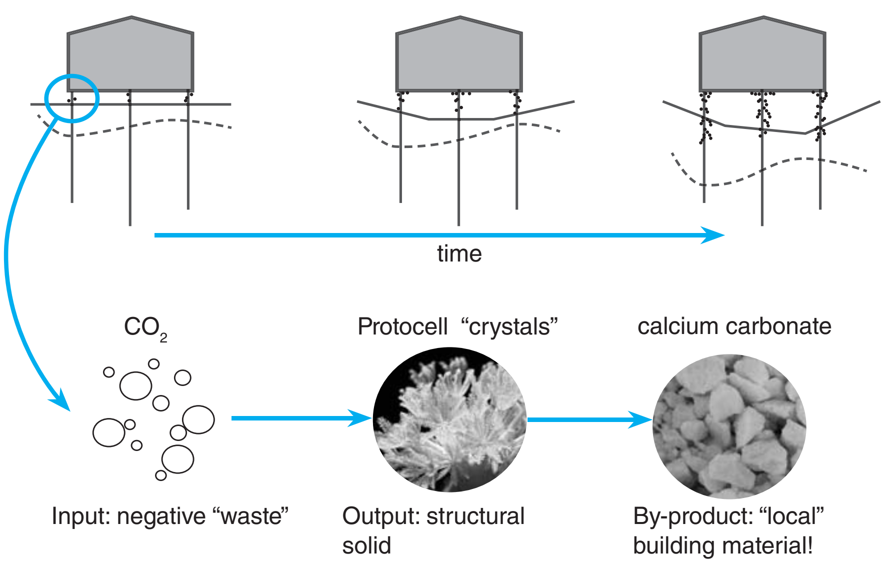
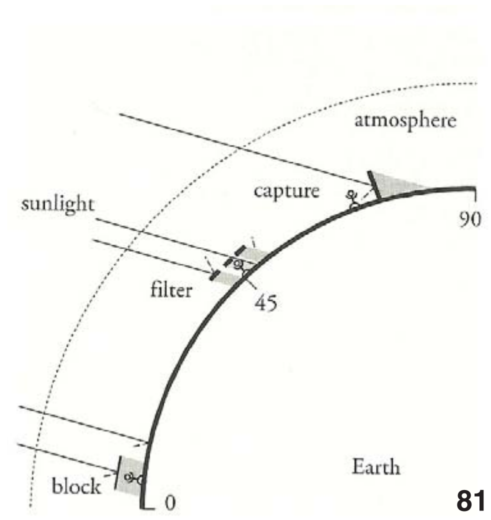
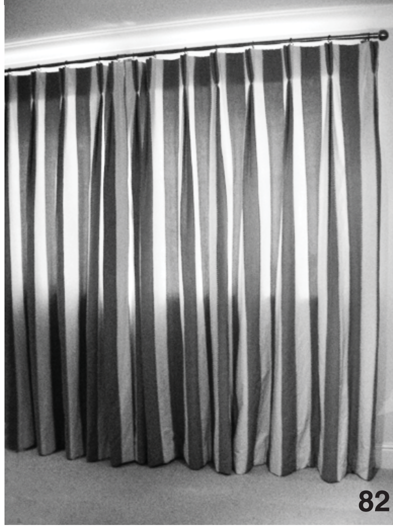


Fig. 80b:







6.3 Sun

The Arctic receives low levels of solar energy due to its high latitude. The angle of the sun is much lower here than at the equator (Fig. 81) which receives high amounts of solar energy. (Bone, 2009; Strub, 1996) The low angle of the sun means that its rays most often hit the vertical surfaces of buildings such as walls and windows, an important consideration in high latitude building design. (Strub, 1996)

One unique characteristic of the Arctic is the extreme variation of solar energy throughout the year. Daylight can last as long as twenty-four hours per day in the summer and only a few hours during the winter depending on the earth's axial tilt and one's latitudinal position. (Bone, 2009; Strub, 1996) The Arctic Circle (66° 33'N) indicates the latitude where daylight occurs for one full day in the summer and darkness for one full day in the winter, on the summer and winter solstice respectively. (Strub, 1996) Latitudes above the Arctic Circle will experience more than one day of continuous light or darkness; increasing as one moves further north. This results in a condition of approximately six months of continuous light in the summer and six months of continuous darkness in the winter at the North Pole. (Ibid, 1996)

Many buildings in the Arctic contain glazed openings that remain static year-round, relying on interior shading devices to regulate daylight. What if buildings could respond to solar variability? Maximising use

Fig. 81
Diagram showing the angle of solar exposure at different latitudes.

Fig. 82
Buildings utilize non-integrated sun control systems, such as curtains or louvers, instead of dynamically responsive systems such as that proposed in Figs. 84-85.

Fig. 83:
Nakasuk elementary school, Iqaluit, NU is inefficient at capturing solar gain.

Fig. 84:
Diagram showing how skin tent lighting principles can be applied to a contemporary ETFE building skin.

Fig. 85:
Diagram showing how principles from the Arctic poppy can be applied to a responsive shading device.

Fig. 84:

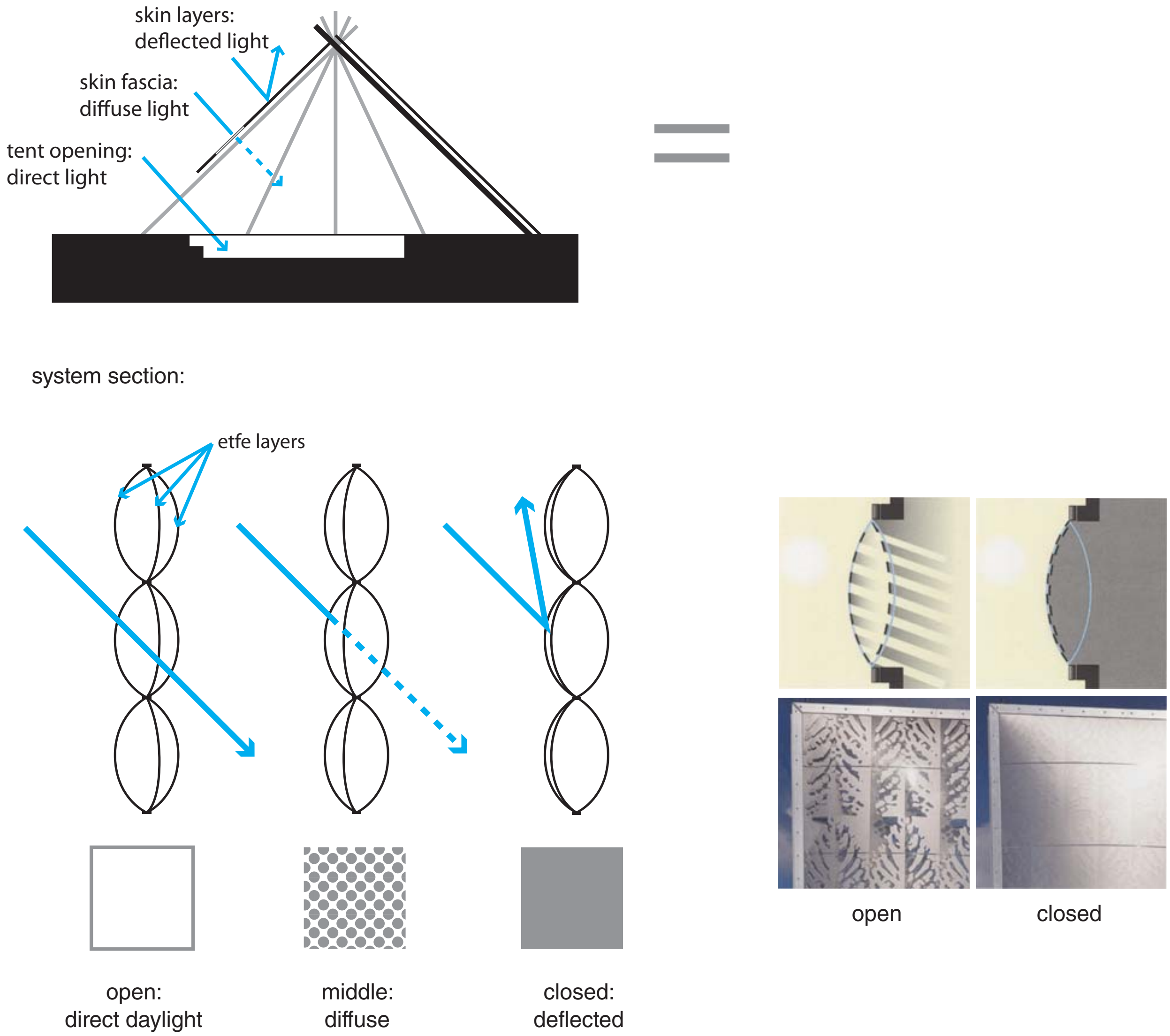
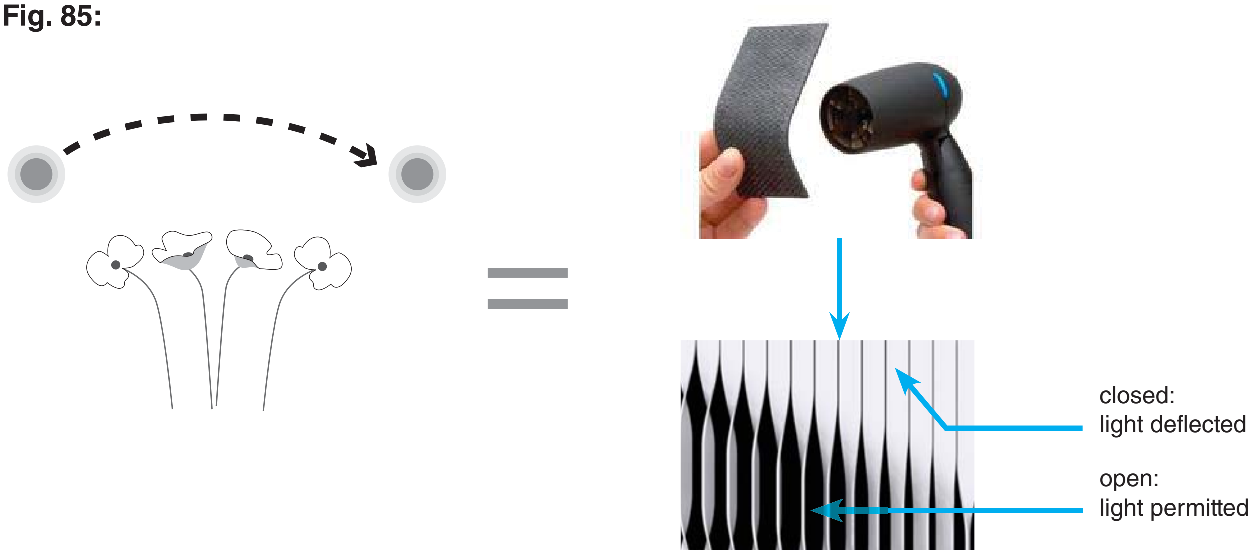
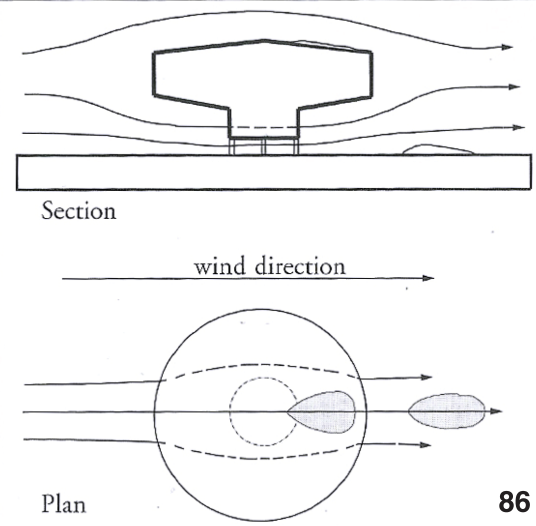

skin layers:
deflected light
skin fascia:
diffuse light
tent opening:
direct light
system section:
etfe layers
open:
direct daylight
middle:
diffuse
closed:
deflected
open
closed

Fig. 85:


closed:
light deflected
open:
light permitted



86


87


88

of available natural light would lower the reliance on artificial lighting and therefore decreasing energy consumption.

The skin tent shows us that it is possible to adjust the levels of transmitted daylight with layers of animal skin. (Fig. 84)

This principle can be replicated through a pneumatic ETFE pillow system. Layers of patterned ETFE, or ethylene-tetra-fluoro-ethylene, a high performance polymer, can be adjusted to allow varying amounts of daylight into a space. The air pockets in each pillow also acts as thermal insulation.

An alternative scheme looks at the sun-tracking technology of the Arctic poppy. New shape memory materials, such as the louver system shown, can change shape by responding to temperature inputs to adjust levels of shading.

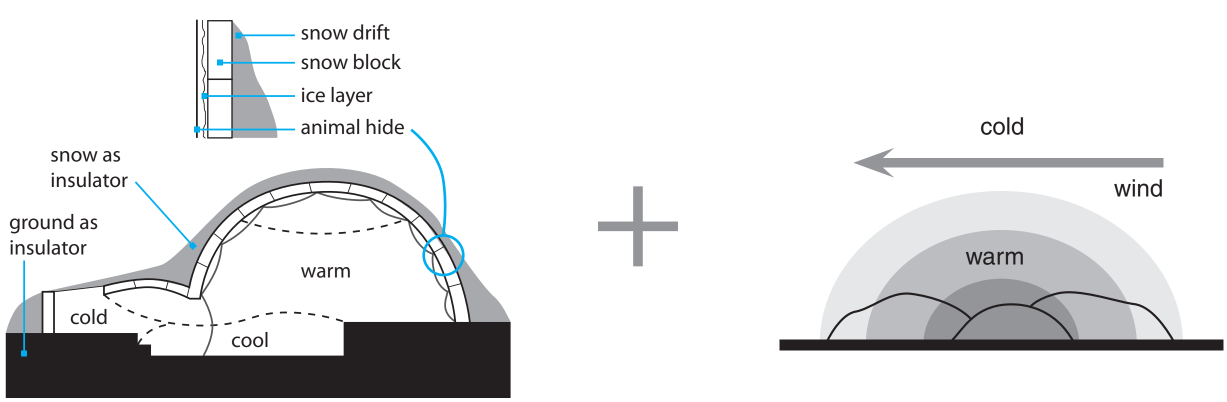
Fig. 86:
Diagram showing how buildings can be designed to deflect wind in the Arctic.

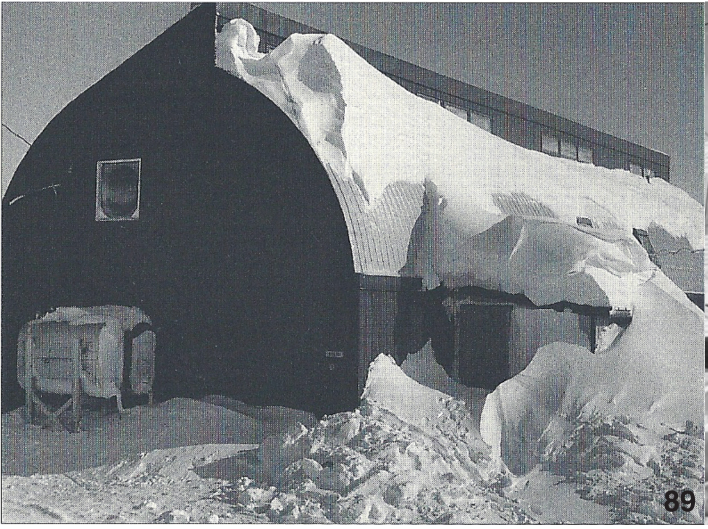
Fig. 87:
Image of a research centre designed to deflect wind and avoid unwanted snow drifting.

Fig. 88:
Poor design can result in unwanted snow drifting in entrance areas.

Fig. 89:
Unwanted snow drifting against a building. Snow can cause water damage in a building envelope if not cleared properly.

Fig. 91:





6.4 Wind

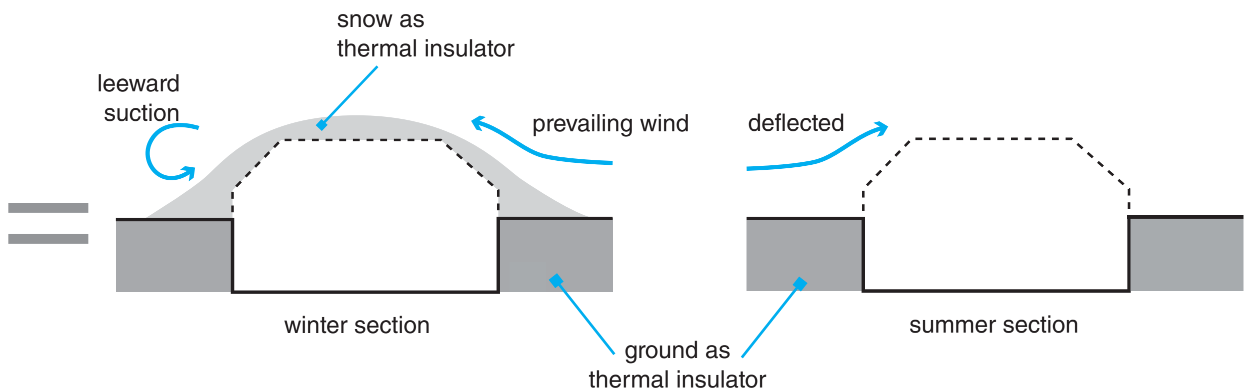
The Arctic is one of the windiest places in Canada with annual average speeds faster than twenty kilometers per hour. (Bone, 2009) Wind directions maintain consistency in the Arctic as there are few obstacles to cause turbulence and variation of speed. (Ibid, 2009) Building orientation must be designed to consider windward force and leeward suction as well as the seasonal prevailing winds to prevent heat loss and unwanted snow drifting. (Strub, 1996) Leaks in the building envelope can cause an increase in unwanted air exchange and heat loss. (Ibid, 1996)

This design proposal looks at utilizing snow as a thermal insulator as well as deflecting it. The bevelled form of this building is designed to hold a layer of snow in the winter, much like the traditional snow house, and deflect winds in the summer. (Fig. 91)

Fig. 90:
These buildings are not sited to avoid unwanted snow drifting.

Fig. 91:
Diagram showing how principles learned from the Inuit snow house and the purple saxifrage can be translated to contemporary architecture.

Fig. 91:



6.5 Water

In contrast to the vast Arctic ocean, freshwater is a more scarce resource in the North (Bone, 2009). Where available, lakes provide water for Arctic communities. However, a large portion of potable water has to be imported. (Ibid, 2009)

The lack of local potable water sources is an issue. In Iqaluit the local reservoir, Lake Geraldine, is being overtaxed by the town's rapidly growing population. The lake is able to provide clean drinking water to approximately 8,300 people (The City of Iqaluit, 2010), however the town is expected to surpass 8,500 people by 2015 (Ibid, 2010).

As the North's population continues to rise alternative sources for water must be considered. The building form in this proposal acts as a snow collector in the winter. In the warmer temperatures of spring and summer, the snow melt can be captured, filtered, and stored for later use within the building. (Fig. 96)

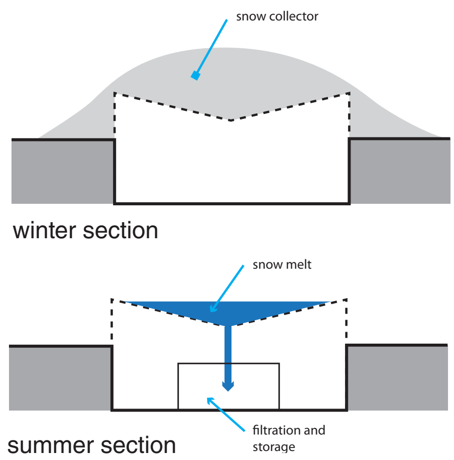
Fig. 92:
Image showing the importation of drinking water to Arctic communities.

Fig. 93:
Residential water system in Iqaluit, NU. (2011) Water trucks supply potable water where underground municipal systems are unavailable due to permafrost soil.

Fig. 96:

traditional water use from local sources

=



6.6 Energy

Traditionally local materials such as natural oils from seal and whale blubber was harvested and burned to provide both indoor lighting and heating. (Fig. 97) Modern energy sources are primarily oil and gas although there is some research being conducted into the viability of renewables such as solar and wind power.

Although oil and gas are abundant in the Arctic they must be processed in facilities in the South after extraction. The refined products are then imported back to northern communities. (Bone, 2009)

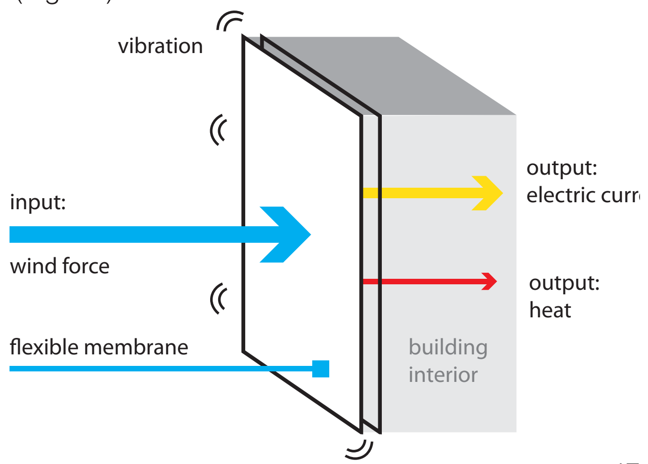
What if we could harness power from the abundant Arctic wind? This scheme proposes a piezoelectric cladding; a flexible membrane that generates energy when the force of the wind is applied. Heat is also a by-product of this process that can be captured and utilized to heat interior spaces. (Fig. 97)

Fig. 94:
Many sources of fuel are must be imported to Arctic communities, often by barge.

Fig. 95:
Fuel tanks in Iqaluit, NU. (2011)

Fig. 97:

traditional oil lamp, *qulliq*



what can an adaptive

architecture look like?

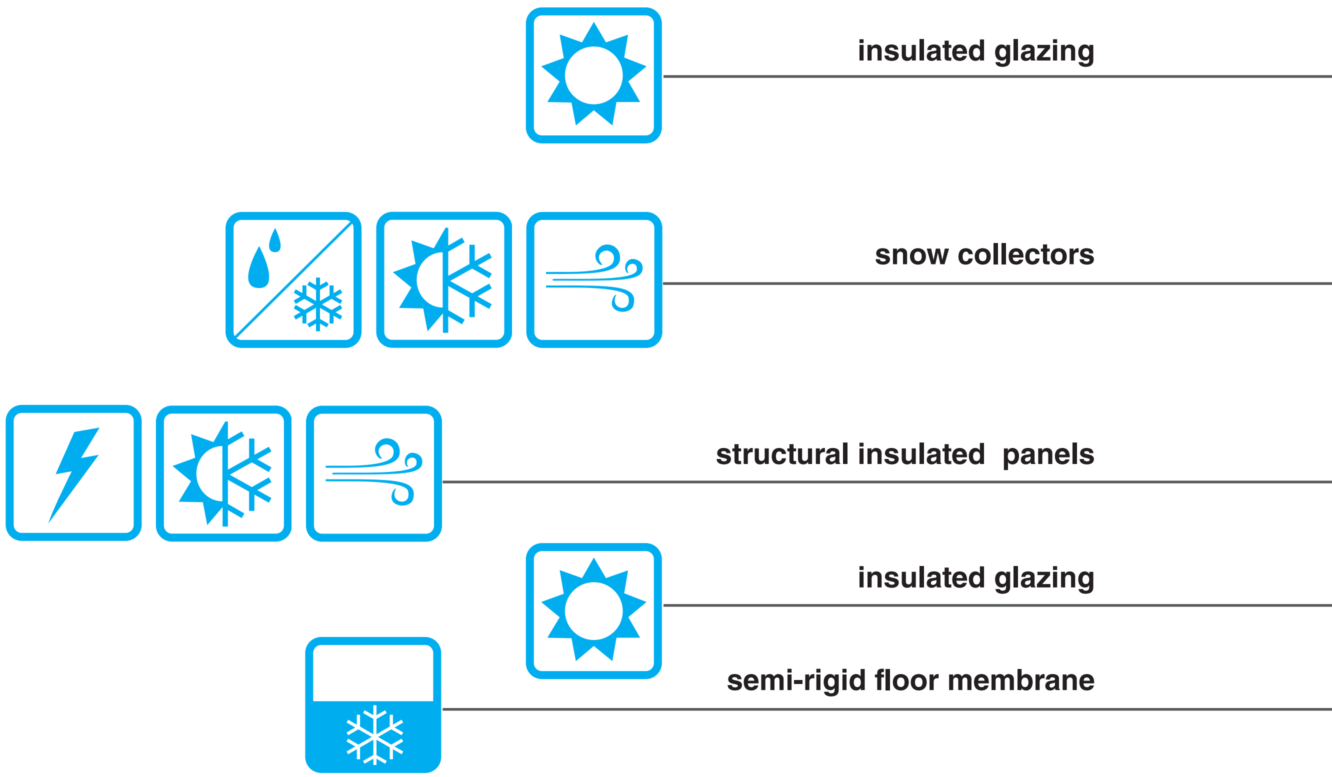
Qaggiq *"community meeting space"*

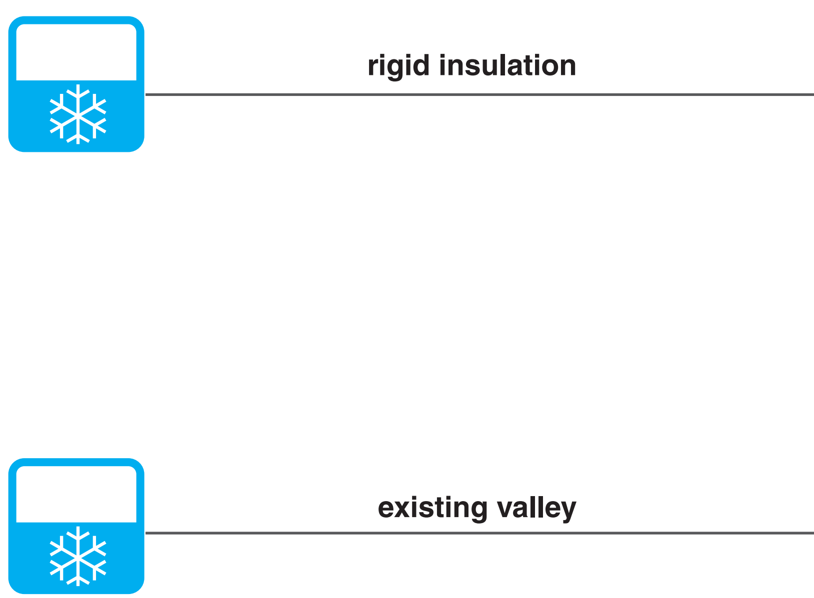
Fig. 99

6.7 Design Project

Taking a combination of systems and strategies learned from vernacular architecture and Arctic ecosystems, what could an Arctic adaptive architecture look like? It is not a literal representation nor caricature of traditional buildings. It does not ignore its geographic, climatic and cultural environments. This design for a modern day *qaggiq* addresses thermal variation, ground, sun, wind, water, snow, and energy production within the context of the Canadian Arctic.

Fig. 100: Components





The design integrates various components from the design handbook such as snow collectors, variable insulation, piezoelectric membranes and a landscape-fitting floor structure. Glazing is incorporated in such a way as to maximize solar exposure throughout the year. (Fig. 100)

The structural insulated panels are a hybrid of snow block and skin tent principles. A layer of insulation and structure is clad in a variable pneumatic skin that contains extruded rubber furs for additional snow collection. This “fur” contains embedded piezoelectric material that generates electricity when the fur is blown in the wind. (Fig. 102)

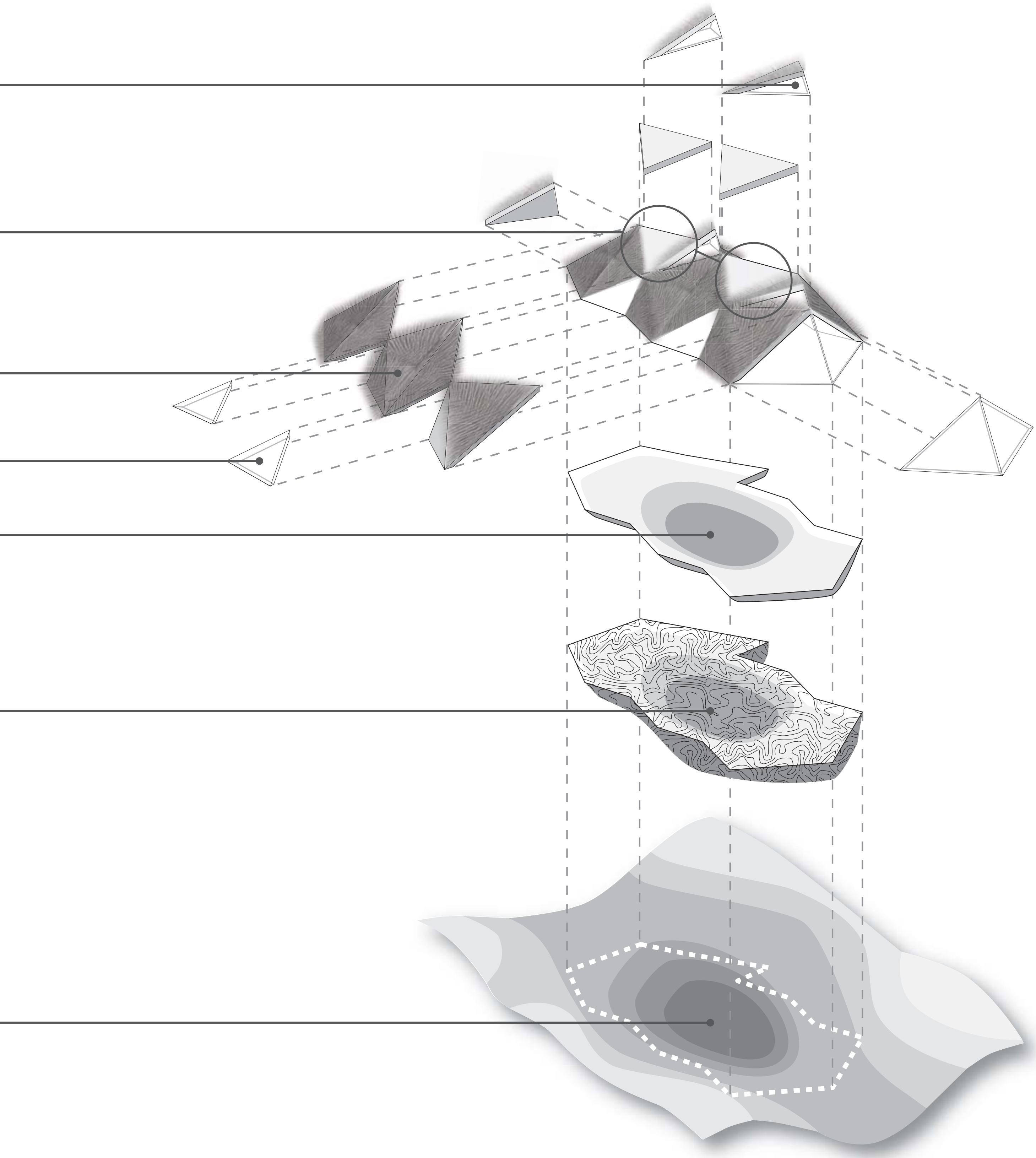
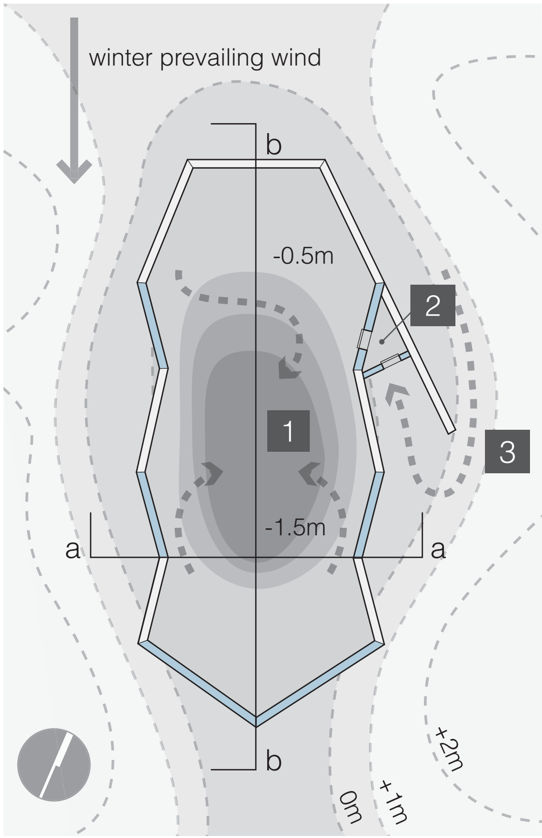
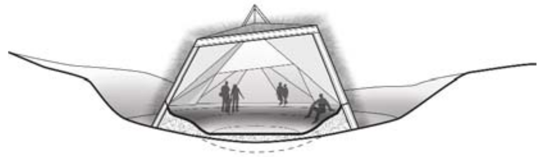


Fig. 101: Drawings

plan 1:200



section a-a 1:200



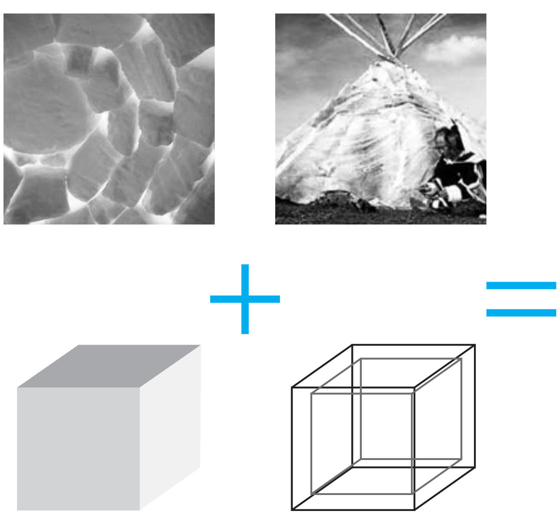
1 multi-purpose community space

2 entrance

3 path slope

Fig. 102: Structural Insulated Panel Detail

precedents: snow house + skin tent



structure / insulation   structure + insulation

partial wall section detail:

snow capture:
flexible rubber cladding

insulation + structure:
structural insulated panel

seasonal insulation:
layer of snow

variable insulation:
adjustable pneumatic system

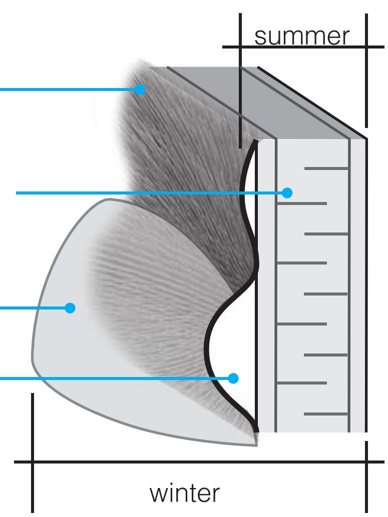
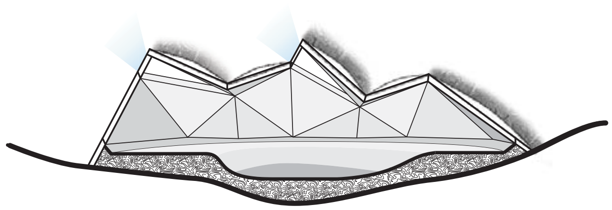
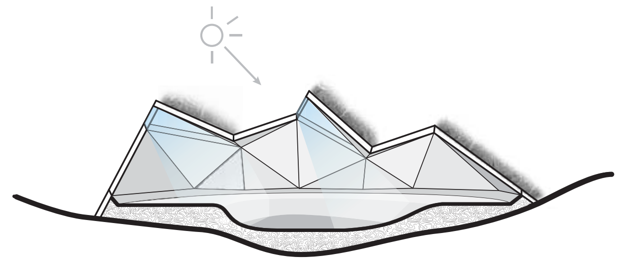


Fig. 103: Section Diagrams



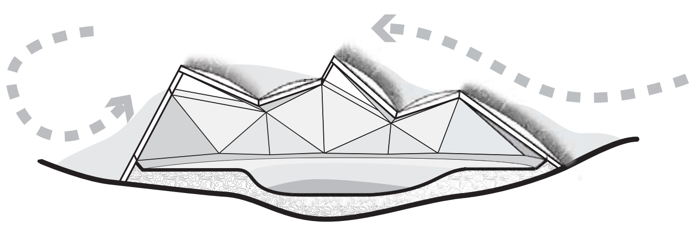
Light: Winter

The light well acts as a beacon in the winter as interior light flows outwards into the dark sky.



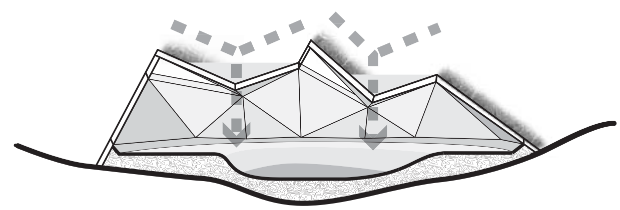
Light: Summer

The light well brings sun into the interior space, taking advantage of the near 24hrs of daylight.



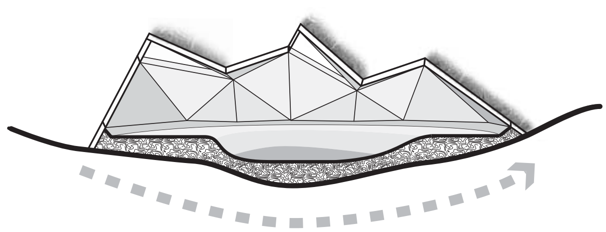
Wind

The building is formed to capture snow in the winter to act as an additional layer of insulation. The rubber "fur" help to stabilize the snow layers.



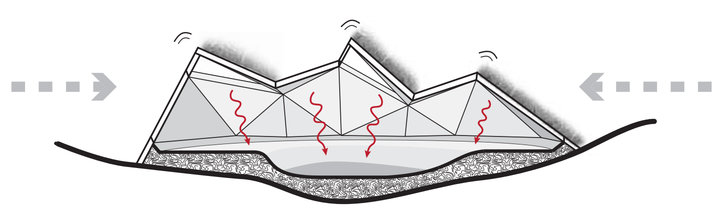
Water

The building captures snow melt in the spring collecting and filtering it for later use within the building.



Ground

The building is sited within an existing valley, utilizing structural insulation and semi-rigid floor membrane technology for form to the landscape.



Energy

Piezoelectric "fur" generate electricity when moved by the wind. Heat caused by this process can be captured to help heat the building interior.

section b-b seasonal variation

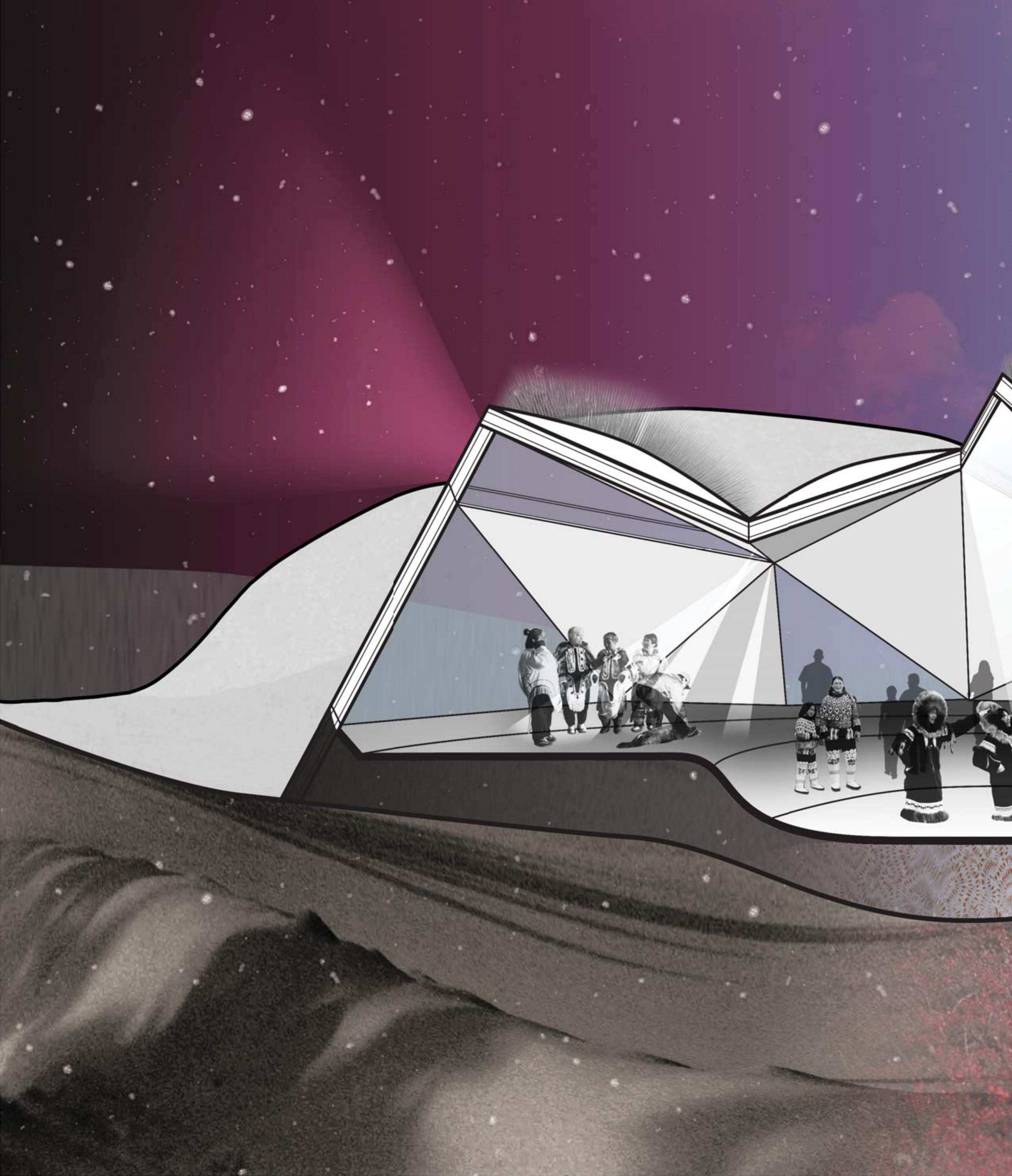


Fig. 104

interior view multi-purpose space

The previous design handbook and design project are but a few examples of the many possibilities for an adaptive Arctic architecture, based on principles learned from vernacular dwellings, Arctic ecosystems and technological innovation.

This thesis was written with hopes to spark a discussion on the future of architecture in the Canadian North.

Fig. 105

A Climatic Data for Arctic Communities

The following data shows climate norms for various communities throughout the Canadian Arctic from 1971-2000.

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

IQALUIT A
NUNAVUT

Latitude: 63°45'00.000" N **Longitude**: 68°33'00.000" W **Elevation**: 33.50 m

Climate ID: 2402590 **WMO ID**: 71909 **TC ID**: YFB

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-26.6	-28	-23.7	-14.8	-4.4	3.6	7.7	6.8	2.2	-4.9	-12.8	-22.7	-9.8	B
Standard Deviation	5	3.8	3.7	2.6	2.1	1.7	1	0.9	1.1	2.5	3.6	4.7	3.4	B
Daily Maximum (°C)	-22.5	-23.8	-18.8	-9.9	-0.9	6.8	11.6	10.3	4.7	-2	-8.9	-18.5	-6	B
Daily Minimum (°C)	-30.6	-32.2	-28.6	-19.6	-7.8	0.3	3.7	3.3	-0.4	-7.7	-16.7	-26.9	-13.6	B
Extreme Maximum (°C)	3.9	4.4	3.9	7.2	13.3	21.7	**25.8**	25.5	17.2	7.3	5.6	3.4		
Date (yyyy/dd)	1958/21	1965/22	1955/19	1981/23	1954/30	1955/22	**2001/28**	1991/08	1964/03	1981/05	1952/19	2001/29		
Extreme Minimum (°C)	-45	**-45.6**	-44.7	-34.2	-26.1	-10.2	-2.8	-2.5	-12.8	-27.1	-36.2	-43.4		
Date (yyyy/dd)	1953/24	**1967/10**	1991/01	1983/10	1949/02	1978/02	1961/03	1996/31	1965/30	1978/30	1978/18	1993/30		
Precipitation:														
Rainfall (mm)	0.1	0	0	0.2	2.8	24.7	59.2	64.8	41.5	4.5	0.5	0	198.3	B
Snowfall (cm)	22.8	16.8	25.3	32.4	25.1	9.8	0.1	0.8	13.7	34.9	32.4	21.7	235.8	B
Precipitation (mm)	21.1	15	21.8	28.2	26.9	35	59.4	65.7	55	36.7	29.1	18.2	412	B
Average Snow Depth (cm)	22	23	25	29	18	2	0	0	0	6	16	20	13	A
Median Snow Depth (cm)	21	23	25	28	16	1	0	0	0	6	15	19	13	A
Snow Depth at Month-end (cm)	23	25	29	27	10	0	0	0	1	10	21	21	14	A
Extreme Daily Rainfall (mm)	2.5	2	0.5	5.1	11.7	28.4	**52.8**	48.2	40.4	23.3	11.9	0.5		
Date (yyyy/dd)	1958/21	1963/03	1958/09	1950/20	1986/14	1961/30	**1968/14**	1995/08	1979/01	1985/24	1955/01	1963/16		
Extreme Daily Snowfall (cm)	30.7	**32.2**	24.6	21.8	29.5	19.2	3.6	6.2	21.3	20.6	27.9	21.8		
Date (yyyy/dd)	1958/18	**1981/12**	1973/08	1973/07	1965/09	1984/09	1970/08	1981/29	1946/26	1961/08	1960/24	1951/03		
Extreme Daily Precipitation (mm)	30.7	27.4	23.9	23.9	27.4	30.2	**52.8**	48.2	40.4	27.2	27.9	21.8		
Date (yyyy/dd)	1958/18	1981/12	1953/29	1973/07	1965/09	1980/06	**1968/14**	1995/08	1979/01	1985/25	1960/24	1951/03		
Extreme Snow Depth (cm)	57	74	69	**86**	86	43	1	3	15	33	52	48		
Date (yyyy/dd)	1977/15	1956/27	1963/01	**1958/30**	1958/01	1987/02	1978/01	1957/24	1992/29	1961/29	1989/27	1958/23		
Days with Maximum Temperature:														
<= 0 °C	30.6	28.2	30.7	27.9	17	0.77	0	0	1.9	19.7	28.1	30.4	215.2	B
> 0 °C	0.41	0.07	0.30	2.2	14	29.2	31	31	28.1	11.3	1.9	0.58	150	B
> 10 °C	0	0	0	0	0.04	5.9	19.6	14.5	1.7	0	0	0	41.7	B
> 20 °C	0	0	0	0	0	0.08	0.88	0.23	0	0	0	0	1.2	B
> 30 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	B
> 35 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	B

Days with Minimum Temperature:														
> 0 °C	0	0	0	0.04	1.6	17	30.5	29.5	13.4	0.92	0.04	0	93.1	B
<= 2 °C	31	28.3	31	30	31	23.8	5.9	7.9	25.7	30.9	30	31	306.4	B
<= 0 °C	31	28.3	31	30	29.4	13	0.46	1.5	16.6	30.1	30	31	272.2	B
< -2 °C	31	28.3	31	29.5	26	4.5	0.04	0.08	6.8	26	29.5	31	243.5	B
< -10 °C	30.6	28.1	29.9	25.7	10.4	0.04	0	0	0.04	9	22.5	29.9	186.2	B
< -20 °C	27.9	26.3	26.8	16.5	0.42	0	0	0	0	1.2	11.2	24.9	135.2	B
< - 30 °C	18.6	18.8	15.7	1.4	0	0	0	0	0	0	1.2	12.2	67.8	B
Days with Rainfall:														
>= 0.2 mm	0.04	0.04	0	0.31	1.5	7.4	13.2	14.7	9.9	1.9	0.26	0	49.2	B
>= 5 mm	0	0	0	0	0.15	1.5	4	4.2	2.6	0.23	0.04	0	12.8	B
>= 10 mm	0	0	0	0	0.08	0.58	1.5	1.6	1.2	0.08	0	0	5.1	B
>= 25 mm	0	0	0	0	0	0	0.23	0.23	0.19	0	0	0	0.65	B
Days With Snowfall:														
>= 0.2 cm	12	10.7	12.5	12.8	11.6	4.7	0.12	0.58	7.5	15.3	14.5	12.1	114.3	B
>= 5 cm	1.2	0.52	1.4	2	1.3	0.58	0	0.04	0.62	2.4	1.9	1.1	13.2	B
>= 10 cm	0.33	0.22	0.52	0.62	0.31	0.19	0	0	0.31	0.38	0.48	0.30	3.7	B
>= 25 cm	0	0.04	0	0	0	0	0	0	0	0	0	0	0.04	B
Days with Precipitation:														
>= 0.2 mm	11.9	10.6	12	12.5	12.2	10.5	13.2	15	15.3	15.4	14.3	11.8	154.6	B
>= 5 mm	1	0.48	1	1.7	1.5	2.2	4	4.4	3.3	2.5	1.6	0.81	24.5	B
>= 10 mm	0.26	0.19	0.33	0.46	0.42	0.85	1.5	1.6	1.5	0.46	0.33	0.22	8.1	B
>= 25 mm	0	0.04	0	0	0	0.04	0.23	0.23	0.23	0.04	0	0	0.81	B
Days with Snow Depth:														
>= 1 cm	31	28.3	31	30	28.8	10.5	0.08	0.04	2.7	24	30	31	247.3	A
>= 5 cm	31	28.3	31	29.9	26.3	5.7	0	0	0.31	15.6	28.4	31	227.4	A
>= 10 cm	29.6	27.3	29.9	27.8	20.8	2.1	0	0	0.04	7.8	24	30.3	199.6	A
>= 20 cm	19.2	16.2	20.7	22.6	12	0.69	0	0	0	2.1	8.2	14.3	115.9	A
Wind:														
Speed (km/h)	15	14.8	14.1	15.8	17.3	15.3	12.4	13.9	15	17.6	17.6	15.4	15.4	A
Most Frequent Direction	NW	NW	NW	NW	NW	SE	SE	SE	SE	NW	NW	NW	NW	A
Maximum Hourly Speed (km/h)	108	100	**129**	116	85	72	80	90	97	104	97	111		
Date (yyyy/dd)	1962/17	2001/23	**1960/29**	1962/05	1961/11	2000/23	1958/15	1961/23	1960/22	1986/12	1957/10	1982/04		
Direction of Maximum Hourly Speed	NE	NE	NW	NW	NW	NE	SE	NW	SE	NW	NE	NW	NW	
Maximum Gust Speed (km/h)	146	114	**156**	153	103	93	117	109	126	137	126	141		
Date (yyyy/dd)	1963/21	1962/07	**1960/29**	1962/05	1960/25	1994/16	1958/14	1961/22	1960/22	1986/12	1957/10	1982/04		
Direction of Maximum Gust	NE	NW	NW	NW	NW	W	E	NW	SE	NW	NE	NW	NW	
Days with Winds >= 52 km/h	3.8	3.2	3.1	2.8	2.3	0.8	0.7	1.1	1.7	2.4	3.7	3.6	29.1	C
Days with Winds >= 63 km/h	1.9	1.2	0.8	0.6	0.4	0.2	0	0.4	0.5	0.8	1.4	1.3	9.5	C
Degree Days:														
Above 24 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	B
Above 18 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	B
Above 15 °C	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0.2	B
Above 10 °C	0	0	0	0	0	1.4	10.4	5.5	0	0	0	0	17.3	B
Above 5 °C	0	0	0	0	0	21	88.2	64.1	5.3	0	0	0	178.6	B
Above 0 °C	0	0	0	0.5	10.8	112	237.7	210.9	75.8	5.7	0.6	0	653.8	B
Below 0 °C	824.1	792.5	735.9	443.5	146.5	4.8	0	0	10.8	156.7	381.8	700	4196.5	B
Below 5 °C	979.1	933.8	890.8	593.1	290.7	63.9	5.5	8.2	90.3	306	531.2	855	5547.6	B
Below 10 °C	1134.1	1075.1	1045.8	743.1	445.7	194.2	82.7	104.6	235	461	681.2	1010	7212.6	B
Below 15 °C	1289.1	1216.4	1200.8	893.1	600.7	342.9	227.4	254.2	385	616	831.2	1165	9021.8	B
Below 18 °C	1382.1	1301.2	1293.8	983.1	693.7	432.9	320.3	347.1	475	709	921.2	1258	10117.4	B
Bright Sunshine:														
Total Hours	34.2	97.7	170.3	223.8	193.7	196.9	217.5	169.7	88.8	54.2	40	19.2	1506	C
Days with measureable	13	20.6	26.5	25.6	26.1	26.2	26.6	25.9	20.9	18.3	15	10	254.8	C
% of possible daylight hours	19.6	40.4	46.9	49.8	34.2	31.9	36.1	33.5	22.6	17.8	19.9	13.5	30.5	C
Extreme Daily	6.5	9.3	11.9	15.4	16.9	**18.1**	17.7	16.2	13.2	9.9	7.4	4.4		A
Date (yyyy/dd)	1985/31	1980/29	1987/31	1988/30	1977/28	**1987/26**	1986/09	1991/03	1974/03	1991/01	1979/01	1987/05		
Humidex:														

Extreme Humidex	3.3	3.9	3.9	5.1	13.3	21.7	**27.8**	27.6	18.8	8.3	4.8	3.4		
Date (yyyy/dd)	1958/21	1965/22	1955/19	1995/24	1954/30	1955/22	**2001/28**	1991/08	1968/18	1998/01	1985/25	2001/29		
Days with Humidex >= 30	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days with Humidex >= 35	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days with Humidex >= 40	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Wind Chill:														
Extreme Wind Chill	-64	**-65.6**	-61.5	-53.1	-36	-18.8	-7.2	-8.6	-18.6	-42.9	-56.8	-60.1		
Date (yyyy/dd)	1983/22	**1979/16**	1984/06	1963/02	1993/08	1978/03	1972/03	1976/25	1997/29	1978/31	1963/27	1953/25		
Days with Wind Chill < -20	30.1	27.8	28.9	22.8	5.7	0	0	0	0	5.9	19.6	28.1	168.8	A
Days with Wind Chill < -30	26.7	25.4	24.1	11.4	0.4	0	0	0	0	1	10	22.4	121.4	A
Days with Wind Chill < -40	19.1	18.4	14.1	2.6	0	0	0	0	0	0.1	2.2	12.2	68.7	A
Humidity:														
Average Vapour Pressure (kPa)	0.1	0.1	0.1	0.2	0.4	0.6	0.8	0.8	0.6	0.4	0.2	0.1	0.4	A
Average Relative Humidity - 0600LST (%)	66.3	64.9	67.3	73.6	80.4	80.3	81.8	84.4	84.8	80.8	76.2	69.8	75.9	A
Average Relative Humidity - 1500LST (%)	66.1	64.2	65.4	71.8	75.7	70.2	68.5	69.9	74.7	78.2	75.7	69.9	70.9	A
Pressure:														
Average Station Pressure (kPa)	100.3	100.6	101	101.3	101.1	100.8	100.5	100.4	100.5	100.6	100.5	100.5	100.7	A
Average Sea Level Pressure (kPa)	100.7	101	101.4	101.7	101.5	101.2	100.9	100.8	100.9	101	100.9	100.9	101.1	A
Visibility (hours with):														
< 1 km	27	19.8	21.7	12.5	6.5	2.9	6.8	6.3	8.2	7.2	12.6	14.8	146.2	C
1 to 9 km	170.2	153.5	146.2	116.2	87.2	38.5	43.9	45	75.8	103.2	121.1	144.4	1244.9	C
> 9 km	546.8	504.8	576.1	591.4	650.3	678.6	693.4	692.7	636	633.7	586.3	584.8	7374.8	C
Cloud Amount (hours with):														
0 to 2 tenths	268.7	253.9	276.4	237.8	118.2	100.9	94.9	84	73.5	86.3	170.4	267.9	2033	C
3 to 7 tenths	148.7	143	135.8	118.7	108.5	117.2	160.2	144	105	90	105.8	149.3	1526.1	C
8 to 10 tenths	326.6	281	331.8	363.5	517.3	501.9	488.9	516	541.5	567.8	443.8	326.8	5206.9	C

Environment Canada. (2011) Canadian Climate Normals 1971-2000, Iqaluit, NU. Retrieved from: http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1758&lang=e&dCode=0&province=NU&provBut=Search&month1=0&month2=12

Environment Canada / Environnement Canada — Canada

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

RESOLUTE CARS *
NUNAVUT

Latitude: 74°43'01.000" N Longitude: 94°58'10.000" W Elevation: 67.70 m

Climate ID: 2403500 WMO ID: 71924 TC ID: YRB

*** This station meets WMO standards for temperature and precipitation.**

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-32.4	-33.1	-30.7	-22.8	-10.9	-0.1	4.3	1.5	-4.7	-14.9	-23.6	-29.2	-16.4	A
Standard Deviation	3	3.2	2.5	2.7	2.2	2	1	1.2	2	2.8	2.9	2.8	1.1	A
Daily Maximum (°C)	-28.8	-29.7	-27.2	-19.1	-7.7	2.2	7.1	3.8	-2.5	-11.8	-20.1	-25.6	-13.3	A
Daily Minimum (°C)	-35.9	-36.6	-34.2	-26.5	-14	-2.5	1.4	-0.8	-6.9	-18	-27	-32.7	-19.5	A
Extreme Maximum (°C)	0	-3.9	-2.7	0	6.1	13.9	**18.3**	15.3	9.4	0.7	18.1	-4.3		
Date (yyyy/dd)	2000/23	1963/04	1989/15	1975/29	1995/31	1951/30	**1962/18**	1999/08	1973/01	1984/13	1991/05	1983/24		
Extreme Minimum (°C)	**-52.2**	-52	-51.7	-42.1	-29.4	-16.7	-3.1	-9.3	-20.6	-37.3	-42.8	-46.1		
Date (yyyy/dd)	**1966/07**	1979/14	1956/16	1983/04	1961/04	1974/05	1982/21	1997/31	1965/29	1986/23	1967/21	1948/27		
Precipitation:														
Rainfall (mm)	0	0	0	0	0.5	6.5	15.7	21.8	5.4	0.5	0	0	50.3	A
Snowfall (cm)	4.7	3.7	7	6.6	11.1	8.7	4.2	13.1	21	16.2	8.6	5.5	110.3	A
Precipitation (mm)	4.3	3.4	6.5	6.1	9.5	14.7	20.2	34.3	25	13.8	7.6	4.7	150	A
Average Snow Depth (cm)	22	23	24	25	27	11	0	0	5	15	19	21	16	A
Median Snow Depth (cm)	22	22	24	25	27	11	0	0	4	15	19	21	16	A
Snow Depth at Month-end (cm)	23	23	25	26	24	2	0	1	10	17	20	22	16	A
Extreme Daily Rainfall (mm)	0	0	0	1.2	8.4	18	20.6	**25.1**	15.6	12.2	0	0		
Date (yyyy/dd)	1948/01	1948/01	1948/01	2003/23	1994/27	1951/14	1967/24	**1960/12**	1985/11	1984/13	1947/01	1947/01		
Extreme Daily Snowfall (cm)	13.4	5.6	10	7.8	8.6	10.8	9.4	10.4	13.2	14.2	**27**	7		
Date (yyyy/dd)	1997/19	1995/06	1993/24	1998/11	1948/10	1990/09	1974/22	1981/18	1977/18	2003/06	**2004/17**	1994/26		
Extreme Daily Precipitation (mm)	13.4	4.7	8.9	7.8	8.6	19.6	20.6	25.1	18.2	14.2	**35**	7		
Date (yyyy/dd)	1997/19	1995/06	1993/24	1998/11	1948/10	1951/14	1967/24	1960/12	1978/16	2003/06	**2004/17**	1994/26		
Extreme Snow Depth (cm)	50	53	54	56	69	**79**	28	12	36	66	41	49		
Date (yyyy/dd)	1995/20	1961/24	1995/23	1961/30	1974/29	**1974/06**	1964/01	1997/31	1989/28	1967/31	1960/15	1994/27		
Days with Maximum Temperature:														
<= 0 °C	31	28.3	31	30	29.1	7.7	0.03	3.9	23	30.9	30	31	275.9	A
> 0 °C	0	0	0	0	1.9	22.3	31	27.1	7	0.07	0.03	0	89.4	A
> 10 °C	0	0	0	0	0	0.57	6.6	1.6	0	0	0.03	0	8.8	A
> 20 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
> 30 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
> 35 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A

Days with Minimum Temperature:														
> 0 °C	0	0	0	0	0.10	6.6	21.8	10.4	1	0	0	0	39.9	A
<= 2 °C	31	28.3	31	30	31	28.6	20.9	27.7	29.9	31	30	31	350.3	A
<= 0 °C	31	28.3	31	30	30.9	23.4	9.2	20.6	29	31	30	31	325.3	A
< -2 °C	31	28.3	31	30	30.4	13.1	0.20	8	26	30.9	30	31	289.8	A
< -10 °C	31	28.3	31	29.7	22.9	1.7	0	0	7.4	27.4	29.9	31	240.4	A
< -20 °C	30.8	28.1	30.4	25	4.9	0	0	0	0.03	11.7	25.2	30.2	186.2	A
< - 30 °C	27.1	24.8	24.4	9.3	0	0	0	0	0	0.67	10.4	22.6	119.3	A
Days with Rainfall:														
>= 0.2 mm	0	0	0	0	0.40	3.8	8.6	8.4	2.2	0.20	0	0	23.5	A
>= 5 mm	0	0	0	0	0.03	0.37	0.90	1.4	0.27	0.03	0	0	3	A
>= 10 mm	0	0	0	0	0	0.10	0.03	0.37	0.13	0.03	0	0	0.66	A
>= 25 mm	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days With Snowfall:														
>= 0.2 cm	6.1	5.3	7.3	6.8	9.7	6.1	3	7.5	12.3	12.3	8.6	6.5	91.4	A
>= 5 cm	0.07	0.03	0.10	0.10	0.33	0.27	0.10	0.73	0.73	0.40	0.24	0.10	3.2	A
>= 10 cm	0.03	0	0.03	0	0	0.03	0	0.03	0.10	0.03	0	0	0.25	A
>= 25 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days with Precipitation:														
>= 0.2 mm	5.9	5.2	7.2	6.6	9.2	8.1	10	13.4	13.5	12.1	8.4	6.3	106	A
>= 5 mm	0.07	0	0.07	0.10	0.23	0.70	1.1	2.1	1	0.33	0.14	0.07	6	A
>= 10 mm	0.03	0	0	0	0	0.13	0.10	0.43	0.30	0.07	0	0	1.1	A
>= 25 mm	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days with Snow Depth:														
>= 1 cm	31	28.3	31	30	31	22.2	1.7	3.8	20.6	30.6	30	31	291.1	A
>= 5 cm	31	28.3	31	30	30.5	16.2	0.77	1.1	12.9	28.6	29.5	31	270.8	A
>= 10 cm	28.6	27.2	30.8	30	29.9	11.9	0.20	0.27	6	22.3	27.1	29.6	243.7	A
>= 20 cm	20.4	17.5	19.2	20	21.7	7.3	0	0	0.70	8.1	10.7	17.2	142.9	A
Wind:														
Speed (km/h)	20.4	20.5	20.8	20	20.3	20.2	20.8	20.7	23.9	23	21.9	19.4	21	A
Most Frequent Direction	NW	NW	NW	NW	NW	NW	NW	W	NW	NW	NW	NW	NW	A
Maximum Hourly Speed (km/h)	103	111	97	113	100	89	101	96	91	102	**142**	108		
Date (yyyy/dd)	1965/11	1964/29	1958/22	1964/29	1965/31	1977/27	1958/31	1986/24	1981/04	1985/24	**1965/20**	1964/10		
Direction of Maximum Hourly Speed	NE	NE	E	E	SE	E	E	E	E	E	E	E	E	
Maximum Gust Speed (km/h)	138	135	117	138	119	109	108	120	107	124	**158**	132		
Date (yyyy/dd)	1965/10	1966/27	1991/07	1964/29	1965/31	1977/27	1966/29	1987/31	1981/04	1985/23	**1965/20**	1964/10		
Direction of Maximum Gust	N	E	E	E	E	E	E	E	E	E	E	E	E	
Days with Winds >= 52 km/h	7.7	6.4	7.6	5.2	3.8	2.6	4	3.6	5.4	6.1	7.6	5.7	65.6	A
Days with Winds >= 63 km/h	3.8	2.8	3	1.8	1.1	0.7	1.1	1.4	1.5	2.2	3	2.2	24.6	A
Degree Days:														
Above 24 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Above 18 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Above 15 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Above 10 °C	0	0	0	0	0	0	0.6	0.1	0	0	0	0	0.6	A
Above 5 °C	0	0	0	0	0	2.4	23.9	5.5	0.1	0	0	0	31.9	A
Above 0 °C	0	0	0	0	0.6	40.4	132.7	63.1	4.3	0	0	0	241.2	A
Below 0 °C	1003.3	936.5	952.1	684.7	337.6	44.7	0.2	12.9	146	461.7	707.8	905	6192.6	A
Below 5 °C	1158.3	1077.9	1107.1	834.7	492	156.6	46.4	110.3	291.7	616.7	857.8	1060	7809.5	A
Below 10 °C	1313.3	1219.2	1262.1	984.7	647	304.3	178.1	259.8	441.7	771.7	1007.8	1215	9604.6	A
Below 15 °C	1468.3	1360.5	1417.1	1134.7	802	454.3	332.5	414.8	591.7	926.7	1157.8	1370	11430.3	A
Below 18 °C	1561.3	1445.3	1510.1	1224.7	895	544.3	425.5	507.8	681.7	1019.7	1247.8	1463	12526.1	A
Soil Temperature:														
at 5 cm depth (AM obs) (°C)	-17.4	-19.5	-20.5	-19.6	-15.6	-2.3	4.7	2.2	-1	-5.7	-10.6	-14.5	-10	C
at 5 cm depth (PM obs) (°C)	-17.5	-19.5	-20.5	-19.6	-15.5	-1.3	7	3.9	-0.7	-5.8	-10.6	-14.5	-9.5	C
at 10 cm depth (AM obs) (°C)	-17.3	-19.3	-20.4	-19.6	-15.8	-3.3	3.5	1.9	-0.7	-5.5	-10.4	-14.2	-10.1	C
at 10 cm														

depth (PM obs) (°C)	-17.3	-19.3	-20.4	-19.6	-15.8	-2.6	5.2	3.1	-0.6	-5.6	-10.4	-14.3	-9.8	C
at 20 cm depth (AM obs) (°C)	-17.6	-19.6	-20.7	-20.1	-16.5	-4.6	2.2	1	-1.4	-6	-10.7	-14.6	-10.7	C
at 20 cm depth (PM obs) (°C)	-17.6	-19.6	-20.7	-20	-16.4	-4.2	3.3	1.7	-1.3	-6.1	-10.8	-14.6	-10.5	C
at 50 cm depth (AM obs) (°C)	-15.3	-17.2	-18.5	-18.3	-15.6	-6.2	0.5	1.1	-0.2	-4.2	-8.5	-12.1	-9.5	C
at 100 cm depth (AM obs) (°C)	-16.5	-18.7	-20.2	-20.1	-17.6	-8.9	-2.5	-1.6	-2.6	-6.3	-10.4	-13.9	-11.6	C
at 150 cm depth (AM obs) (°C)	-14.4	-16.5	-18	-18.3	-16.7	-10.7	-4.6	-2.8	-2.8	-5.2	-8.6	-11.8	-10.9	C
Humidex:														
Extreme Humidex	-0.8	-3.9	-8.5	0	5.6	13.5	**19.4**	15	8.9	0.7	-2.8	-4.4		
Date (yyyy/dd)	1977/11	1963/04	2006/29	1975/29	1995/31	1987/30	**1962/18**	1999/08	1973/01	1984/13	1955/03	1983/24		
Days with Humidex >= 30	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Days with Humidex >= 35	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Days with Humidex >= 40	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Wind Chill:														
Extreme Wind Chill	**-72**	-69.6	-69.9	-60.5	-41.5	-27.1	-9.8	-17.1	-32.4	-57.1	-60.3	-63.8		
Date (yyyy/dd)	**1966/07**	1979/13	1986/06	1984/03	1970/01	1974/01	1976/06	1986/30	1975/29	1986/23	1976/28	1989/23		
Days with Wind Chill < -20	31	28.3	31	29.5	19.1	0.5	0	0	5.4	25.8	29.9	31	231.4	A
Days with Wind Chill < -30	30.8	28.3	30.6	24.6	4.4	0	0	0	0.1	11.5	25.8	30.3	186.4	A
Days with Wind Chill < -40	28.2	26.2	26.3	12	0	0	0	0	0	2.3	14.5	24.7	134.1	A
Humidity:														
Average Vapour Pressure (kPa)	0	0	0	0.1	0.3	0.5	0.7	0.6	0.4	0.2	0.1	0.1	0.3	C
Average Relative Humidity - 0600LST (%)	64.9	65.8	64.8	67.9	82.3	88.4	87.2	91.3	89.9	82.5	70.9	65.3	76.8	C
Average Relative Humidity - 1500LST (%)	65	65.4	64.5	69	81	84.3	79.9	85.2	87.6	82.1	70.3	65.3	75	C
Pressure:														
Average Station Pressure (kPa)	100.2	100.5	100.7	101.1	101	100.5	100.3	100.1	100.3	100.4	100.4	100.3	100.5	A
Average Sea Level Pressure (kPa)	101.2	101.4	101.6	102	101.8	101.4	101.1	101	101.2	101.3	101.3	101.2	101.4	A
Radiation:														
Extreme Global - RF1 (MJ/m2)	0	3.9	12.2	23.3	33.7	**37.1**	35.4	24.5	13.2	5.1	0.3	0		
Date (yyyy/dd)	2003/31	2001/28	2001/31	1971/30	1981/29	**1968/26**	1968/04	1970/01	1990/03	1964/04	1959/01	1957/01		
Extreme Diffuse - RF2 (MJ/m2)	0	2.2	8	16.2	24.4	**26.8**	23.2	13.8	8.9	4.2	0.2	0		
Date (yyyy/dd)	2003/31	1997/28	1958/24	1991/30	2000/25	**1976/06**	1964/01	1965/03	1975/04	1958/03	1977/01	1957/01		
Extreme Reflected - RF3 (MJ/m2)	0	2.2	8.6	17.5	25	**26**	9.3	9.6	9.1	3.2	0.2	0		
Date (yyyy/dd)	1995/31	1961/28	2002/31	1996/30	1968/28	**1968/11**	1957/05	1997/05	1994/05	1972/01	1967/01	1957/01		

Extreme Net - RF4 (MJ/m2)	1.3	1.4	1.6	4.4	15.1	**18**	15.9	11	4.8	2.1	0.4	1.6		
Date (yyyy/dd)	1965/11	1965/23	1967/26	2002/28	2001/30	**2002/10**	1970/02	2000/02	2003/04	1983/07	1975/10	1984/31		
Visibility (hours with):														
< 1 km	50.7	45.6	51.3	30.2	22.3	39.2	49.6	73.2	33.1	43.9	31.2	22.5	492.7	C
1 to 9 km	181.6	195.9	202.3	125.6	128.2	78.9	55.5	98.8	120.4	169.8	169	163.2	1689.3	C
> 9 km	511.7	436.7	490.4	564.2	593.5	601.9	638.9	572	566.5	530.3	519.8	558.3	6584.2	C
Cloud Amount (hours with):														
0 to 2 tenths	403.3	343.6	356.9	348.8	179.6	116.6	107.1	67.5	71.4	179.7	294.6	393.8	2862.9	C
3 to 7 tenths	157.9	145.5	154.4	127.8	114.9	116.2	136.1	103.3	85.2	121.5	147.9	146.9	1557.4	C
8 to 10 tenths	182.9	189.2	232.8	243.4	449.4	487.2	500.8	573.2	563.4	442.8	277.5	203.4	4346	C

Environment Canada. (2011) Canadian Climate Normals 1971-2000, Resolute, NU. Retrieved from: http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1776&lang=e&dCode=1&province=NU&provBut=Search&month1=0&month2=12

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

KUGLUKTUK A
NUNAVUT

Latitude: 67°49'00.000" N **Longitude**: 115°08'38.000" W **Elevation**: 22.60 m
Climate ID: 2300902 **WMO ID**: 71938 **TC ID**: YCO

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-27.8	-27.4	-25.3	-17	-5.3	5.2	10.7	8.8	2.8	-7.2	-19.6	-25.5	-10.6	C
Standard Deviation	3.8	4.2	3.2	3	3.2	2	2	1.9	1.5	2.5	4.3	3.4	4	C
Daily Maximum (°C)	-23.7	-23	-20.6	-12.1	-1.4	9.5	15.4	13.1	6	-4	-15.7	-21.4	-6.5	C
Daily Minimum (°C)	-31.9	-31.7	-29.8	-21.8	-9.2	0.8	6	4.5	-0.4	-10.3	-23.4	-29.6	-14.7	C
Extreme Maximum (°C)	0.8	-1.2	-0.1	14	19.8	31.1	**34.9**	29.2	22.6	13.4	2.8	27.4		
Date (yyyy/dd)	1981/16	1980/07	1999/22	2000/06	1994/24	1996/25	**1989/15**	2000/01	1994/01	1988/06	1983/03	1999/19		
Extreme Minimum (°C)	-46.9	**-47.2**	-47	-39.7	-30.2	-12.1	0.3	-4.4	-18.9	-35.4	-41	-44.5		
Date (yyyy/dd)	2002/21	**1998/20**	1979/05	1979/04	1983/03	2000/01	1978/04	1995/29	2000/26	1996/29	1985/24	1977/12		
Precipitation:														
Rainfall (mm)	0	0	0	0.6	5.8	12.8	36.3	40.8	32.1	5.1	0	0	133.4	C
Snowfall (cm)	15.4	16.5	16	17.8	16.6	2.7	0	0.3	8.1	34.1	19.7	18.6	165.7	C
Precipitation (mm)	11	9.9	10.6	13.3	19.5	15.1	36.3	41.1	39	29.5	12.6	11.5	249.3	C
Average Snow Depth (cm)	35	43	47	48	28	3	0	0	0	9	20	28	22	C
Median Snow Depth (cm)	36	42	47	49	28	1	0	0	0	9	19	28	22	C
Snow Depth at Month-end (cm)	38	45	48	42	15	0	0	0	2	17	24	32	22	C
Extreme Daily Rainfall (mm)	0	0	0	7.4	20.6	27.4	30.5	**53.7**	28.8	19.3	3.4	0		
Date (yyyy/dd)	1978/01	1978/06	1978/01	1980/27	1992/27	1987/13	1983/10	**1982/12**	1983/07	1980/08	2001/17	1977/01		
Extreme Daily Snowfall (cm)	**26.2**	24.6	8.6	16	21	13	0.4	5	13.5	23	12.4	26		
Date (yyyy/dd)	**1988/01**	1981/21	2000/27	1980/30	1993/07	1991/05	1985/07	1986/23	1981/22	1981/29	1981/06	1994/25		
Extreme Daily Precipitation (mm)	25.8	9.1	6	16	21.8	27.4	30.5	**53.7**	28.8	23	12.4	14.8		
Date (yyyy/dd)	1988/01	1981/21	1990/07	1980/30	1978/25	1987/13	1983/10	**1982/12**	1983/07	1981/29	1981/06	1994/25		
Extreme Snow Depth (cm)	80	92	104	107	**128**	64	3	0	23	43	49	73		
Date (yyyy/dd)	1993/30	1993/22	1991/31	1991/03	**1993/08**	1993/01	1986/01	1978/01	1981/24	1995/29	1992/30	1994/26		
Days with Maximum Temperature:														
<= 0 °C	31	28.3	31	28.4	18.7	1.1	0	0	2.5	23.1	29.6	30.9	224.5	C
> 0 °C	0.05	0	0	1.6	12.3	28.9	31	31	27.5	7.9	0.45	0.08	140.8	C
> 10 °C	0	0	0	0.04	0.91	12	25.6	20.8	5.4	0.10	0	0.08	65	C
> 20 °C	0	0	0	0	0	2.5	6	3.9	0.22	0	0	0.08	12.7	C
> 30 °C	0	0	0	0	0	0.09	0.26	0	0	0	0	0	0.35	C
> 35 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Days with Minimum Temperature:														

> 0 °C	0	0	0	0	0.95	17.9	31	27.7	14	0.71	0	0	92.3	C
<= 2 °C	31	28.3	31	30	30.8	20.7	2.7	7.6	22.7	30.9	30	31	296.7	C
<= 0 °C	31	28.3	31	30	30.1	12.1	0	3.3	16	30.3	30	31	273	C
< -2 °C	31	28.3	31	29.8	27.1	5.1	0	0.59	8.6	27.7	30	31	250.1	C
< -10 °C	30.9	28.2	30.9	28	12.8	0.09	0	0	0.39	14.6	28.6	30.9	205.3	C
< -20 °C	28.7	26.7	28.5	18.4	2	0	0	0	0	3.1	20	27.9	155.3	C
< - 30 °C	20.1	18	16.5	4.7	0.05	0	0	0	0	0.29	6.6	16.2	82.5	C
Days with Rainfall:														
>= 0.2 mm	0	0	0	0.35	2.1	6.4	10.2	12.5	10.4	1.9	0.05	0	43.8	C
>= 5 mm	0	0	0	0.04	0.27	0.65	2.6	2.4	1.9	0.27	0	0	8.1	C
>= 10 mm	0	0	0	0	0.18	0.13	0.78	0.73	0.65	0.09	0	0	2.6	C
>= 25 mm	0	0	0	0	0	0.04	0.04	0.23	0.04	0	0	0	0.35	C
Days With Snowfall:														
>= 0.2 cm	9.4	9.8	10.7	9.4	6.5	1.6	0.09	0.27	3.9	13.9	11.7	10.1	87.4	C
>= 5 cm	0.52	0.65	0.35	0.87	0.86	0.17	0	0.05	0.52	2.1	0.91	0.63	7.6	C
>= 10 cm	0.13	0.04	0	0.17	0.27	0.04	0	0	0.09	0.55	0.18	0.25	1.7	C
>= 25 cm	0.04	0	0	0	0	0	0	0	0	0	0	0.04	0.08	C
Days with Precipitation:														
>= 0.2 mm	8.6	9.1	10	8.9	7.3	7.4	10.2	12.6	12.9	14.5	10.7	9.4	121.5	C
>= 5 mm	0.30	0.22	0.17	0.52	1	0.83	2.6	2.4	2.3	1.7	0.18	0.33	12.6	C
>= 10 mm	0.04	0	0	0.13	0.45	0.17	0.78	0.73	0.74	0.32	0.05	0.08	3.5	C
>= 25 mm	0.04	0	0	0	0	0.04	0.04	0.23	0.04	0	0	0	0.39	C
Days with Snow Depth:														
>= 1 cm	31	28.3	31	30	29.5	9.8	0.70	0	2.4	25.5	29.9	31	249	C
>= 5 cm	31	28.3	31	29.9	26.1	6.4	0	0	0.70	17.8	29.1	31	231.3	C
>= 10 cm	31	28.3	31	29.8	22.8	3.1	0	0	0.39	11.4	25.7	31	214.5	C
>= 20 cm	22.9	24.6	26.6	25.7	16.8	1.4	0	0	0.13	4.8	12	20.5	155.3	C
Wind:														
Speed (km/h)	19	18.5	15.6	13.4	13.9	14	14.4	15.5	16.8	17.4	16.8	18.2	16.1	C
Most Frequent Direction	SW	SW	SW	SW	E	E	E	E	E	SW	SW	SW	SW	C
Maximum Hourly Speed (km/h)	**93**	76	83	72	74	61	67	74	74	80	83	93		
Date (yyyy/dd)	**1988/01**	1978/08	1980/03	1984/16	1986/28	1995/26	1991/25	1986/22	2002/24	1982/27	1994/19	1983/25		
Direction of Maximum Hourly Speed	NW	S	NW	E	NW	NW	N	NW	NW	NW	NW	NW	NW	
Maximum Gust Speed (km/h)	**106**	106	106	83	89	74	81	83	85	89	100	104		
Date (yyyy/dd)	**1988/01**	1978/06	1980/03	1984/16	1986/28	1992/11	1988/23	1984/10	1983/28	1982/27	1994/05	1983/26		
Direction of Maximum Gust	NW	SW	NW	E	NW	W	NW	NW	NW	NW	NW	NW	SW	
Days with Winds >= 52 km/h	1.8	2.7	1.7	0.9	0.6	0.1	0.2	0.8	1.2	1.3	0.9	2.2	14.4	C
Days with Winds >= 63 km/h	0.5	0.8	0.4	0.2	0.3	0	0	0.2	0.4	0.5	0.2	0.7	4.2	C
Degree Days:														
Above 24 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Above 18 °C	0	0	0	0	0	0.6	3.1	0.8	0	0	0	0	4.4	C
Above 15 °C	0	0	0	0	0	1.8	12.3	5.7	0	0	0	0	19.7	C
Above 10 °C	0	0	0	0	0.1	13.8	60.3	37.7	2.3	0	0	0	114.1	C
Above 5 °C	0	0	0	0	1.9	56.7	178.7	129.1	20.6	0.3	0	0	387.3	C
Above 0 °C	0	0	0	0.3	14	160.6	332.2	274.9	100.3	5.2	0	0	887.5	C
Below 0 °C	855.2	783.1	782.7	510.1	177.8	6	0	0	15.8	225.4	581.5	790.4	4728.1	C
Below 5 °C	1010.2	924.5	937.7	659.7	320.7	52.2	1.5	9.2	86.1	375.5	731.5	945.4	6054.3	C
Below 10 °C	1165.2	1065.8	1092.7	809.7	474	159.2	38.1	72.8	217.9	530.2	881.5	1100.4	7607.5	C
Below 15 °C	1320.2	1207.2	1247.7	959.7	628.9	297.3	145.1	195.8	365.6	685.2	1031.5	1255.4	9339.5	C
Below 18 °C	1413.2	1292	1340.7	1049.7	721.9	386	228.9	283.9	455.6	778.2	1121.5	1348.4	10420	C
Bright Sunshine:														
Extreme Daily	5.2	8.4	12.9	17.2	22.9	**24**	24	19.1	14.1	10.5	6.4	1		C
Date (yyyy/dd)	1998/30	1980/27	1997/28	1994/28	1985/31	**1981/09**	1982/05	1987/01	2000/01	1988/02	2000/05	1981/01		
Humidex:														
Extreme Humidex	0.3	-1.7	-0.3	7.9	19.8	30.3	36.8	**36.8**	22.7	12.3	2.2	-1.5		
Date (yyyy/dd)	1981/16	1980/07	1999/22	1995/28	1994/24	1996/25	1989/15	**1992/02**	1994/01	1988/06	1983/03	1999/24		
Wind Chill:														
Extreme Wind Chill	-64.3	-64.4	**-65**	-54.4	-39.7	-15.6	-6.2	-11.8	-22.9	-46.5	-54.1	-61.5		
Date														

(yyyy/dd)	1990/26	1985/21	**1979/05**	1979/04	1983/04	1978/09	1985/21	1995/29	1992/25	1996/27	1985/25	1984/09		
Days with Wind Chill < -20	30.7	28.1	30.4	25.5	7.8	0	0	0	0.2	10.5	27.1	30.7	190.9	C
Days with Wind Chill < -30	28.4	25.3	27.2	14.7	1.2	0	0	0	0	2.4	18.8	27.1	145.1	C
Days with Wind Chill < -40	22.3	18.9	17.2	4.6	0	0	0	0	0	0.2	8.1	18	89.3	C
Pressure:														
Average Station Pressure (kPa)	101.6	101.7	101.8	101.8	101.7	101.2	101.1	101	101	101.2	101.4	101.5	101.4	C
Average Sea Level Pressure (kPa)	101.9	102	102.1	102.1	102	101.5	101.4	101.3	101.3	101.5	101.7	101.8	101.7	C

Environment Canada. (2011) Canadian Climate Normals 1971-2000, Kugluktuk, NU. Retrieved from: http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?stnID=1641&lang=e&dCode=0&province=NU&provBut=Search&month1=0&month2=12

Environment Canada / Environnement Canada — Canada

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

INUVIK A *
NORTHWEST TERRITORIES

Latitude: 68°18'15.000" N Longitude: 133°28'58.000" W Elevation: 68.30 m

Climate ID: 2202570 WMO ID: TC ID: YEV

*** This station meets WMO standards for temperature and precipitation.**

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-27.6	-26.9	-23.2	-12.8	0.2	11.3	14.2	11	3.7	-8.2	-21	-25.7	-8.8	A
Standard Deviation	4.8	4.7	3.7	4	3	1.6	1.8	2	2.2	2.7	4.8	3.4	1.9	A
Daily Maximum (°C)	-23.2	-22	-17.5	-7.1	5	17.3	19.8	16.1	7.8	-4.8	-16.8	-21.3	-3.9	A
Daily Minimum (°C)	-31.9	-31.7	-28.8	-18.4	-4.7	5.3	8.5	5.9	-0.4	-11.6	-25.1	-30.1	-13.6	A
Extreme Maximum (°C)	5.4	5.2	6.1	13.8	25	**32.8**	32.8	32.5	26.2	15	10.6	5		
Date (yyyy/dd)	1981/15	1989/25	1965/09	1995/27	1998/28	**1999/17**	2001/20	1994/02	1989/10	1969/12	1970/01	1973/31		
Extreme Minimum (°C)	-54.4	**-56.7**	-50.6	-46.1	-27.8	-6.1	-3.3	-6.1	-20.1	-35	-46.1	-50		
Date (yyyy/dd)	1975/12	**1968/04**	1964/14	1971/01	1961/06	1959/04	1966/29	1966/13	1983/26	1965/29	1963/24	1964/31		
Precipitation:														
Rainfall (mm)	0.1	0	0	0	6.1	20.2	32.9	37.5	18.7	1.3	0	0	117	A
Snowfall (cm)	17.4	15	14.6	13.5	13.1	1.9	0.3	2.4	10.7	34.9	23.7	20.4	167.9	A
Precipitation (mm)	13.8	11.6	11	10.5	17	22.1	33.2	39.9	28	28	17.8	15.7	248.4	A
Average Snow Depth (cm)	46	54	57	54	20	0	0	0	0	11	29	39	26	C
Median Snow Depth (cm)	47	54	57	55	19	0	0	0	0	10	29	39	26	C
Snow Depth at Month-end (cm)	51	56	59	41	1	0	0	0	2	22	34	41	25	C
Extreme Daily Rainfall (mm)	1.8	0.2	0.8	0.4	19.3	19.1	**41**	33	22.9	13.2	0.8	0.4		
Date (yyyy/dd)	1981/19	1982/03	1989/13	1998/15	1961/27	1972/10	**1998/08**	1970/16	1976/29	1964/09	1967/21	1988/16		
Extreme Daily Snowfall (cm)	11.4	13.7	13	17.8	24.9	10.2	4.8	22.6	12.2	**44.2**	22	18.6		
Date (yyyy/dd)	1963/19	1962/26	1967/12	1961/28	1966/28	1970/07	1974/01	1969/16	1957/27	**1971/17**	1994/11	1986/09		
Extreme Daily Precipitation (mm)	10.4	13.7	10.8	17.8	24.2	19.3	41	**42.9**	30.7	29.2	16.9	15.8		
Date (yyyy/dd)	1958/07	1962/26	1990/06	1961/28	1987/02	1962/05	1998/08	**1969/16**	1976/29	1971/17	1994/11	1986/09		
Extreme Snow Depth (cm)	89	97	96	**99**	87	8	3	5	16	81	79	81		
Date (yyyy/dd)	1983/21	1977/03	1983/01	**1983/15**	1980/01	1965/01	1974/01	1969/08	1992/30	1971/20	1971/30	1971/01		
Days with Maximum Temperature:														
<= 0 °C	30.7	27.9	30.3	22.9	9.1	0	0	0	3.1	24.7	29.4	30.8	208.9	A
> 0 °C	0.28	0.34	0.66	7.1	21.9	30	31	31	26.9	6.3	0.57	0.25	156.4	A
> 10 °C	0	0	0	0.59	7.6	25.2	29.3	25.3	10.7	0.14	0	0	98.9	A
> 20 °C	0	0	0	0	0.86	11	15.7	7.9	0.39	0	0	0	35.9	A
> 30 °C	0	0	0	0	0	0.11	0.29	0.18	0	0	0	0	0.58	A
> 35 °C	0	0	0	0	0	0	0	0	0	0	0	0	0	A
Days with Minimum Temperature:														

> 0 °C	0	0	0	0.52	6.1	25.8	30.7	28.1	15	0.39	0.04	0	106.7	A
<= 2 °C	31	28.2	31	29.9	27.4	9	1.6	6.2	21.9	30.9	30	31	278.2	A
<= 0 °C	31	28.2	31	29.5	24.9	4.2	0.32	2.9	15	30.6	30	31	258.5	A
< -2 °C	31	28.2	31	28.8	19.8	1.3	0.04	0.75	8.6	29	29.9	31	239.4	A
< -10 °C	30.7	28.1	30.7	24.3	6.5	0	0	0	1.1	16.6	29.1	30.7	197.8	A
< -20 °C	27.6	24.8	26.8	12.9	0.43	0	0	0	0.04	3.9	20.9	27	144.4	A
< - 30 °C	18	16.4	13.9	3	0	0	0	0	0	0.25	9	16.1	76.7	A
Days with Rainfall:														
>= 0.2 mm	0.07	0.07	0.03	0.17	2.3	8	10.1	13.4	8.2	0.86	0.07	0.07	43.3	A
>= 5 mm	0	0	0	0	0.45	1.3	1.9	2.4	1	0.04	0	0	7.1	A
>= 10 mm	0	0	0	0	0.10	0.29	0.57	0.57	0.32	0	0	0	1.9	A
>= 25 mm	0	0	0	0	0	0	0.07	0.04	0	0	0	0	0.11	A
Days With Snowfall:														
>= 0.2 cm	11.2	10.9	11.3	8.3	5.9	1.3	0.11	1	5.3	15.1	13	12.4	95.8	A
>= 5 cm	0.66	0.55	0.34	0.41	0.72	0.07	0	0.21	0.57	1.9	0.93	0.61	7	A
>= 10 cm	0.03	0.10	0.07	0.10	0.28	0	0	0	0	0.43	0.25	0.14	1.4	A
>= 25 cm	0	0	0	0	0	0	0	0	0	0.04	0	0	0.04	A
Days with Precipitation:														
>= 0.2 mm	10.6	10.1	10.5	7.8	7.1	8.5	10.1	13.8	12.2	14.6	12.3	11.7	129.4	A
>= 5 mm	0.28	0.31	0.10	0.21	0.97	1.4	2	2.8	1.5	1.4	0.61	0.39	12	A
>= 10 mm	0	0	0.03	0.03	0.38	0.29	0.57	0.61	0.30	0.25	0.14	0.11	2.7	A
>= 25 mm	0	0	0	0	0	0	0.07	0.04	0.04	0.04	0	0	0.19	A
Days with Snow Depth:														
>= 1 cm	31	28.2	31	30	21.6	0.39	0.04	0.14	3.6	25.8	30	31	232.8	C
>= 5 cm	31	28.2	31	30	19	0.11	0	0	1.4	19.4	30	31	221.1	C
>= 10 cm	31	28.2	31	29.8	16.9	0	0	0	0.04	13.6	28.7	31	210.3	C
>= 20 cm	30.2	28.2	31	29.2	12.1	0	0	0	0	6.4	22.5	28.2	187.7	C
Wind:														
Speed (km/h)	7.5	8	9.1	10.3	12.2	12.8	11.4	10.8	10.4	9.5	7.5	7.3	9.7	A
Most Frequent Direction	E	E	E	E	NE	NE	NE	E	E	E	E	E	E	A
Maximum Hourly Speed (km/h)	**65**	56	61	46	47	46	46	56	50	56	56	64		
Date (yyyy/dd)	**1991/26**	1995/14	1967/12	2002/06	1968/13	1991/24	2002/02	1984/26	1999/24	1981/10	1964/24	1964/21		
Maximum Gust Speed (km/h)	97	83	84	83	77	65	70	89	77	78	80	**109**		
Date (yyyy/dd)	1962/17	1995/14	1967/12	1979/22	1967/05	1991/24	1985/06	1962/31	1972/26	1984/25	1964/24	**1964/21**		
Direction of Maximum Gust	NW	NW	NW	W	NW	NW	W	W	NW	W	NW	NW	NW	
Days with Winds >= 52 km/h	0.1	0.1	0.1	0	0	0	0	0.1	0	0	0.1	0.1	0.6	C
Days with Winds >= 63 km/h	0	0.1	0	0	0	0	0	0	0	0	0	0	0.2	C
Degree Days:														
Above 24 °C	0	0	0	0	0	0	0.2	0.1	0	0	0	0	0.3	A
Above 18 °C	0	0	0	0	0	5.1	14.6	4.6	0.1	0	0	0	24.4	A
Above 15 °C	0	0	0	0	0.7	21.6	47	16.5	0.4	0	0	0	86.1	A
Above 10 °C	0	0	0	0	6.3	86.8	143.5	77.1	5.4	0	0	0	319	A
Above 5 °C	0	0	0	0.7	27.4	196.5	284.6	192.3	40.2	0.3	0	0	742.1	A
Above 0 °C	0	0	0	8.3	83.5	338.6	439.1	340.8	132.7	4.9	0.2	0	1348.2	A
Below 0 °C	855.8	758.5	718.3	390.9	84.9	0.2	0	0	21.2	260	628.6	798.2	4516.4	A
Below 5 °C	1010.8	899.7	873.3	533.3	183.8	8.1	0.5	6.5	78.7	410.5	778.4	953.2	5736.6	A
Below 10 °C	1165.8	1040.9	1028.3	682.6	317.6	48.3	14.4	46.3	193.8	565.1	928.4	1108.2	7139.7	A
Below 15 °C	1320.8	1182.1	1183.3	832.6	467	133.2	72.9	140.7	338.9	720.1	1078.4	1263.2	8733	A
Below 18 °C	1413.8	1266.8	1276.3	922.6	559.3	206.7	133.5	221.8	428.6	813.1	1168.4	1356.2	9766.9	A
Humidex:														
Extreme Humidex	5.2	4.9	5.6	12.8	25.2	35.8	**40**	36.6	26.7	13.9	10	5		
Date (yyyy/dd)	1981/15	1989/25	1965/10	1976/27	1998/28	1999/17	**1961/28**	1994/02	1995/22	1969/07	1970/01	1973/31		
Days with Humidex >= 30	0	0	0	0	0	0.1	0.8	0.5	0	0	0	0	1.4	C
Days with Humidex >= 35	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1	C
Days with Humidex >= 40	0	0	0	0	0	0	0	0	0	0	0	0	0	C
Wind Chill:														
Extreme Wind Chill	-64.1	**-67**	-59.6	-51.1	-35.2	-13.3	-5.2	-9.2	-23.4	-43.1	-55	-59.6		
Date														

(yyyy/dd)	1975/12	**1968/04**	1962/05	1971/07	1961/06	1969/01	1966/29	1961/31	1983/28	1965/29	1963/25	1974/29		
Days with Wind Chill < -20	29.9	27.2	29.7	20.3	2.4	0	0	0	0.2	9.4	26.4	29.8	175.3	A
Days with Wind Chill < -30	24.6	22.5	23.5	8.6	0.1	0	0	0	0	1.8	15.5	23.8	120.3	A
Days with Wind Chill < -40	15	13.7	10	1.3	0	0	0	0	0	0.1	4.2	11	55.4	A
Humidity:														
Average Vapour Pressure (kPa)	0.1	0.1	0.1	0.2	0.4	0.8	1	1	0.6	0.3	0.1	0.1	0.4	C
Average Relative Humidity - 0600LST (%)	67.5	68.1	66.7	73.3	78.1	74	78.5	84.8	85.8	84	73.9	69.3	75.3	D
Average Relative Humidity - 1500LST (%)	68	65.8	59.8	60.7	61	50.2	54.1	61.8	68.4	77.8	73.4	69.2	64.2	C
Pressure:														
Average Station Pressure (kPa)	101	101.1	101.1	100.9	100.8	100.4	100.5	100.4	100.4	100.4	100.7	100.8	100.7	A
Average Sea Level Pressure (kPa)	101.9	102	102	101.8	101.6	101.3	101.3	101.2	101.2	101.3	101.5	101.7	101.6	A
Radiation:														
Extreme Global - RF1 (MJ/m2)	1.2	5.1	14.1	23.1	30	**30.8**	30.2	23.7	14.7	7.3	2.2	0.1		
Date (yyyy/dd)	1971/31	1961/27	1961/31	1972/27	1968/31	**1972/16**	1972/02	1966/01	1972/03	1972/01	1967/01	1967/01		
Visibility (hours with):														
< 1 km	6.7	5.9	1.6	5.4	13	6.9	3	7.5	11.6	11.2	5.9	2.1	80.6	C
1 to 9 km	137.6	115.2	78.9	74.3	69.2	28.5	29.3	46.2	63.5	124.6	99	110.2	976.3	C
> 9 km	599.8	557.6	663.6	640.3	661.8	684.6	711.7	690.4	645	608.3	615.2	631.7	7709.8	C
Cloud Amount (hours with):														
0 to 2 tenths	281.5	252	309.9	257.1	201.3	172	132	106.3	108.5	117.8	225.1	256	2419.6	C
3 to 7 tenths	137.1	132.8	147	133.2	143.3	195.5	204.8	163.6	119	96.2	121.9	129.9	1724.2	C
8 to 10 tenths	325.4	293.9	287.2	329.6	399.4	352.5	407.2	474	492.6	530	373	358.1	4622.9	C

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B Inuit Creation Myths

B1 The Wind

The wind is a being in the form of a person. When he feels warm, he opens his coat and the wind escapes. The only way to make the wind stop is for an angakkuq to go to the wind spirit, fasten his coat, and cross his arms. Only then will the wind subside.

The Netsilik say that one of their angakkuq once went to see the wind spirit and threatened to kill him with a knife. The wind spirit replied that he would level everything on earth. The angakkuq did not believe him and asked him to show his power by destroying a certain mountain. The wind spirit at once pushed it over with his foot. Then the angakkuq believed him and never questioned the wind's power again.

Recorded in the Kivalliq region.

From Christopher, N., McDermott, N., and Flaherty, L. (eds.) (2011) *Unikkaaqtuat, An Introduction to Traditional Inuit Myths and Legends*. Toronto, ON: Inhabit Media Inc. pp. 27-28.

Image (opposite page): Retrieved from: http://tinder.ca/tinderblog/?tag=photography

B2 The Struggle for Night and Day

In the very first times there was no light on earth. Everything was in darkness: the lands could not be seen, the animals could not be seen. Both people and animals lived on earth, but there was no difference between them. They lived indiscriminately: a person could become an animal and an animal could become a human being. There were wolves, bears, and foxes, but as soon as they turned into humans they were all the same. They may have had different habits, but all spoke the same language, lived in the same kind of house, and spoke and hunted in the same way.

That is the way they lived here on earth in the very earliest times, times that no one can understand now. That was the time when magic words were made. A word spoken by chance would suddenly become powerful, and what people wanted to happen could happen, and nobody could explain how it came to be.

In those times when everyone lived together and there was no difference between humans and animals, a fox and a hare met. “Taaq-taaq-taaq: Darkness-darkness-darkness,” said the fox. It liked the dark when it was going out to steal from the caches of the humans. “Ublu-ublu-ublu: Day-day-day,” said the hare. It wanted the light of day, so that it could find a place to feed.

Suddenly the sky became as the hare wished it to be; its words were the most powerful. Day came and replaced night, and when night had gone day came again. Light and dark took turns with each other.

Recorded in the Netsilik region.

From Christopher, N., McDermott, N., and Flaherty, L. (eds.) (2011) *Unikkaaqtuat, An Introduction to Traditional Inuit Myths and Legends*. Toronto, ON: Inhabit Media Inc. pp. 33-34.

B3 The Origin of Lightening and Thunder

In the earliest times there was no such thing as stealing. There were no thieves among mankind. But then one day, during a song festival, a brother and sister were left alone in a house. They found a caribou skin with the hair removed and a flint rock. These they stole, but hardly had they stolen them when a great fear of being caught by others in their village cam upon them.

"What shall we do to get away from everyone?" said one.
"Let us turn into caribou," said the other.
"Then people will kill us."
"Let us turn into wolves."
"Then people will kill us."
"Let us turn into foxes."

And so they went through all animals in turn and always they were afraid people would kill them. But then one said: "Let us turn into thunder and lightening, and then people will not be able to catch us."

So they turned into thunder and lightening and went up into the sky. When there is thunder and lightening now, it is because one of them rattles the dry caribou skin, while the other strikes the flint rock and sends sparks across the sky.

Recorded in the Kivalliq region.

From Christopher, N., McDermott, N., and Flaherty, L. (eds.) (2011) *Unikkaaqtuat, An Introduction to Traditional Inuit Myths and Legends*. Toronto, ON: Inhabit Media Inc. pp. 76.

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