Canadian Program and Facilities for the Functional Testing of Surface Weather Instruments and Systems

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ABSTRACT

High quality meteorological data are essential to the needs of forecasters and climatologists. Selecting instruments to provide those data requires thorough testing to ensure data quality and system reliability. To meet that need, the Meteorological Service of Canada (MSC) has developed and implemented an extensive program for evaluating meteorological instruments and systems. This program combines the activities of calibration, laboratory and environmental testing, and functional testing. Prior to making changes to hardware or software used in its networks, MSC conducts a vigorous change management process. This process reviews test results and examines such factors as data quality, life cycle costs, and maintainability.

MSC conducts functional testing of meteorological instruments at a set of test sites configured specifically for this purpose and selected to provide a range of conditions representative of the various Canadian climate conditions. These sites have a complex infrastructure which allows evaluators to assess the functional performance of sensors and instruments in an outdoor, natural environment where instruments are expected to operate over a wide variety of meteorological conditions and climatic regimes.

MSC operates six major test sites for evaluating surface weather monitoring systems. Two of sites – St. John's (Newfoundland) and Iqaluit (Nunavut Territory) - merit particular attention. St. John's has a maritime climate and is frequently subject to extreme weather events such as heavy snowfall, freezing rain, and fog. Iqaluit, MSC's newest site, has an arctic climate and is prone to cold temperature extremes and severe winter storms.

In addition to meeting MSC's operational testing requirements, Iqaluit has significant potential to meet the needs of the international scientific community. Several initiatives are currently under discussion to carry out field tests in support of such initiatives as SEARCH and the International Polar Year.

INTRODUCTION

High quality meteorological data have long been essential to meeting the needs of weather forecasters and climatologists. With increasing emphasis on the need to detect signals of climate change, national meteorological services need to pay particular attention to ensuring that measurement uncertainty neither masks nor misrepresents those signals.

When selecting and integrating new meteorological sensors and measurement systems, it is particularly important to carry out thorough testing to ensure that uncertainly lies within acceptable limits. It is equally important to fully understand and document the more subtle biases that instrument changes may introduce into the data set. Such an understanding is critical to ensuring that current and future researchers are fully able to distinguish differences caused by environmental factors from those simply due to instrument change.

Canada's vast size along with its diverse and variable climate combine to present major challenges when selecting meteorological sensors and measurement systems. The selection process requires answers to such questions as:

a) What is the sensor or system accuracy?
b) What is the variability of measurements in a network containing such systems or sensors?
c) What change, or bias, will there be in the data provided by the sensor or system when its siting or location is changed?
d) What change or bias will there be in the data when a new instrument or method of observation replaces an existing one measuring the same weather element(s)?

To answer those questions and to assure the validity and relevance of the meteorological data provided to users, the Meteorological Service of Canada (MSC) has developed and implemented an extensive program for evaluating meteorological instruments and systems. This program combines the activities of calibration, laboratory and environmental testing, and functional testing.

MSC operates meteorological sensors and systems in a set of observing networks that are generally organized according to the primary purpose of the data collected e.g. public weather, aviation, climate reference, marine, and upper air. Prior to making changes to hardware or software used in these networks, MSC conducts a vigorous change management process. This process reviews the results of testing and examines such factors as data quality, life cycle costs, and maintainability. The quality of a measuring system is assessed by comparing the stated and implied user requirements and the ability of the systems to fulfill them, with optimal cost/benefit and cost/performance ratios. This involves a shared responsibility among users, technical experts, and network managers to best balance user requirements with technical, operational, and financial considerations.

A recent driving force behind the strengthening of the program for the testing of meteorological instruments for surface weather has been the need to qualify meteorological sensors through a competitive process. Examples include:

- wind, pressure, temperature, and humidity sensors for use in the reference climate and surface weather networks

- wind and pressure sensors for the marine weather network

- automated weather systems and sensors for the aviation weather network (in support of NAV CANADA, the operator of the Canadian air navigation system).

A related initiative has been the development of an algorithm for deriving snowfall amount data from snow depth measurements at sites equipped with snow-depth sensors. The algorithm uses simultaneous data from the snow-depth sensors, total precipitation gauge, and potentially wind, and/or temperature data. It is expected to improve both the quality of the reporting of snowfall amount and of depth of snow on the ground.

MSC TEST SITES

MSC conducts functional testing of meteorological instruments at a set of test sites configured specifically for this purpose and selected to provide a range of conditions representative of the various Canadian climate conditions. These sites have a complex infrastructure which allows evaluators to assess the functional performance of sensors and instruments in an outdoor, natural environment where instruments are expected to operate over a wide variety of meteorological conditions and climatic regimes.

The location of these sites is as follows:

a) St. John's, Newfoundland: situated in Eastern Canada near the Atlantic shore; subject to conditions such as heavy snow and rainfall, high wind speeds, fog, and freezing rain.

b) Iqaluit, Nunavut: situated in the eastern Arctic, on the south end of Baffin Island; subject to arctic conditions such as extreme cold, ice crystals, and permafrost.

c) Egbert, Ontario: approximately 50 km north of Toronto; situated in a temperate, continental climate regime.

d) Wiarton, Ontario: located approximately 100 km north of Toronto near the Lake Huron shoreline; subject to heavy snowfall conditions.

e) Bratt's Lake, Saskatchewan: located in rural central Saskatchewan on the Canadian prairies; situated in a continental climate regime.

f) Terrace, British Columbia: located on the west coast of Canada with a maritime climate strongly influenced by the Pacific Ocean.

MSC also operates a facility to carry out operational testing of upper air systems and radiosondes at Stony Plain, Alberta. It has also recently added a site for testing marine weather instruments in Burlington, Ontario (approximately 50 km west of Toronto on the shore of Lake Ontario).

The map in Figure 1 indicates the approximate locations of the above sites.

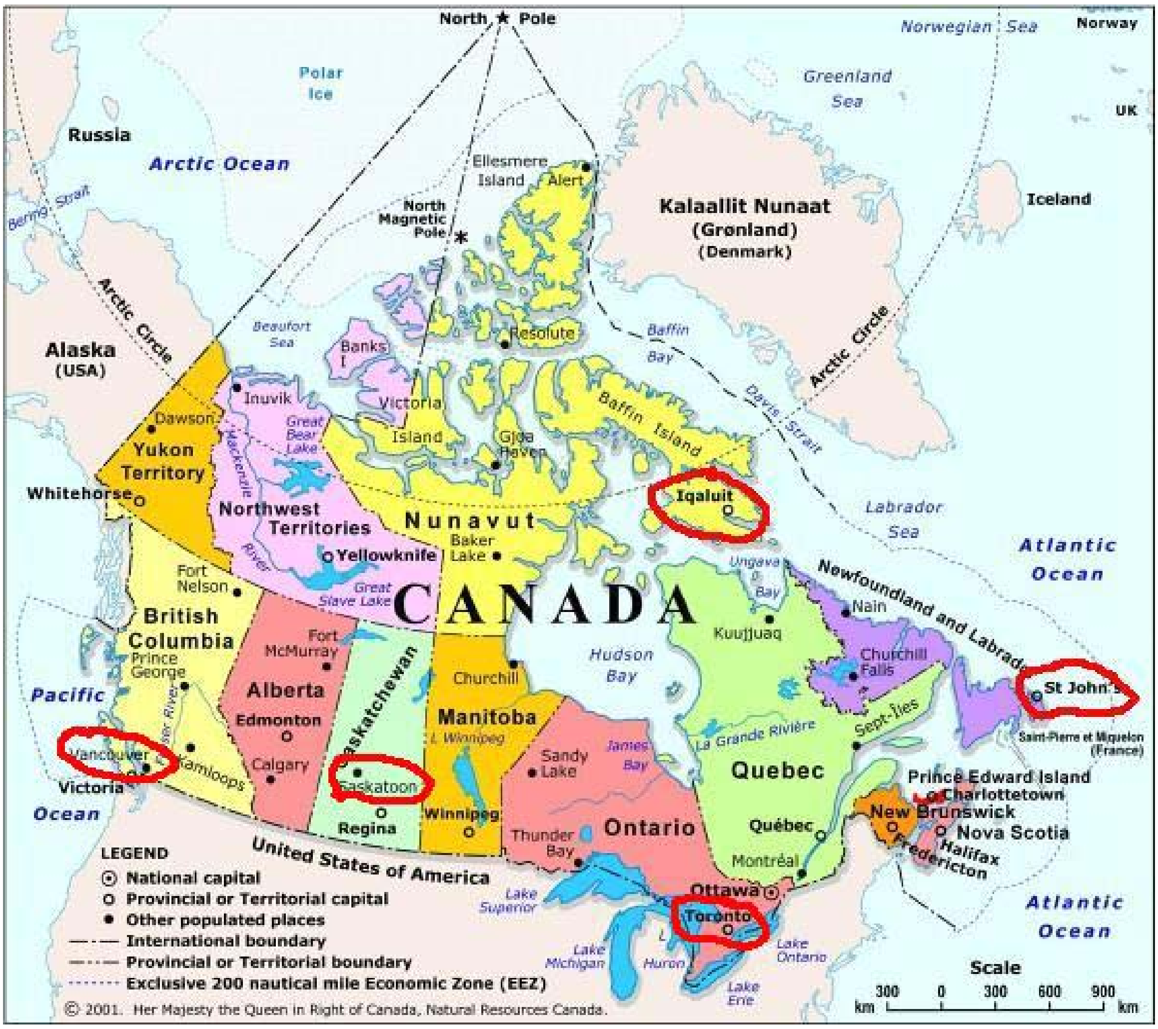


Figure 1 - MSC test sites

The charts in Appendix A summarize the climatology of the areas where the test sites are located and illustrate how they compare with the Canadian extremes for each of the parameters evaluated. The analysis uses meteorological data collected between the early fifties and 2001.

Two of the test sites - St. John’s and Iqaluit - merit particular attention because of their local conditions and location.

St. John’s Newfoundland

St. John’s Newfoundland is situated in eastern Canada on the shore of the Atlantic Ocean. The site is noted for its very active weather, offering ideal conditions for testing the performance and the performance limits of any meteorological instrument.

Of all the major Canadian cities, St. John's is the foggiest (124 days), snowiest (359 cm), wettest (1514 mm), windiest (24.3 km/h average speed), and cloudiest (1497 hours of sunshine). It also has more days with freezing rain and precipitation than any other city. While the city does have relatively mild winters (the third mildest among major Canadian cities), it’s location along principle storm tracks has provided it with a well earned reputation as one of North America’s stormiest cities. The day-to-day variability of the winter temperature in the St. John’s area is characteristic of a storm-prone maritime climate, with frequent incursions of moist, mild Atlantic air.

Freezing rainstorms are a major hazard in many parts of Canada, but they are nowhere more frequent than in the province of Newfoundland where they are known as silver thaws. The St. John's area is prone to prolonged periods of freezing precipitation that last for several hours or intermittently for two days or more. One of the worst ever freezing rainstorms struck St. John's on the evening of April 11, 1984, and continued intermittently until the 14th. Jackets of ice as much as 15 cm thick formed on over-head wires. Freezing rain or freezing drizzle occur an average of 150 hours each winter, with March being the worst month.

Another characteristic of the St. John's weather is the fog, sometimes known as "sea smoke". The fog develops when warm, humid air from the south strikes the cold, sometimes ice-infested, waters of the Labrador Current, and is often accompanied by strong winds. Normally, winds can be expected to disperse fog, but there the fog is frequently so dense and widespread that the winds have little clearing effect.

All these conditions create the ideal environment for the functional testing of meteorological instruments intended for use in the diverse Canadian climate. The site has also been used for the WMO intercomparison of present weather sensors in 1994, and for the field evaluation of ice-resistant wind sensors for the U.S. National Weather Service.

Iqaluit, Nunavut

Given increasing scientific interest in arctic weather and climate, MSC recognized the need to establish a permanent test facility in the arctic. Iqaluit is the newest MSC test site, established in 2004. It is located at 63°45'N, 68°31'W on Baffin Island in the south-eastern arctic.

Situated approximately 200 km south of the Arctic Circle, Iqaluit is the capital of the territory of Nunavut and is its largest community. Daily flights to southern Canada facilitate easy access and direct, year-round communications with the site. The test facility is located next to the airport where there is a human observing program. This offers the opportunity to use the METAR observation as a reference for various test programs. MSC also has a permanent office collocated with the test site which provides a local source of skilled maintenance and site supervision.

Meteorological hazards and storms in the Arctic are common and some of the most intense storms occur in the eastern Arctic. This is due to the natural progression of low-pressure systems that form to the west and south that intensify as they track east and north. In fact, Baffin Bay is considered the "burial ground" for intense storms where open water can exist even in mid-winter, acting as a supply of heat and moisture that can re-intensify storms. See Appendix B for additional details about weather conditions in the Iqaluit area.

The primary objective of the test site is to evaluate the performance of the surface weather instruments and systems and related processing algorithms in arctic conditions. Given that about 25% of Canadian territory is situated above the Arctic Circle, the site is critical to effectively managing the operation of all surface-based weather observing networks. In addition, the site provides an infrastructure suitable for other environmental research initiatives. It has the potential to become a base for major research projects organized to provide a better understanding of the physical features of arctic storms and their hazards.

The Test and Evaluation group of MSC is currently negotiating its participation in the STAR project (Storm Studies in the Arctic) initiated by a network of Canadian university and federal/provincial government researchers in 2004. The stated goal of the project is to better understand severe Arctic storms and the hazards associated with them, to contribute to their better prediction, and to assess how conditions may change in the future.

The proposed project will focus, although not exclusively, on storms occurring in the southern Baffin Island region. This region has the best developed environmental monitoring infrastructure in the area and has the highest population density. Iqaluit itself is a thriving community that is increasing in population through industry, tourism and recreation.

The project will also examine atmospheric-related extremes in the Arctic and assess the likely impact of climate change on their occurrence, frequency, severity and location. Examples include harsh temperatures, strong winds, heavy precipitation, blowing snow, low visibility, freezing rain, and lightning. Such extremes may also significantly affect sea-ice behavior and generate storm surges. They also produce human hardship on a daily scale and there is concern that they may become more frequent in the future.

The proposed project has numerous international linkages. It will be carried out in a complementary manner with the U.S. based SEARCH program and the International Arctic Research Center (IARC) weather research initiative (J. Walsh, D. Atkinson). It is expected that joint activities will be carried out with the Alfred Wegener Institute in Germany with researchers at the University of Bergen. Discussions are also under way for Japanese involvement and the project will contribute to the objectives of the International Polar Year (IPY). The major activity of the initiative will be the acquisition of enhanced detailed data collection in the vicinity of Iqaluit over the period from the spring of 2007 through to the winter of 2007/08.

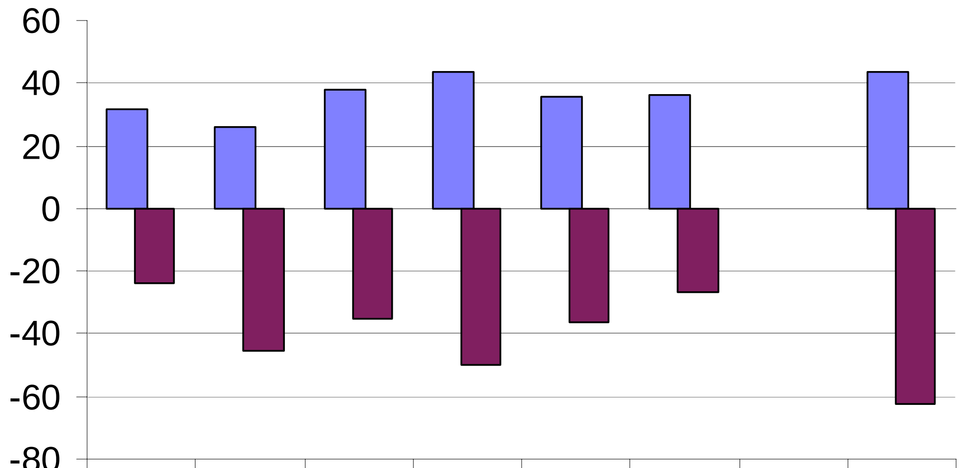
There are also other indications that the international meteorological community can benefit from the access to the Iqaluit test site. The U.S. National Weather Service (NWS) and the National Center for Climate Data (NCDC) have expressed a strong interest in using the facility to test their monitoring technologies. The first cooperative project at Iqaluit will begin in January 2005, when NWS will begin testing their ice-resistant wind sensors in an arctic environment.

The work proposed at Iqaluit will improve understanding of the performance of meteorological sensors and systems before their network-wide deployment. This in turn can be expected to improve data quality and availability and enable MSC to better manage the life cycle costs of its networks in the harsh arctic environment. Overall, it will create the conditions for effective use of monitoring technologies in support of MSC's programs to deliver its services in the North, contributing to better service to northern communities, and increasing the capacity to accurately predict climate variability and climate change.

Appendix A

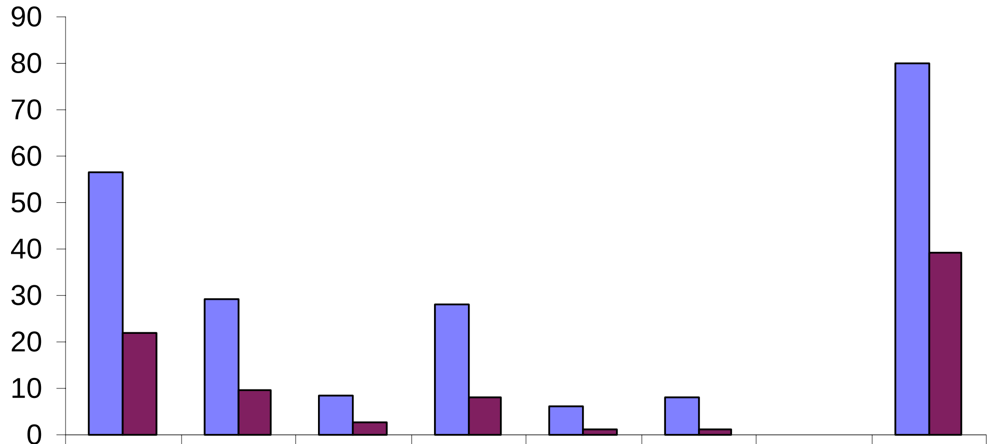
Summary of the climate conditions of the MSC test sites

Extreme maximum and minimum daily temperature (deg C)



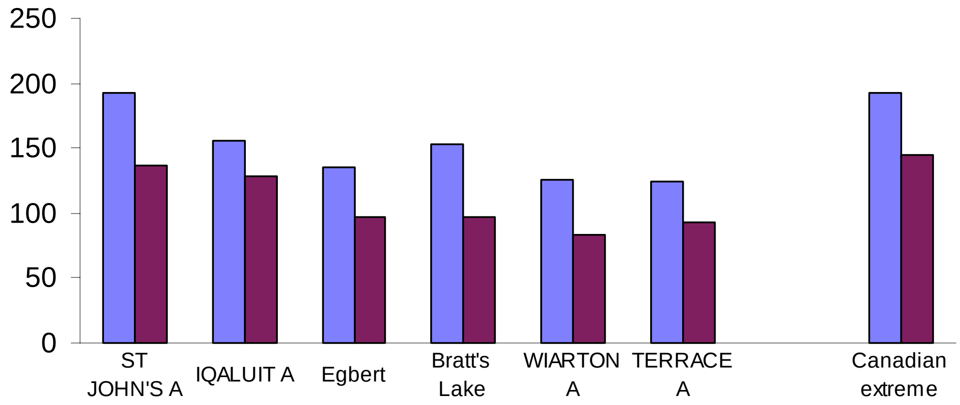
	ST JOHN'S A	IQALUIT A	Egbert	Bratt's Lake	WIARTON A	TERRACE A		Canadian extreme
Extreme maximum daily max temp (C)	31.5	25.8	37.8	43.3	35.6	36.2		43.3
Extreme minimum daily min temp (C)	-23.8	-45.6	-35.2	-50	-36.4	-26.7		-62.2

Wind speed distribution chart (days/year)



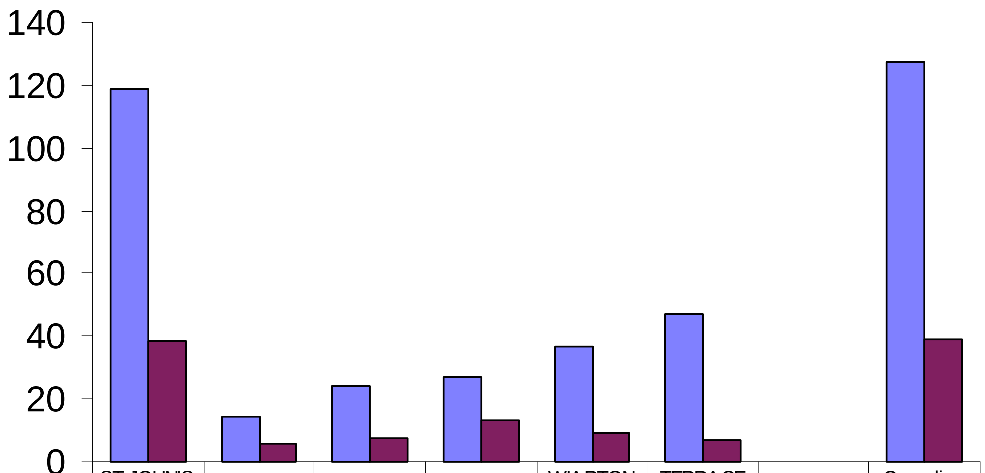
	ST JOHN'S A	IQALUIT A	Egbert	Bratt's Lake	WIARTON A	TERRACE A		Canadian extreme
Days with Wind>=28 knots	56.65	29.09	8.51	27.96	6.04	8.19		80.02
Days with wind>=34knots	22.11	9.51	2.85	8.14	1.33	1.1		39.17

Extreme wind gust and hourly wind speed (km/h)

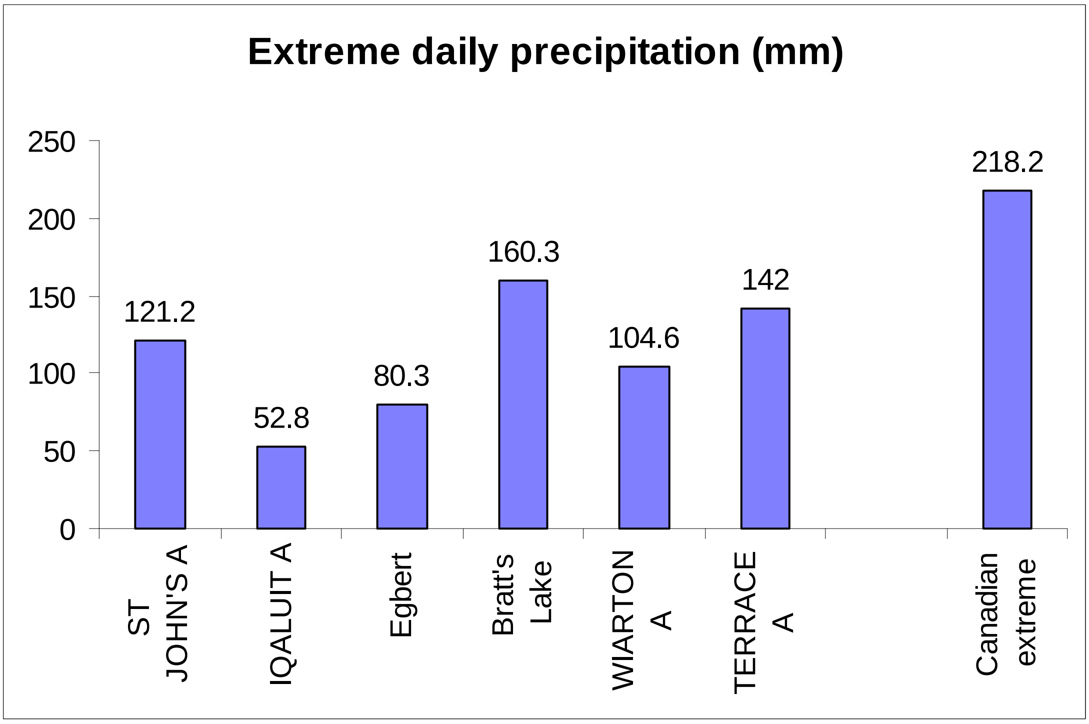


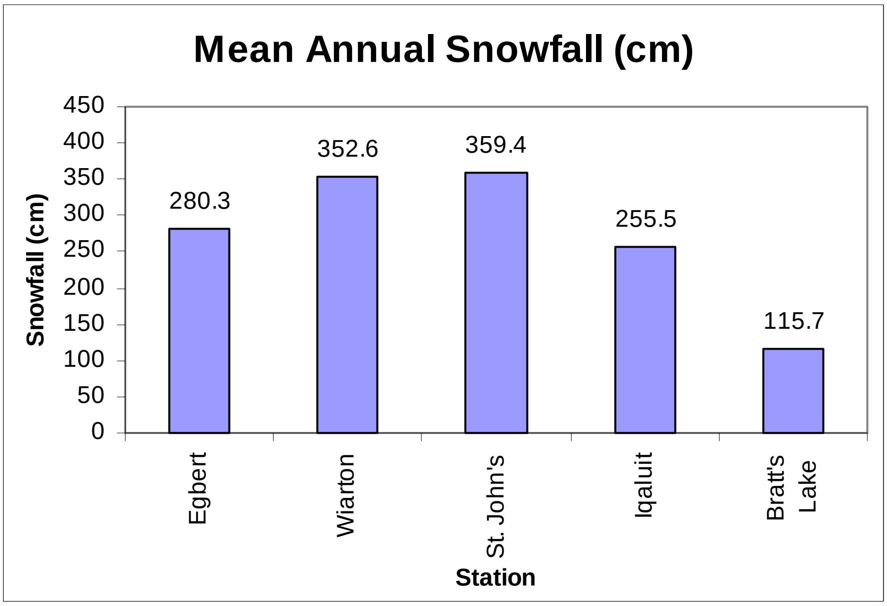
	ST JOHN'S A	IQALUIT A	Egbert	Bratt's Lake	WIARTON A	TERRACE A	Canadian extreme
Extreme dayly max gust (km/h)	193	156	135	153	126	124	193
Hourly max 10 min wind speed(km/h)	137	129	97	97	84	93	145

Precipitation chart (days/year)



	ST JOHN'S A	IQALUIT A	Egbert	Bratt's Lake	WIARTON A	TERRACE A		Canadian extreme
Days with fog, ice fog, or freezing fog	118.96	14.44	24.03	27.2	36.63	47		127.32
Days with freezing rain, rain, or freezing drizzle	38.62	5.6	7.51	12.99	9.16	6.94		39.07


Extreme daily precipitation (mm)
250
200
150
100
50
0
121.2
52.8
80.3
160.3
104.6
142
218.2
ST JOHN'S A
IQALUIT A
Egbert
Bratt's Lake
WIARTON A
TERRACE A
Canadian extreme


Mean Annual Snowfall (cm)
Snowfall (cm)
450
400
350
300
250
200
150
100
50
0
280.3
352.6
359.4
255.5
115.7
Egbert
Wiarton
St. John's
Iqaluit
Bratt's Lake
Station

Appendix B

The climatology of Iqaluit and area

January and February are characterised by a mean temperature of about -27°C and relatively little precipitation (about 20 cm of snow per month). Although mean monthly wind speeds on the order of 4.3 m/s are relatively low, this period can have very strong gusts and it has the highest occurrence of blowing snow.

The periods of March through May and from October through December are defined as the two storm seasons. They are characterised by monthly snow amounts in excess of 30 cm, very little rain, and mean monthly wind speeds greater than 5 m/s. The fall season (October to December) is the stormiest with southern latitude air clashing with invading cold air from the north over a relatively warm ocean surface. This of course represents an ideal environment for extreme storms to form and evolve.

From June to September the dominant precipitation is rain. With a dominant wind direction from the southeast over the fjord, fog is common. During the rest of the year, the prevailing wind direction is from the northwest.

From October to May there are preferential areas of open water (Frobisher Bay and Cumberland Sound polynyas[1]). Open water areas are a moisture source and are prone to low cloud and fog. In addition, during fall and winter, the cloud and fog are often composed of supercooled water and are capable of producing both freezing drizzle and significant aircraft icing.

The highest temperatures at Iqaluit may approach 30°C. Usually, however, maximum annual temperatures are in the low 20s. During winter, temperatures routinely fall to below -30°C, and occasionally to below -40°C. While such low temperatures are potentially dangerous, the most hazardous conditions related to temperature may occur due to unseasonable temperatures or extreme warming and cooling events.

Bibliography

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WMO #8. (1996) *Guide to meteorological instruments and methods of observation.*

[1] source: Canadian Ice Service