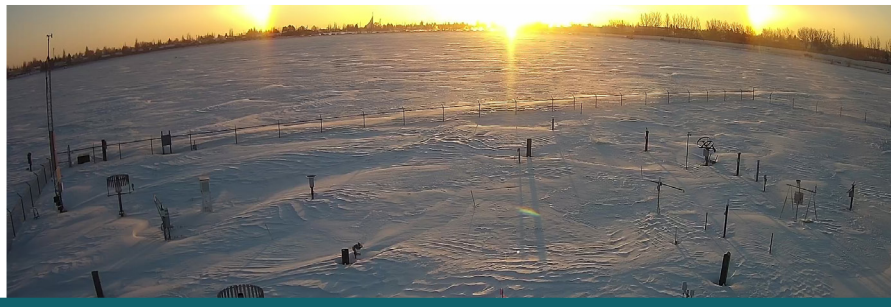
State of Surface Weather and Climate Monitoring in Canada

Version 1.0 *March 2023*



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Executive Summary

Purpose

The purpose of this report is to document and highlight the existing weather and climate monitoring networks across Canada. The report also acts to highlight topics, discussions, and actions that the Canadian Council for Weather and Climate Monitoring (CWAC) will take over the coming years. This report is meant to be updated in the future to represent the current updates for both CWAC, and weather and climate monitoring within Canada.

Audience

The principal audience for this report will be the CWAC representatives from each province and territory, network owners and operators across the county, MSC senior management, and MSC network managers who will all have input on recommendations and future actions.

Overview

This report contains key drivers and trends that are expected to influence both the MSC and other weather and climate monitoring networks in Canada. Drivers and trends have been selected that have a current impact on network operators, but also will continue to evolve in the future.

A breakdown of the surface weather and climate monitoring networks across each province and territory are highlighted, including information on each network such as station counts, element-level analysis, operation periods, and level of automation. Feedback has also been gathered through CWAC discussions to report on common collaboration and operational challenges faced within each monitoring jurisdiction across the country. A station density analysis was also conducted by ECCC for each province and territory to identify coverage gaps.

A detailed National Data Management Strategy is also presented, which aims to improve on important and common data management issues that have been expressed throughout CWAC discussions. Efforts have been made regionally and nationally to amalgamate data sources from a variety of data operators, however, this strategy aims to address remaining challenges related to data dissemination, archiving, and metadata management. The strategy will provide guidance and direction towards a national data management system that incorporates data from network operators across Canada.

Finally, a set of recommendations from CWAC are proposed to guide the future actions and discussions of the committee. The recommendations are geared towards the implementation of the National Data Management Strategy; beginning with metadata, developing data access and visualization tools, and investing in key IM/IT themes of interest highlighted between bilateral discussions between ECCC and the provinces and territories.

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Section 1: Introduction

Weather, water and climate monitoring activities provide critical information for Canadians to make decisions to protect their health and safety. The Meteorological Service of Canada (MSC), of Environment and Climate Change Canada (ECCC), envisions an observing system that encourages and facilitates access to observations from a variety of network operators, within a structured national framework. This observing system leverages the long-term investments of all Canadian institutions in weather, water quantity and climate observations and ensures they are monitored in an efficient, collaborative and sustainable manner.

Although there is a strong national program known as the National Hydrometric Program (NHP) for monitoring water quantity across the country, there is no national program to support weather and climate monitoring in Canada. This has resulted in a lack of coordination on the location of stations, inconsistent data management practices and standards, and a fragmented system for the dissemination and exchange of data.

MSC established the Collaborative Monitoring Initiative to strengthen the national capacity to monitor weather and climate through increased collaboration with provinces and territories (PTs), Federal Departments as well as other network operators/data owners (e.g. academia, regional/municipal governments, private sector, etc.). Collaborative Monitoring is designed to encourage timely and open exchange of data and to facilitate integrated network planning and joint operations.

In 2019, the Canadian Council for Weather and Climate Monitoring (CWAC) was created to facilitate federal-provincial-territorial coordination and discussion on weather and climate monitoring activities in Canada. One representative from each province and territory and the Government of Canada (represented by ECCC) participate in regular meetings to share progress, challenges and lessons learned from monitoring programs within their jurisdiction[1]. The Council regularly discusses opportunities to improve collaboration, focusing on issues of common interests to members.

This report has been developed by ECCC with feedback and review by CWAC members to document the current state of weather and climate monitoring networks across Canada and to guide the actions CWAC will take in the coming years. The report will be updated as networks and challenges continue to evolve and as new priorities are identified.

1 Quebec participates as an observer within CWAC. Although it supports the general objectives of CWAC, it is not bound by the decisions made therein. Go back.

Section 2: Drivers and Trends

There are several key drivers and trends which are expected to influence weather and climate monitoring networks moving forward as well as expectations for future data services. This section outlines current drivers and trends influencing federal, provincial and territorial network operators across Canada.

2.1 Client Requirements

Higher Spatial and Temporal Resolution, Real-time Information: An increasingly mobile and connected world has raised expectations for the availability and targeted relevance of weather and other environmental information. Decisions made by governments, industry leaders and communities require more detailed and easier access to information through a broader range of communication platforms. This trend reinforces the importance of real-time observations as a valued product from weather and climate network operators across Canada.

Extreme Weather: Climate change is resulting in more frequent and more extreme weather events with greater infrastructure and property impacts. This drives the need for instruments that are specified and maintained to capture mean and extreme values with the required accuracy and precision, and observing sites that are resilient to severe conditions.

2.2 New Technology and Innovation

Low-Cost Equipment: The cost of observation systems is lowering as new technologies are productized and commercialized. This trend is evident for low-cost weather sensors and stations, and also for more sophisticated instruments. This opens the opportunity for new players in the collection of observation and new observing technologies that were previously not considered affordable or mature enough for operational deployment.

Machine Learning & Artificial Intelligence: Big data analytics and machine learning have the potential to enhance data management capabilities and streamline monitoring operations. This includes modern techniques to enhance data quality assessment and correction processes and enable predictive maintenance to reduce sensor failures and down time. These advancements could help network operators to fully leverage weather and climate data that is currently available and ensure data and service delivery.

2.3 International Directions

WMO Integrated Global Observing System: The WMO has developed the WMO Integrated Observing System (WIGOS) to enable the integration of a range of observations from a variety of sources to meet the diverse needs of WMO programs. WIGOS recognizes a “fit-for-purpose” approach to data quality that is supported by descriptive metadata for each observation and a tiered network structure based on data quality and the network operator. OSCAR/Surface is the tool that will be used to manage and share WIGOS metadata openly and freely.

Citizen Observations: The UK Met Office’s Weather Observations Website (WoW), the Community Collaborative Rain, Hail and Snow network (CoCoRaHS), and NOAA’s “mPING” app have been established to utilize the large volume of weather observations available from amateur observers and social media. They are strong examples of citizen and community-based monitoring built on national data management platforms.

2.4 Data Policies

Open Government and Open Data policies: Open Data policies demonstrate the desire by governments to support the public good, based on the expectation that the open availability of data will stimulate innovation and downstream environmental and economic benefits that are greater than the costs of the data itself. The Government of Canada and several provincial and territorial governments have Open Data policies in place which support the free and open exchange of hydrometeorological data in Canada.

WMO Unified Data Policy: In October 2021, the WMO approved a new data policy to provide a more comprehensive, flexible and easily implementable approach to data exchange. The new policy encourages free, open and unrestricted data exchange across all Earth system domains – weather, climate, hydrology, ocean, atmospheric composition, cryosphere, and space weather – and covers the exchange of data from all network operators to increase the availability of known quality data to meet national and international user needs.

Section 3: Regional and Federal Overviews of Surface Weather and Climate Monitoring in Canada

This section provides an overview of current surface weather and climate monitoring networks across Canada, including existing collaborative arrangements for data sharing and common challenges and drivers within each region. High-level gap analyses are included for purposes of this report but are expected to be expanded upon at a later stage. A detailed metadata list of existing weather and climate monitoring networks listed in this report can be found in Appendix A.

3.1 Northern Canada

The impacts of climate change and global warming are already being felt in Northern Canada and are only expected to increase in the future[1]. Surface weather and climate monitoring is essential in better understanding climate trends, however data availability remains sparse in some of Canada's most remote regions. This section highlights nearly 250 weather and climate monitoring stations that are operated by territorial governments, academia and private organizations in Northern Canada. Detailed information for weather and climate stations in Nunavut are not available at this time, but will be included in a subsequent version of this report.

3.1.1 Yukon

The current Yukon (YT) network includes seven territorial government networks, one academic network, one private network and one crown corporation as depicted below in Figure 3.1.1.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
YT - Department of Highways and Public Works Road Weather Network	25	Temperature, Precipitation (all weather), Wind	Automated	Continuous	Real time
YT - Department of Environment Yukon Parks	3	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time
YT - Department of Environment Water Resources Network	6	Temperature, Humidity, Pressure, Precipitation (all weather), Wind, Radiation, Soil	Automated	Continuous	Real time
YT - Department of Environment Snow Survey Network	58	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time
YT - Department of Energy Mines and Resources Permafrost Outreach Program	7	Temperature, Soil	Automated	Continuous	Non real time
YT - Department of Energy Mines and Resources Abandoned Mines Network	3	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (snow), Wind	Automated	Continuous	Real time
YT - Department of Community Services Fire Weather Network	27	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Yukon Avalanche Association Avalanche Weather Network	4	Temperature, Humidity, Precipitation (snow), Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time
Yukon Energy	7	Temperature, Precipitation (all weather)	Automated	Continuous	Real time

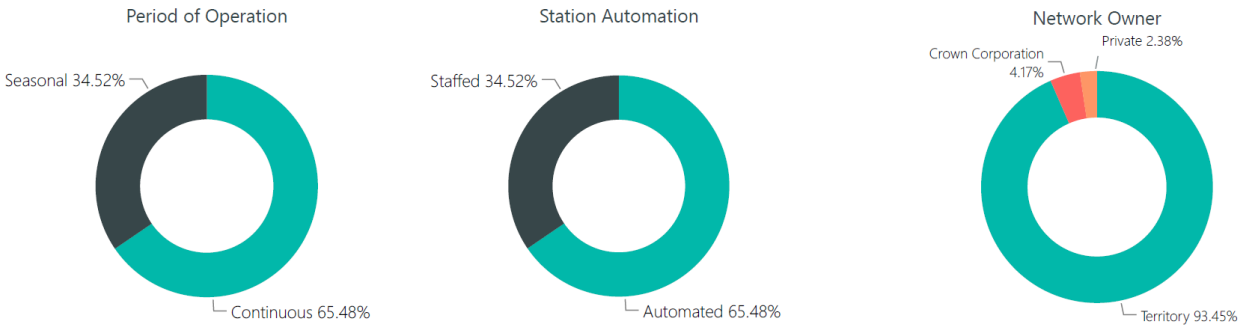


Figure 3.1.1.1 Overview of networks within Yukon

A Memorandum of Understanding (MoU) for data sharing and network planning is signed between the Yukon Government (including Highways and Public Works; Environment; Energy, Mines and Resources; and Community Services) and ECCC. Monitoring priorities are widespread in Yukon due to the number and diversity of networks in the territory. Climate and climate change are a key priority across all networks while network-specific priorities include water management, fire forecasting, environmental monitoring, and road safety.

Parameters vary per network, with over 75 stations throughout the territory measuring air temperature and wind and less than 30 stations measuring air pressure and solar radiation. Precipitation is measured by almost every network in Yukon, however not all stations measure precipitation over the winter months. The territorial government owns and operates the majority of networks in Yukon. Most networks in this region operate year-round and have automated stations.

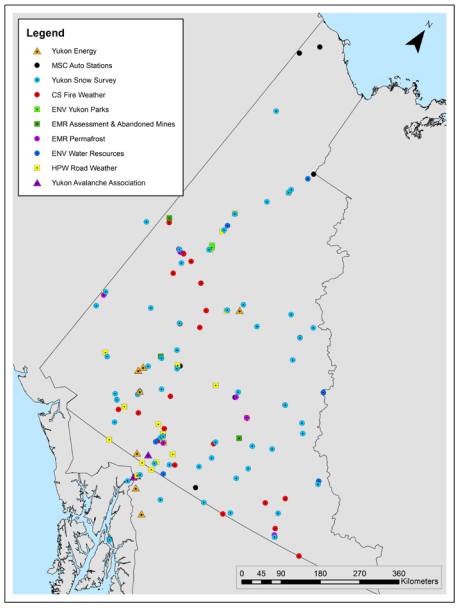


Figure 3.1.1.2 Map of Yukon Surface Weather and Climate Networks

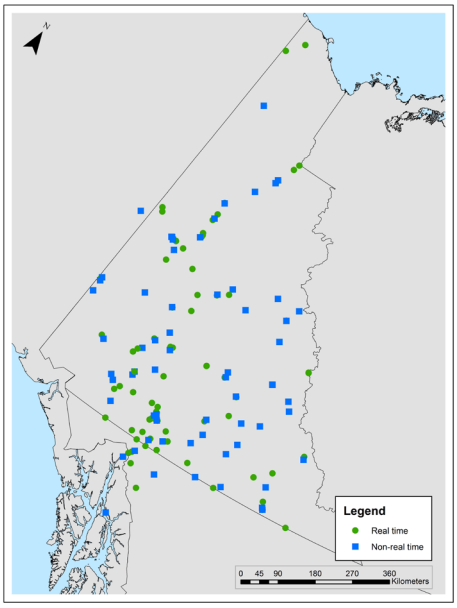


Figure 3.1.1.3 Map of Yukon non-real time and real time stations

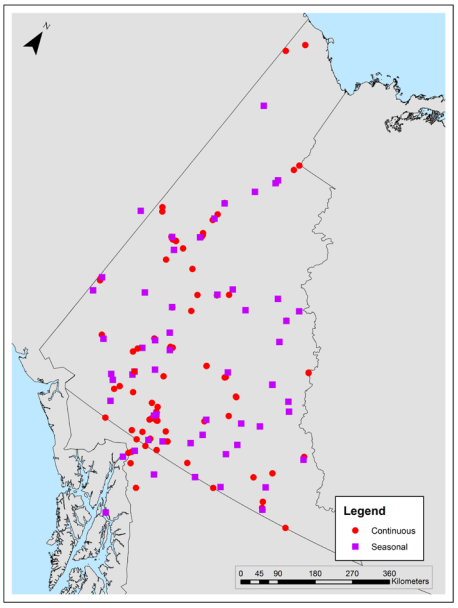


Figure 3.1.1.4 Map of Yukon continuous and seasonal stations

3.1.2 Northwest Territories

The current Northwest Territories (NWT) network includes four territorial government networks a depicted below in Figure 3.1.2.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
NWT - Department of Environment and Natural Resources Fire Weather Network	42	Temperature, Humidity, Precipitation (rain), Wind, Radiation, Soil	Automated	Continuous	Real time
NWT - Department of Environment and Natural Resources Snow Survey Network	49	Snow Water Equivalent	Staffed	Seasonal	Non real time
NWT - Department of Environment and Natural Resources Water Management and Monitoring Network	13	Temperature, Humidity, Precipitation (rain), Snow depth, Wind	Automated	Continuous	Mixed
NWT - Department of Infrastructure Road Weather Network	1	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time

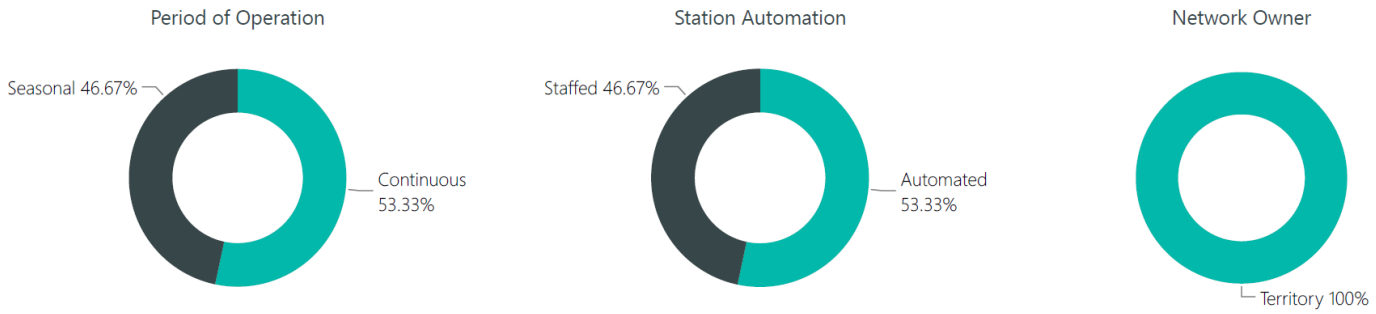


Figure 3.1.2.1 Overview of the networks within Northwest Territories

A data sharing MoU is signed between the Government of Northwest Territories (including Environment and Natural Resources; and Infrastructure) and ECCC. Archiving weather and climate data is a key priority in NWT in order to support climate research and adaptation activities. Other network priorities include water management, fire forecasting and road safety.

Parameters measured are fairly consistent across the territory as almost all stations measure air temperature, humidity, wind and rainfall. The majority of networks are operated year-round however some stations are only maintained seasonally which can affect data availability during the winter months.

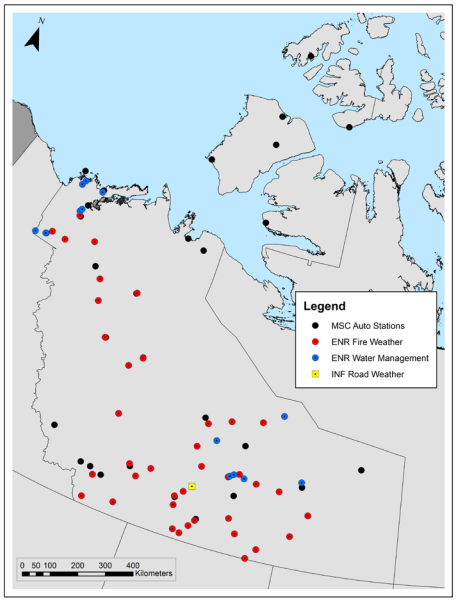


Figure 3.1.2.2 Map of Northwest Territories Surface Weather and Climate Networks

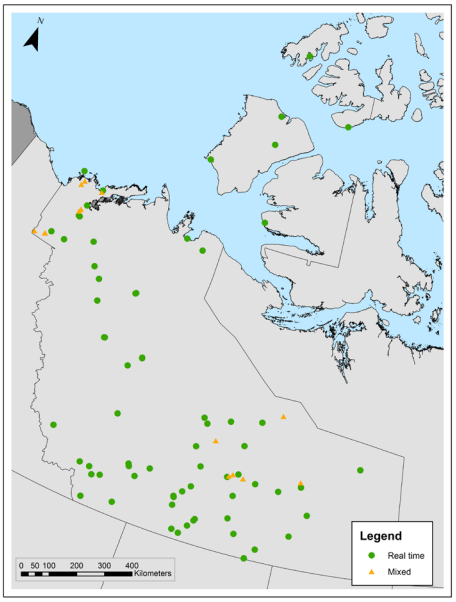


Figure 3.1.2.3 Map of Northwest Territories non-real time and real time stations

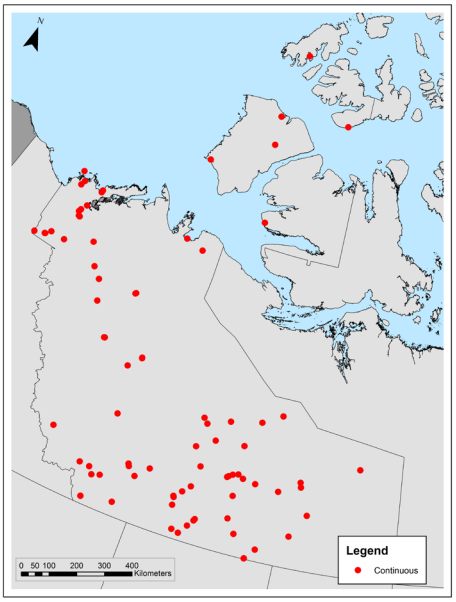


Figure 3.1.2.4 Map of Northwest Territories continuous and seasonal stations

3.1.3 Common Challenges in Northern Canada

Monitoring in Northern Canada comes with many challenges, from limited funding and resources to differences in data collection and management across networks. The following have been identified as the main challenges for surface weather and climate monitoring in Northern Canada.

Operational Challenges:

Limited funding to support new station installation, long-term maintenance and life-cycle management. This is a common issue between all jurisdictions in Northern Canada and limits the growth of surface weather and climate networks.

Limited access to remote locations for station maintenance and data download. This is a challenge in the north due to the number of remote locations, limiting data availability during the winter months.

Lack of standardization in collection and management of data across networks. There is no common approach for data and metadata collection resulting in inconsistencies between networks in Northern Canada.

Collaborative Challenges:

No formal governance mechanism to discuss common monitoring issues. Without a formal mechanism, common issues or needs between networks and jurisdictions cannot be addressed collaboratively.

No common system for sharing data. While some organizations exchange weather and climate data, there is no common approach to standardize and share data between networks in any given territory.

Limited capacity to facilitate collaboration and operate networks. This is a common problem between NWT and Nunavut (NU), limiting further collaboration due to a lack of resources.

3.1.4 Gap Analysis for Northern Canada

The density of surface weather and climate observations in northern Canada is significantly lower than southern parts of the country where there is higher population and ample infrastructure to support monitoring. The limited availability of in-situ data is exacerbated by the scarcity of other data sources, including observations from geostationary satellites, radar and upper air soundings.

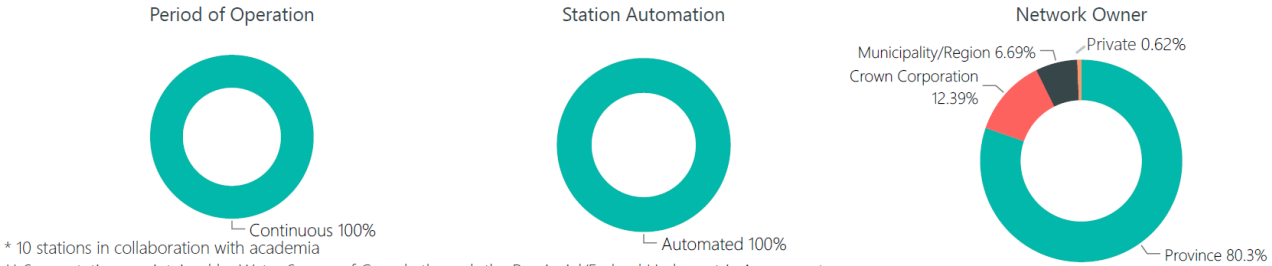
3.2 Western Canada

Western Canada represents the second largest region in Canada with great social and economic diversity. Having experienced the strongest warming in southern Canada to date, the region is expected to face increased and more severe extreme weather events moving forward as a result of the changing climate[2]. This section highlights over 3,000 weather and climate monitoring stations that support public safety, and research and adaptation activities.

3.2.1 British Columbia

The current British Columbia (BC) network includes six provincial government networks, one private network, two municipal/regional networks and 1 crown corporation as depicted below in Figure 3.2.1.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
BC - Ministry of Transportation and Infrastructure Avalanche & Road Weather Network	162	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (snow), Wind	Automated	Continuous	Real time
BC - Ministry of Forests Fire Weather Network	254	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Wind	Automated	Continuous	Real time
BC - Ministry of Forests - Forest Ecosystems Research Network *	105	Humidity, Precipitation (all weather), Precipitation (snow), Wind, Radiation, Soil	Automated	Continuous	Real time
BC - Ministry of Environment and Climate Change Strategy Automated Snow Weather Network	46	Temperature, Precipitation (all weather), Precipitation (snow), Snow Water Equivalent	Automated	Continuous	Real time
BC - Ministry of Environment and Climate Change Strategy Air Quality-Met Network	54	Temperature, Humidity, Pressure, Precipitation (all weather), Wind, Air quality, Radiation	Automated	Continuous	Real time
BC - Ministry of Agriculture and Foods	27	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Rio Tinto - BC	5	Temperature, Humidity, Precipitation (all weather), Precipitation (snow), Snow Water Equivalent	Automated	Continuous	Real time
Metro Vancouver Watershed Management Network	14	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Snow water equivalent, Wind	Automated	Continuous	Real time
Metro Vancouver Air Quality Network	29	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Capital Regional District	11	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
BC Hydro **	100	Temperature, Precipitation (all weather), Snow depth, Snow water equivalent	Automated	Continuous	Real time



* 10 stations in collaboration with academia

** Some stations maintained by Water Survey of Canada through the Provincial/Federal Hydrometric Agreement

Figure 3.2.1.1 Overview of networks within British Columbia

A data sharing MoU is signed between the Government of British Columbia (including Environment and Climate Change Strategy; Transportation and Infrastructure; and Forests) and ECCC. Supplemental to the MoUs, ECCC has formally joined into BC's Climate Related Monitorin Program by formally signing the Agreement on Management of Hydrometeorological Networks in the Province of British Columbia. This agreement represents the longstanding effort between four provincial ministries, two regional districts, a private company and a crown corporation. The intention of this group is to improve the effectiveness of hydrometeorological monitoring in the province by making data publicly available, make more consistent operating procedures, collaborate more on siting and technology and improve climate data coverage in the province.

Monitoring priorities are widespread in the province from agriculture and forest research, to fire forecasting, water management and road safety. Parameters are fairly consistent across networks with over 500 stations measuring air temperature, humidity, wind and some form of precipitation. All stations in BC are automated and operate year-round. However approximately half of the stations only measure precipitation during the summer months. Available data is shared through a data archive housed at a regional climate center, however there are currently no common quality assurance/quality control (QA/QC) procedures across networks. A formal governance mechanism is in place to support this collaboration and allow all organizations to discuss common monitoring issues.

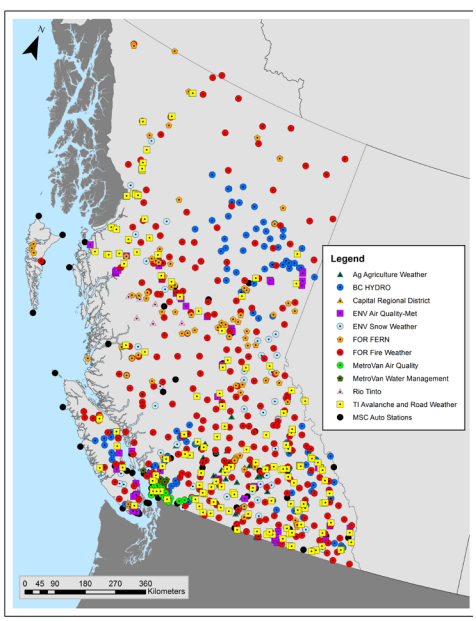


Figure 3.2.1.2 Map of British Columbia Surface Weather and Climate Networks

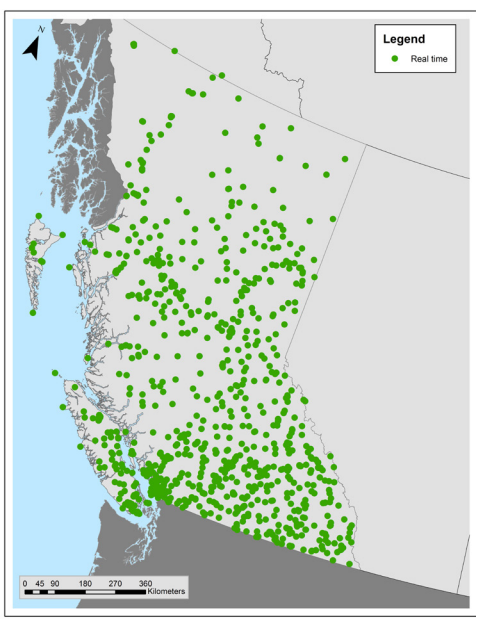


Figure 3.2.1.3 Map of British Columbia non-real time and real time stations

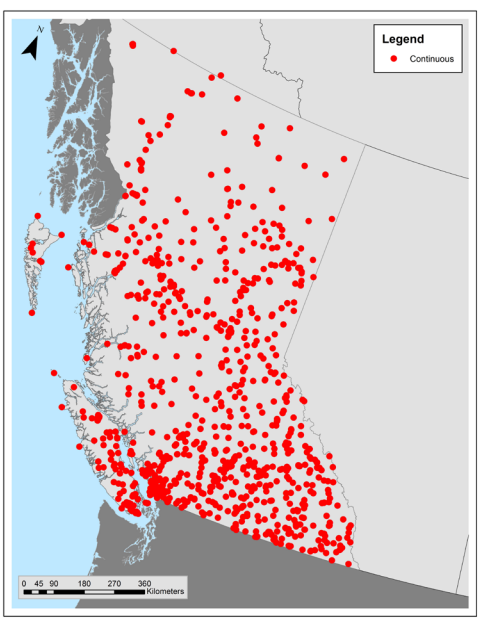


Figure 3.2.1.4 Map of British Columbia continuous and seasonal stations

3.2.2 Alberta

The current Alberta (AB) network includes four provincial government networks as depicted below in Figure 3.2.2.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
AB - Ministry of Transportation Road Weather Network	100	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
AB - Ministry of Environment and Parks Met Network	88	Temperature, Humidity, Precipitation (all weather), Wind	Automated	Continuous	Real time
AB - Ministry of Agriculture, Forestry and Rural Economic Development Fire Weather Network	166	Temperature, Humidity, Precipitation (rain), Wind	Mixed	Continuous	Mixed
AB - Ministry of Agriculture, Forestry and Rural Economic Development Ag-Weather Network	179	Temperature, Humidity, Precipitation (all weather), Wind, Radiation	Automated	Continuous	Real time

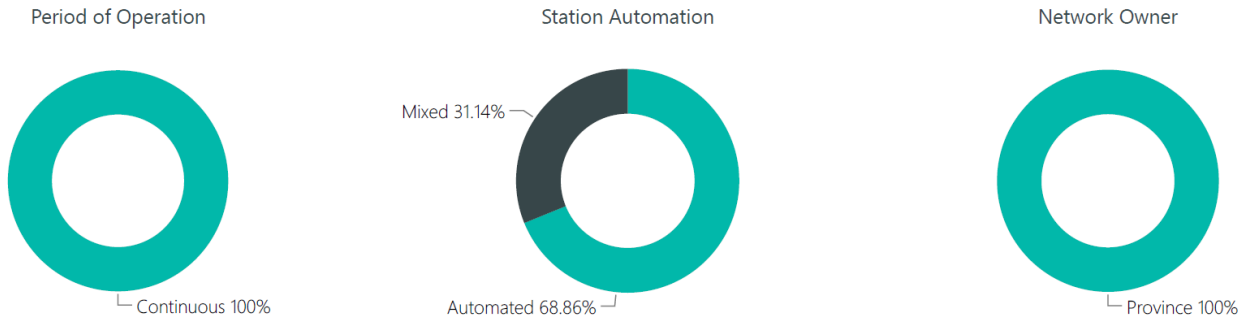


Figure 3.2.2.1 Overview of networks within Alberta

An agreement is signed between the Government of Alberta (including Agriculture and Forestry; and Environment and Parks) and ECCC that includes data sharing as well as a formal working group to discuss network planning and operational issues. Key monitoring priorities in AB include agriculture and fire forecasting, in addition to road safety, water management and environmental monitoring.

Parameters are fairly consistent across networks with all stations measuring air temperature, humidity, wind and some form of precipitation. All stations in AB are operated year-round however only half of the stations measure precipitation during the winter months.

The Alberta government has developed a tool for sharing, quality assessing and archiving weather and climate data known as the Alberta Climate Information Service (ACIS). This tool provides a single access point for data sharing between provincial organizations and is also available for public use.

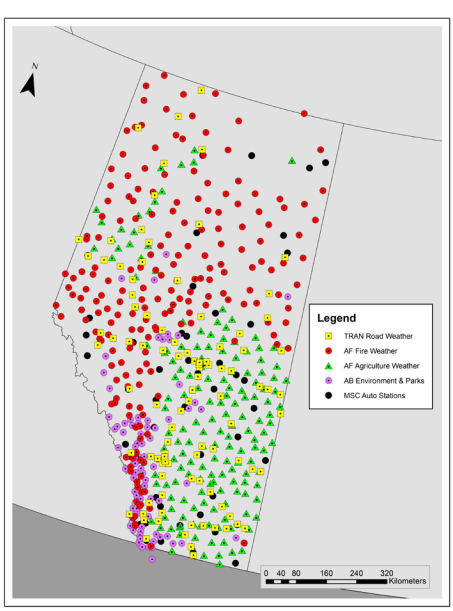


Figure 3.2.2.2 Map of Alberta Surface Weather and Climate Networks

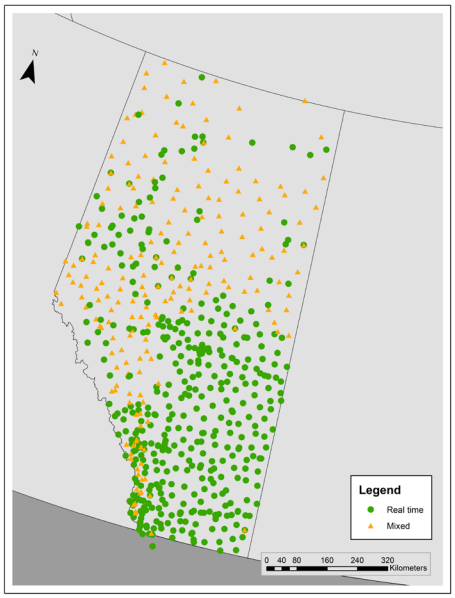


Figure 3.2.2.3 Map of Alberta non-real time and real time stations

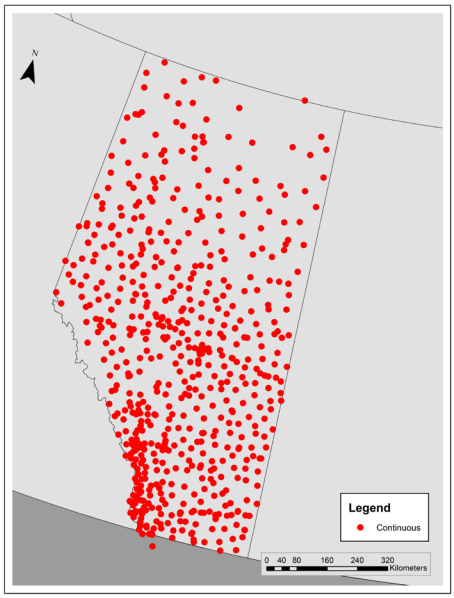


Figure 3.2.2.4 Map of Alberta continuous and seasonal stations

3.2.3 Saskatchewan

The current Saskatchewan (SK) network includes three crown corporation networks as depicted below in Figure 3.2.3.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
Saskatchewan Research Council Climate Reference Station Network	2	Temperature, Humidity, Pressure, Precipitation (all weather)	Automated	Continuous	Real time
Saskatchewan Public Safety Agency Fire Weather Network	89	Temperature, Humidity, Precipitation (rain), Wind, Dew point	Automated	Continuous	Real time
Saskatchewan Crop Insurance Corporation Ag-Weather Network	155	Temperature, Humidity, Precipitation (rain)	Automated	Seasonal	Real time

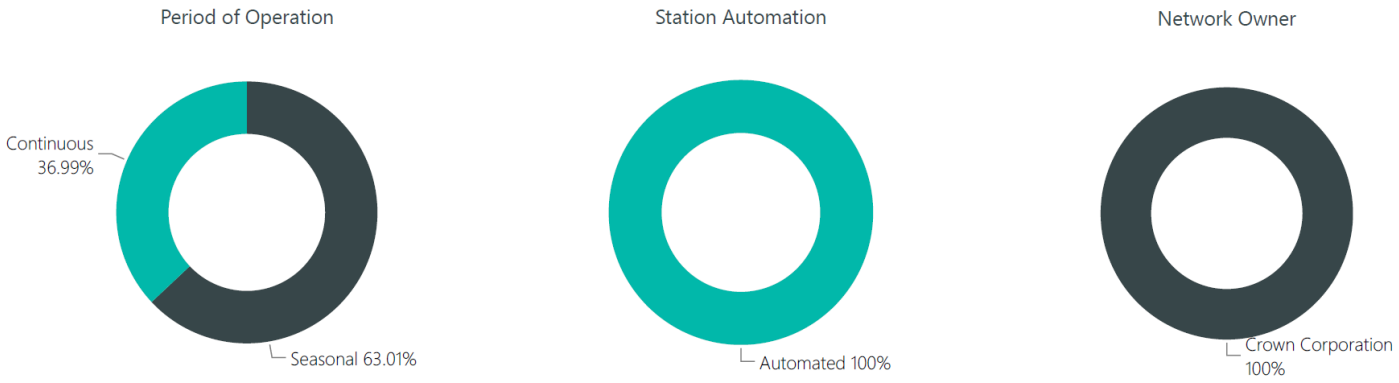


Figure 3.2.3.1 Overview of networks within Saskatchewan

A data sharing MoU is signed between Saskatchewan Research Council, Saskatchewan Public Safety Agency and ECCC. The main priorities for monitoring in the province are agriculture and fire forecasting, with additional interests in climate research.

Parameters are fairly consistent across networks with all stations measuring temperature, humidity, and rainfall but only a subset measuring wind and air pressure. All stations in SK are automated, however not all parameters are reported year-round. In addition, there are seasonal stations operated by a private organization which are not freely available to the public or other organizations in SK. This contributes to gaps in data availability for the southern part of the province.

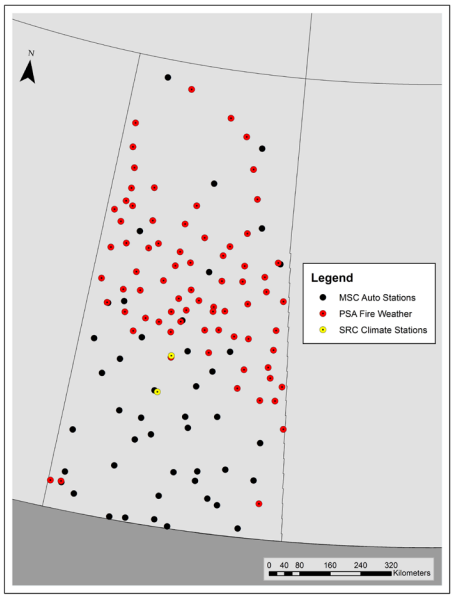


Figure 3.2.3.2 Map of Saskatchewan Surface Weather and Climate Networks

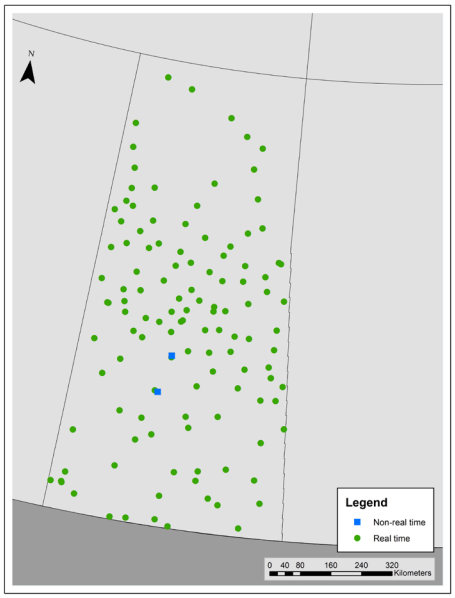


Figure 3.2.3.3 Map of Saskatchewan non-real time and real time stations

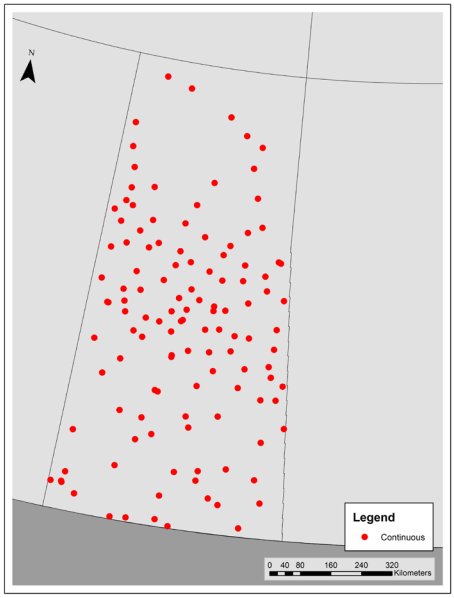


Figure 3.2.3.4 Map of Saskatchewan continuous and seasonal stations

3.2.4 Manitoba

The current Manitoba (MB) network includes three provincial government networks, one crown corporation and one municipal/regional network as depicted below in Figure 3.2.4.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
MB - Department of Transportation and Infrastructure Road Weather Network	32	Temperature, Humidity, Pressure, Water quantity, Wind	Automated	Continuous	Real time
MB - Department of Natural Resources and Northern Development Fire Weather Network	45	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
MB - Department of Agriculture Ag-Weather Network	109	Temperature, Humidity, Precipitation (rain), Wind, Radiation, Soil, Dew Point	Automated	Continuous	Real time
City of Winnipeg Rainfall Network	37	Precipitation (rain)	Automated	Continuous	Real time
Manitoba Hydro	9	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time

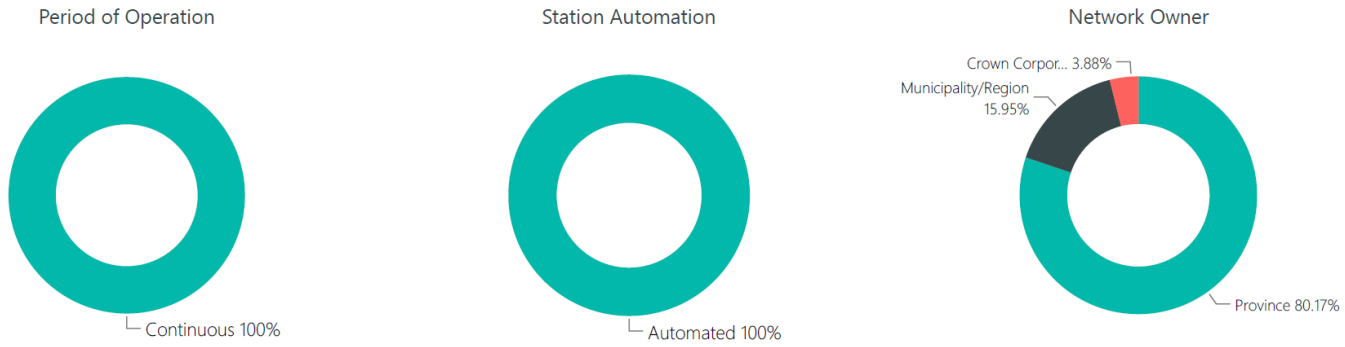


Figure 3.2.4.1 Overview of networks within Manitoba

Key monitoring priorities in MB include agriculture and fire forecasting, in addition to road safety, water management and climate. Parameters vary per network, however the majority of stations measure temperature, humidity, wind and rainfall with less focus on winter precipitation.

A MoU has not yet been signed between the Government of Manitoba and ECCC. However, MB has established a formal working group within the province to discuss common monitoring issues and potential co-location of sites to serve multiple network priorities. Data is shared between provincial departments however varying QA/QC procedures have resulted in a barrier to developing a shared archive. There is currently no system in place for sharing data with the private sector.

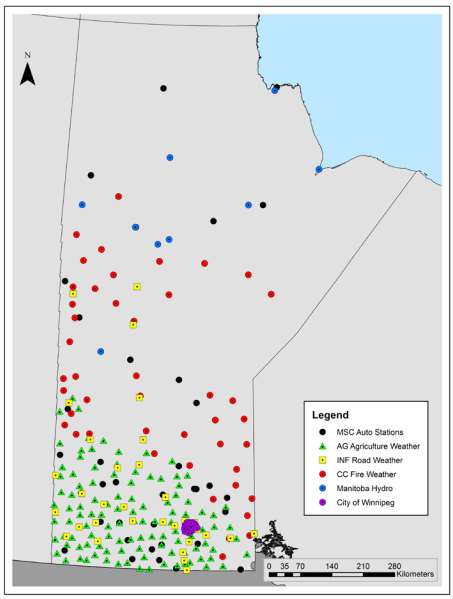


Figure 3.2.4.2 Map of Manitoba Surface Weather and Climate Networks

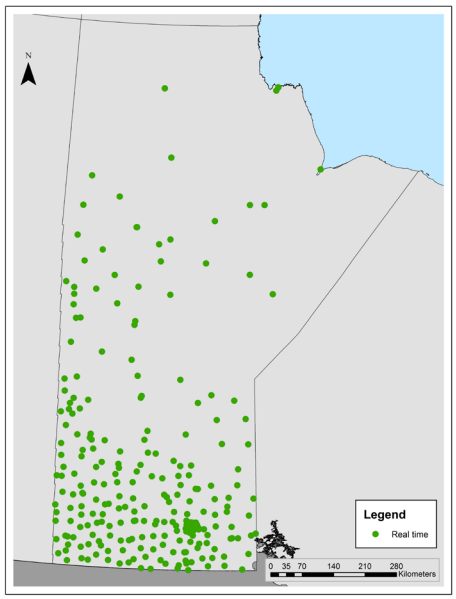


Figure 3.2.4.3 Map of Manitoba non-real time and real time stations

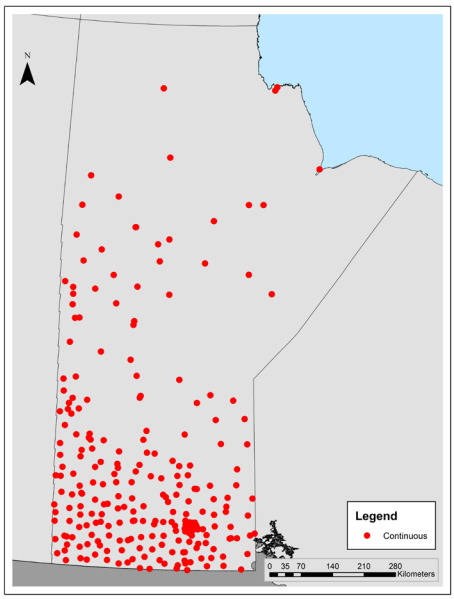


Figure 3.2.4.4 Map of Manitoba continuous and seasonal stations

3.2.5 Common Challenges in Western Canada

Challenges in Western Canada vary from jurisdiction to jurisdiction, however there are common issues related to differences in QA/QC and archiving practices. The following have been identified as the main challenges for surface weather and climate monitoring in Western Canada.

Operational Challenges:

Lack of standardization in collection and management of data across networks. Differing drivers, data attribution, QA/QC processes and metadata collection leads to variability and inconsistency between networks in Western Canada. The considerable effort required to standardize also leads to a barrier for collaboration.

Limited access to data due to seasonal operation of some networks, as well as issues with cellular and satellite transmission impacting data availability.

Collaborative Challenges:

Lack of data sharing with private organizations in some jurisdictions. Although several private networks exist across Western Canada, not all data from these networks are made freely available.

3.2.6 Gap Analysis for Western Canada

The density of surface weather and climate observations in western Canada is noticeably lower in the northern part of each province. Specifically in MB, monitoring in the northern region is of high interest to reflect changes in climate around Hudson Bay. While the number of stations appears high in BC and AB, there are notable gaps due to the variation in topography along the provincial border between these two provinces. In SK, additional gaps are observed in the southern part of the province where station density is lower than that of neighbouring Prairie Provinces. This is largely due to an existing network which does not make its data freely available to other organizations.

3.3 Central Canada

Central Canada represents the most populous region in Canada with strong mandates for public safety and monitoring extreme weather events. With projected increases in annual mean temperature and annual mean precipitation, Ontario and Quebec are likely to face heightened risks for drought, wildfire and urban floods[1]. This section highlights over 1,000 weather and climate monitoring stations that support public safety in some of Canada's most populated regions.

3.3.1 Ontario

The current Ontario (ON) network includes three provincial government networks and two Conservation Authority networks as depicted below in Figure 3.3.1.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
ON - Ministry of Transportation Road Weather Network	148	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
ON - Ministry of Natural Resources and Forestry Surface Water Monitoring Network	122	Precipitation (rain)	Automated	Continuous	Real time
ON - Ministry of Natural Resources and Forestry Fire Weather Network	142	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Wind	Automated	Continuous	Real time
Toronto and Region Conservation Authority	39	Temperature, Precipitation (rain)	Automated	Continuous	Real time
Grand River Conservation Authority	27	Temperature, Precipitation (rain)	Automated	Continuous	Real time

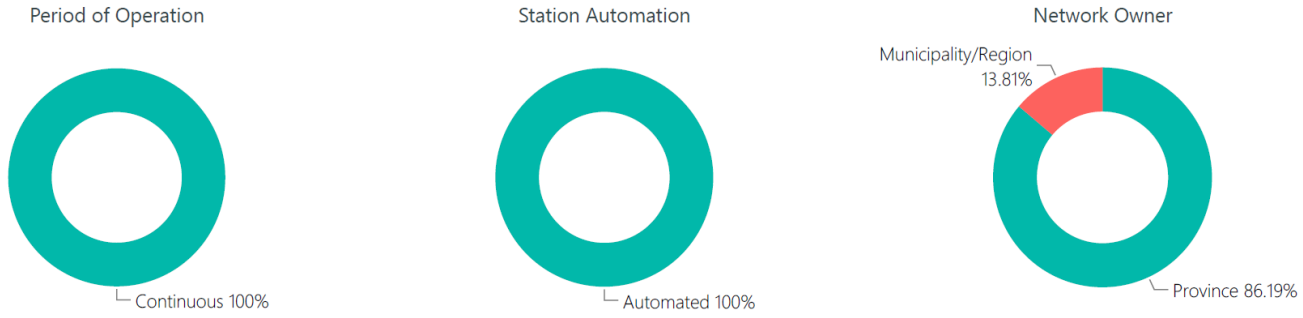


Figure 3.3.1.1 Overview of networks within Ontario

Flood forecasting and water management are key monitoring priorities in ON, in addition to fire forecasting and road safety. Conservation Authorities are unique to Ontario and are local watershed management agencies that deliver services and programs to protect and manage impacts on water and other natural resources in partnership with all levels of government, landowners and many other organizations. There are a total of 36 Conservation Authorities operating in Ontario, 31 in the south and five in the north. They are independent organizations which are legislated under the Conservation Authorities Act. They are largely funded through the municipalities within their watersheds, and they range in size from very large to small which influences the programs and services they are able to offer. Most of the Conservation Authority monitoring stations are included in the Provincial monitoring network listed above, however, a few CAs may operate additional monitoring stations which are currently not included.

Parameters vary per network in ON, however the majority of stations measure temperature, humidity, wind and rainfall. All stations are automated and operate all-year round, with the exception of some precipitation sensors which are not heated or, only operate during the summer months.

A MoU has not yet been signed between the Government of Ontario and ECCC. Although data is shared between some organizations, there is a recognized lack of coordination due to the varying priorities for monitoring in the province.

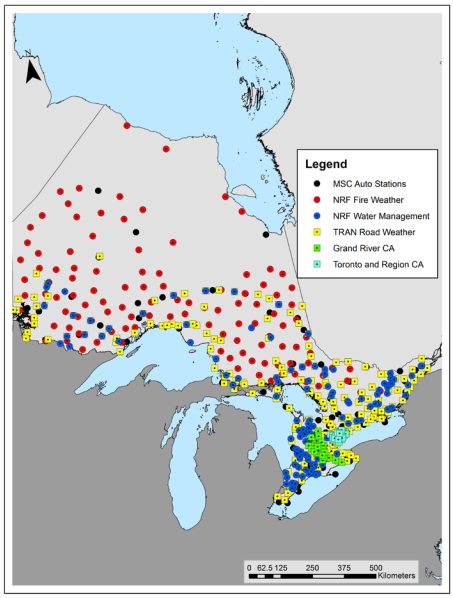


Figure 3.3.1.2 Map of Ontario Surface Weather and Climate Networks

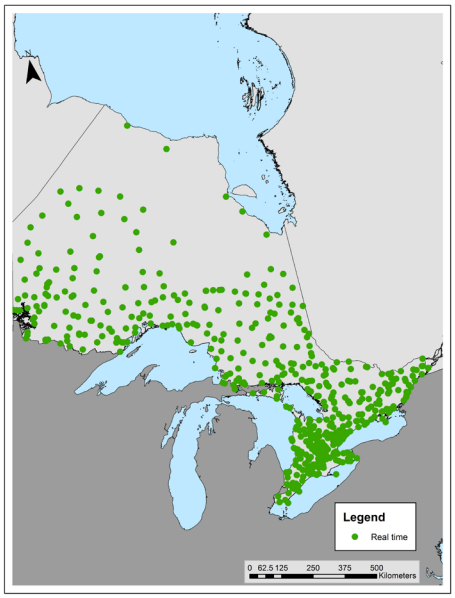


Figure 3.3.1.3 Map of Ontario non- real time and real time stations

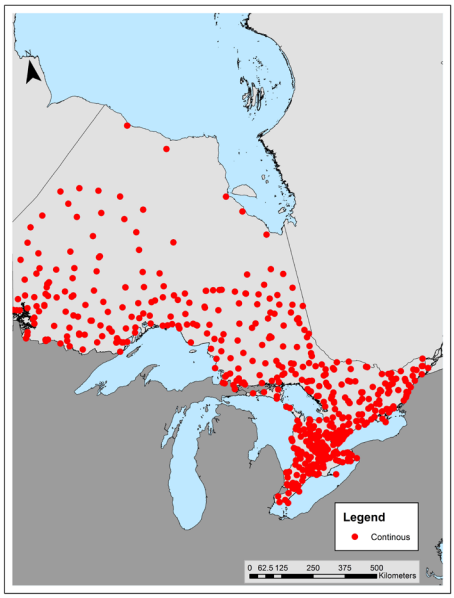


Figure 3.3.1.4 Map of Ontario continuous and seasonal stations

3.3.2 Quebec

Since 2002 there has been a formal collaboration agreement, known as the “Réseau Météorologique Coopératif du Québec” (RMCQ), between the operators of the six main networks of automatic stations in Quebec, listed in the figure below. The purpose of this agreement is to facilitate the real-time exchange of meteorological data in a common format, in order to support each of the parties in achieving their respective mandates. RMCQ partners strive to harmonize data acquisition and processing methods, as much as possible by applying the standards of the WMO, and to improve consultation, planning and coordination of their respective field operations. They meet at least once a year to discuss these issues and to share their expertise and the latest innovations.

In addition to the RMCQ networks, current monitoring in Quebec includes three other networks. The figure below shows these networks.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
Hydro-Québec Snow Weather Network	68	Precipitation (snow), Snow water equivalent	Automated	Continuous	Real time
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Snow Survey Network	107	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time
Société de protection des forêts contre le feu*	69	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
QC - Ministère des Forêts, de la Faune et des Parcs *	16	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
Rio Tinto - QC *	13	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Snow water equivalent, Wind	Automated	Continuous	Real time
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Automated Network *	93	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Snow water equivalent, Wind	Automated	Continuous	Real time
Hydro-Quebec *	80	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Observer Network	157	Temperature, Precipitation (all weather), Precipitation (snow), Snow water equivalent, Weather phenomenon observation	Mixed	Continuous	Non real time

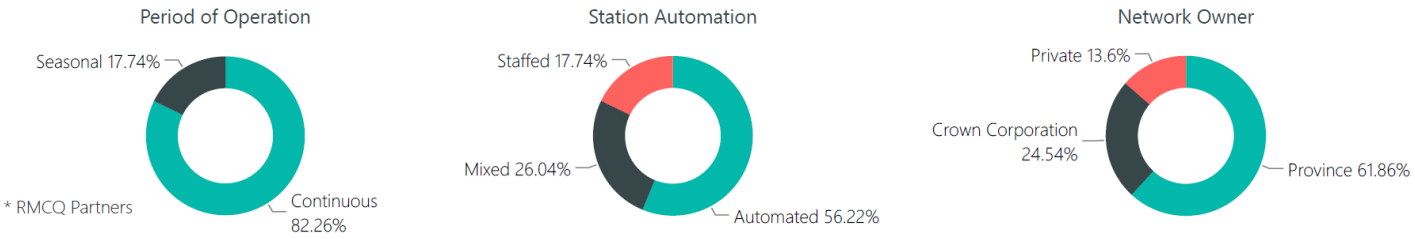


Figure 3.3.2.1 Overview of networks within Quebec

The main monitoring priorities in Quebec revolve around public safety, including extreme weather events, fire forecasting, flood forecasting, and water and dam management. Other priorities include the preservation of historical records to preserve long-term climate knowledge as well as forest management and disease and insect control.

Although the parameters vary between networks, more than 500 stations measure temperature and precipitation throughout the year. The largest network, which includes about 30% of the stations in the province, is made up of stations with an observer where manual observations are complemented by the presence of automatic instruments (tipping bucket rain gauge, from April to October) providing hourly data. However, data from this network is only transmitted twice a day.

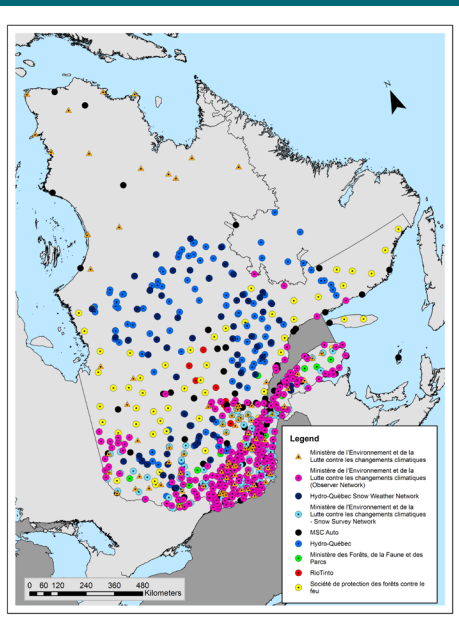


Figure 3.3.2.2 Map of Quebec Surface Weather and Climate Networks

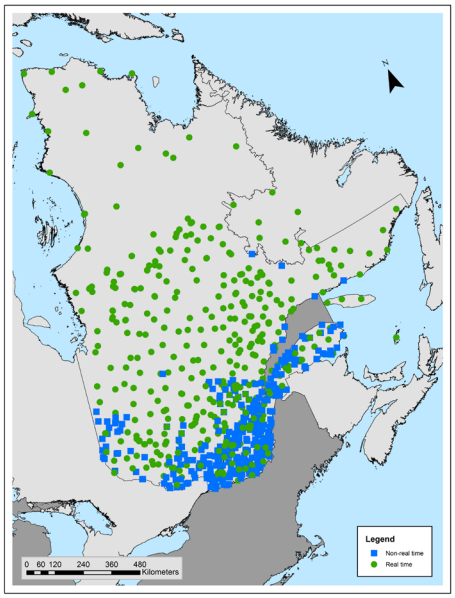


Figure 3.3.2.3 Map of Quebec non-real time and real time stations

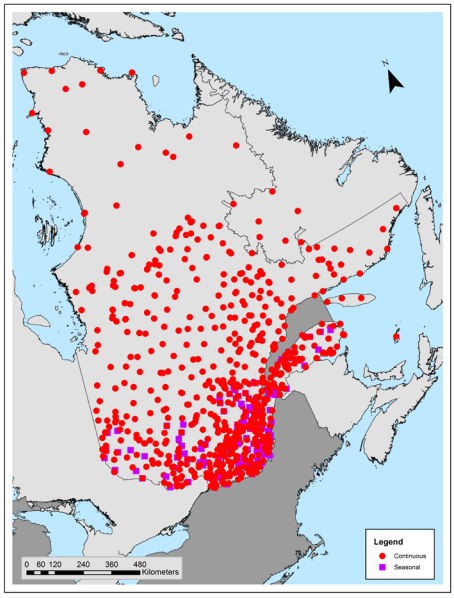


Figure 3.3.2.4 Map of Quebec continuous and seasonal stations

3.3.3 Common Challenges in Central Canada

Although there is collaboration amongst network operators in central Canada, challenges are still faced due to competing priorities for network operation and limited funding. The following have been identified as the main challenges for surface weather and climate monitoring in Central Canada.

Operational Challenges:

Limited funding and human resources to support long-term maintenance and life cycle management. This is a common issue across organizations that can limit the growth of surface weather and climate networks in Central Canada.

Challenges with **station operation in remote locations** due to limited access, power and cell service that can impact data availability.

Collaborative Challenges:

Limited capacity and differing objectives between organizations (Ontario) often create barriers to collaboration. Although information and data is shared between some networks, greater collaboration is often hindered when priorities or network standards do not align.

3.3.4 Gap Analysis for Central Canada

The density of surface weather and climate observations in Central Canada is noticeably lower in the northern part of each province. It can also be noted that the density of stations varies according to the parameter evaluated (temperature, precipitation, wind, etc.). Although the density of observer stations is high in Quebec, and these stations have certain advantages (measurement of winter precipitation, among others) there are still data coverage gaps for users requiring real-time data across the province.

3.4 Eastern Canada

Eastern Canada encompasses a diverse coastal landscape that supports a variety of resource sectors and local communities. This region is expected to experience the largest relative sea-level rise in Canada, increasing flooding and the risk of damage to coastal infrastructure and ecosystems[1]. This section highlights over 500 surface weather and climate stations that can support adaptation activities in Eastern Canada, in addition to public safety, agriculture and water management.

3.4.1 New Brunswick

The current New Brunswick (NB) network includes four provincial government networks and one crown corporation as depicted below in Figure 3.4.1.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
NB Power	4	Temperature, Precipitation (rain)	Automated	Continuous	Real time
NB - Department of Natural Resources and Energy Development Fire Weather Network	26	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
NB - Department of Agriculture, Aquaculture and Fisheries Ag-Weather Network	34	Temperature, Humidity, Pressure, Wind, Radiation, Soil	Automated		Real time
NB - Department of Transportation and Infrastructure Road Weather Network	46	Temperature, Humidity, Precipitation (all weather), Wind	Automated	Continuous	Real time
NB - Department of Environment and Local Government Snow Survey Network	58	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time

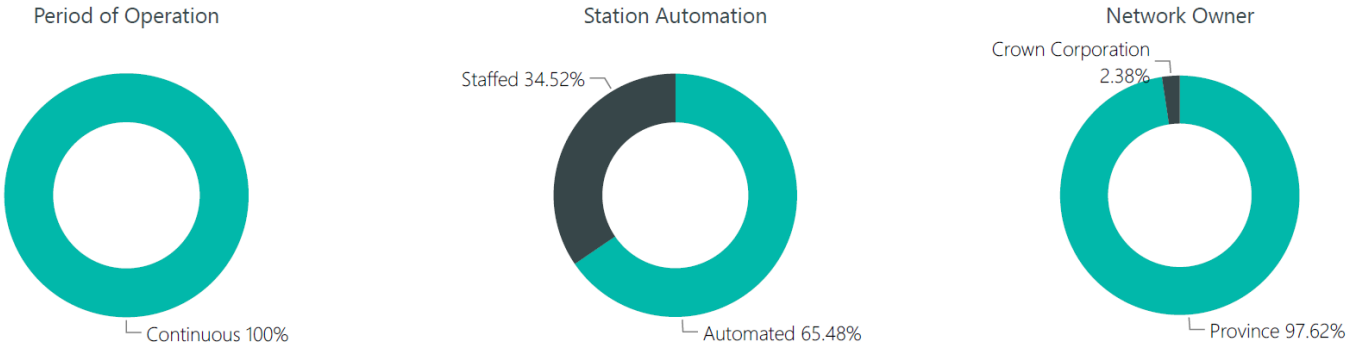


Figure 3.4.1.1 Overview of networks within New Brunswick

A data sharing MoU is signed between the Government of New Brunswick (including Environment and Local Government; Natural Resources and Energy Development; and Agriculture, Aquaculture and Fisheries) and ECCC. Monitoring priorities in the province include water management, flow and flood forecasting, road safety, fire index forecasting and agricultural monitoring.

Parameters vary per network, however the majority of stations measure temperature, humidity, precipitation and wind. Over 70 stations in the province measure precipitation all-year round, while the remaining stations only measure precipitation during the winter or summer months.

There is an ongoing collaborative effort within NB to bring data into one common system that is managed by the Department of Environment and Local Government. No formal governance mechanism has been established to date however some organizations meet to discuss common issues and challenges.

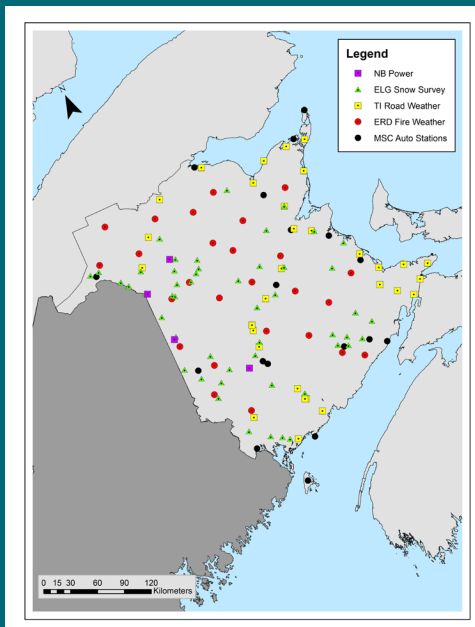


Figure 3.4.1.2 Map of New Brunswick Surface Weather and Climate Networks

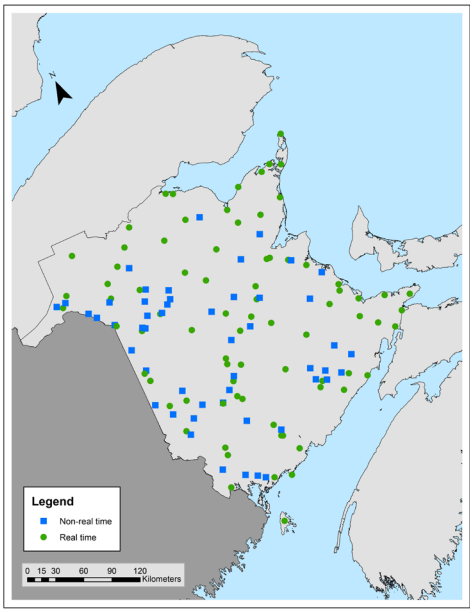


Figure 3.4.1.3 Map of New Brunswick non-real time and real time stations

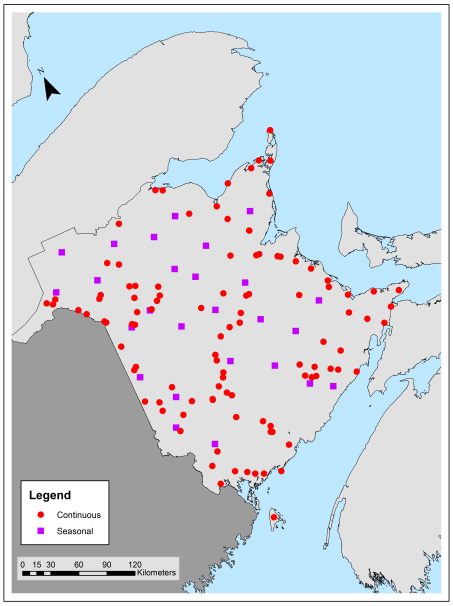


Figure 3.4.1.4 Map of New Brunswick and continuous and seasonal stations

3.4.2 Nova Scotia

In Nova Scotia (NS) there are three provincial government networks for weather monitoring; one municipal network for coastal and estuarine monitoring; one academic network for applied research; one citizen/ volunteer network; an one agriculture industry network. These are described below in Figure 3.4.2.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
NS - Department of Public Works - Road Weather Information System	51	Temperature, Humidity, Wind	Automated	Continuous	Real time
NS - Department of Natural Resources and Renewables - Fire Weather Network	31	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
NS - Department of Agriculture & Perennia - Farm Weather Network	100	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
NS - Municipality of the District of Digby - Coastal Management Network	5	Temperature, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
Nova Scotia Fruit Growers' Association - Smart Farm Network	10	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
Cape Breton Mesonet	89	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
Nova Scotia Community College Ag-Weather Network	72	Temperature, Humidity, Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time

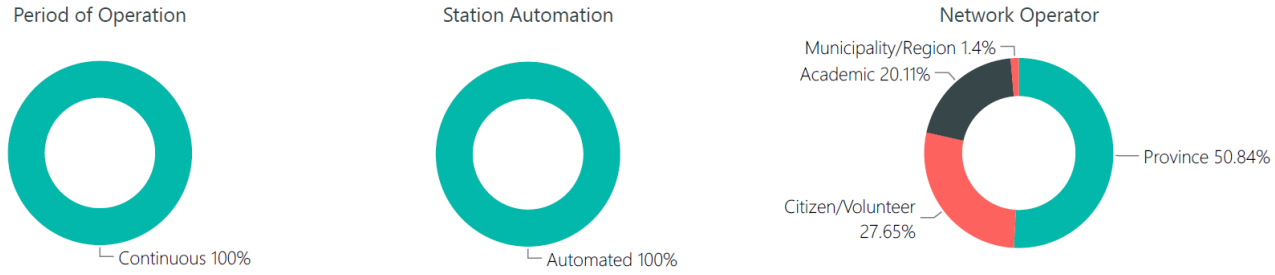


Figure 3.4.2.1 Overview of networks within Nova Scotia

Key monitoring priorities in NS include agriculture, fire forecasting and road safety, with an additional interest in climate. Parameters are fairly consistent across networks, with all stations measuring temperature, humidity and wind. The networks are operated year-round. In the case of the fire network, however, rainfall data is primarily collected during the fire season from March 15 to October 15.

A data sharing MoU has been signed between the Government of Nova Scotia (including Agriculture, and Natural Resources and Renewables) and ECCC. Five Nova Scotia provincial departments and one Crown Corporation meet quarterly as the Interdepartmental Meteorology Working Group (IMWG). This group was formed in 2019 to provide coordinated input into CWAC discussions and activities. While Nova Scotia has an Open Data Policy that provides a supportive framework for sharing weather and climate data, public access to the data varies across the networks.

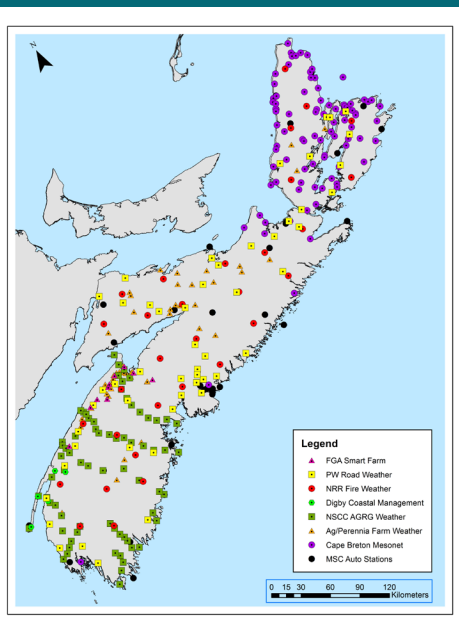


Figure 3.4.2.2 Map of Nova Scotia Surface Weather and Climate Networks

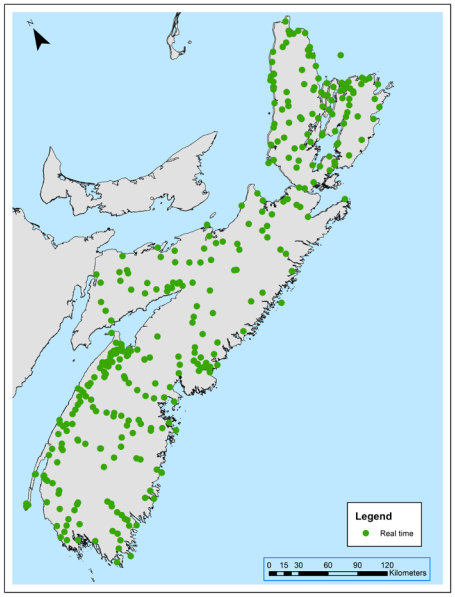


Figure 3.4.2.3 Map of Nova Scotia non-real time and real time stations

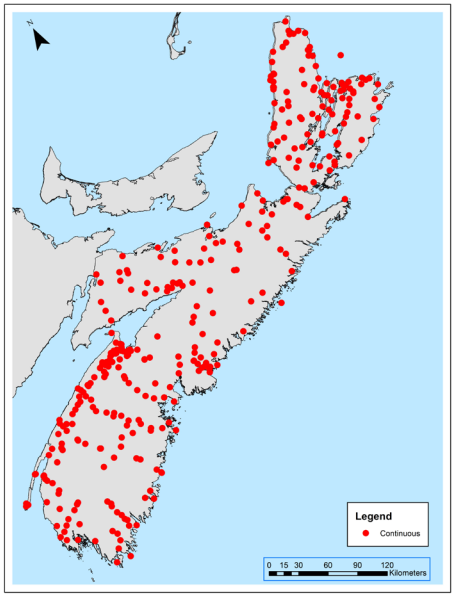


Figure 3.4.2.4 Map of Nova Scotia continuous and seasonal stations

3.4.3 Prince Edward Island

The current Prince Edward Island (PEI) network includes two provincial government networks and one academic network as depicted below in Figure 3.4.3.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
PEI - Department of Transportation and Infrastructure Road Weather Network	5	Temperature, Humidity, Pressure, Wind, Dew Point	Automated	Continuous	Real time
PEI - Department of Agriculture and Fisheries Ag-Weather Network	13	Temperature, Humidity, Vapour pressure, Precipitation (rain), Wind	Automated	Seasonal	Real time
UPEI Climate Research Lab	36	Temperature, Pressure, Precipitation (rain), Wind, Radiation, Marine	Automated	Continuous	Non real time

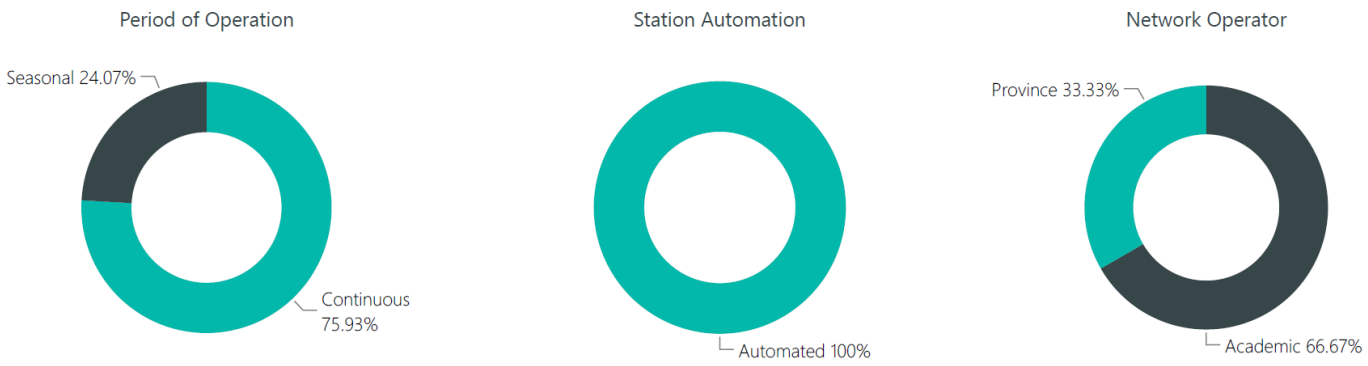


Figure 3.4.3.1 Overview of networks within Prince Edward Island

Key monitoring priorities in PEI include road safety, agriculture and climate. Parameters are fairly consistent across networks, with all stations measuring temperature, pressure, humidity and wind. The majority of stations measure precipitation but only during the summer months.

A MoU has not yet been signed between the Government of Prince Edward Island and ECCC.
There is no common system for sharing data within the province although data exchange occurs between some organizations.

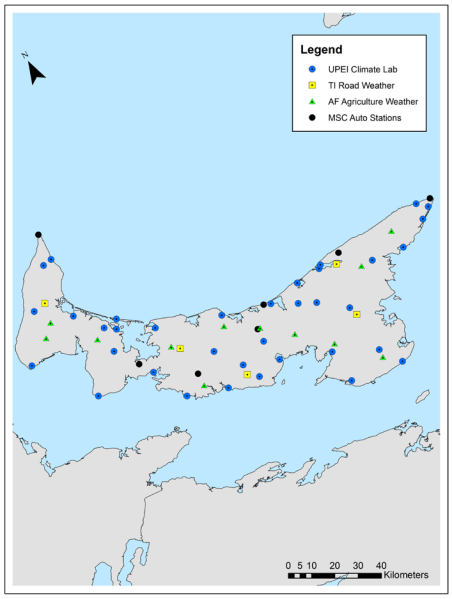


Figure 3.4.3.2 Map of Prince Edward Island Surface Weather and Climate Networks

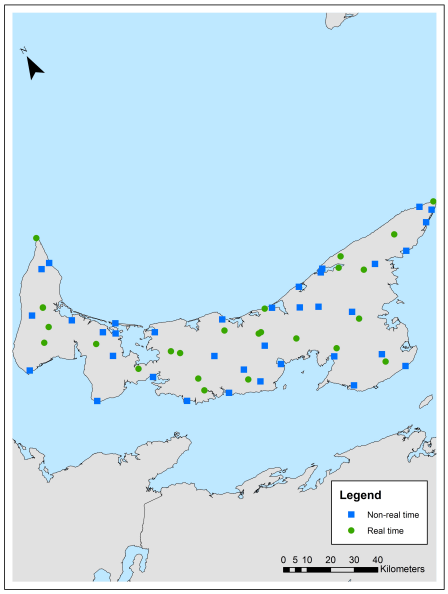


Figure 3.4.3.3 Map of Prince Edward Island non-real time and real time stations

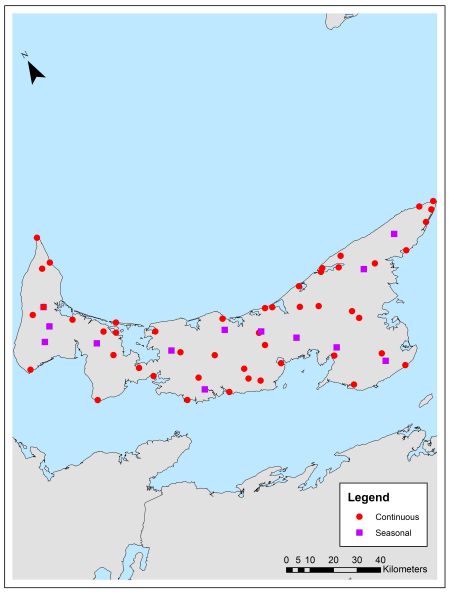


Figure 3.4.3.4 Map of Prince Edward Island continuous and seasonal stations

3.4.4 Newfoundland and Labrador

The current Newfoundland and Labrador (NL) network includes three provincial government networks, two academic networks, three private networks, one municipal/ regional network and one crown corporation as depicted below in Figure 3.4.4.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
NL - Department of Transportation and Infrastructure Road Weather Network	28	Temperature, Precipitation (rain), Wind	Automated	Continuous	Real time
NL - Department of Fisheries, Forestry and Agriculture Fire Weather Network	23	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Smart Atlantic Buoy Network	19	Temperature, Pressure, Wind	Automated	Continuous	Real time
Nalcor Energy	13	Temperature, Humidity, Precipitation (all weather), Wind, Snow Water Equivalent	Automated	Continuous	Real time
NL - Department of Environment and Climate Change, Water Resources Network	12	Temperature, Humidity, Pressure, Precipitation (rain), Precipitation (snow), Wind, Radiation, Snow Depth, Snow Water Equivalence, Dewpoint, Solar Radiation	Automated	Continuous	Real time
Churchill Falls Labrador Corporation (CFLCo)	8	Temperature, Precipitation (rain), Wind	Automated	Continuous	Real time
Queen's University Coastal Labrador Weather and Climate Monitoring Program	6	Temperature, Humidity, Precipitation (snow), Precipitation (rain), Wind, Radiation, Soil	Automated	Continuous	Real time
City of St. John's	5	Temperature, Wind	Automated	Continuous	Real time
Iron Ore Company of Canada	4	Temperature, Humidity, Wind	Automated	Continuous	Real time
Vale Canada	3	Temperature, Humidity, Pressure, Precipitation (snow), Precipitation (rain), Wind	Automated	Continuous	Real time

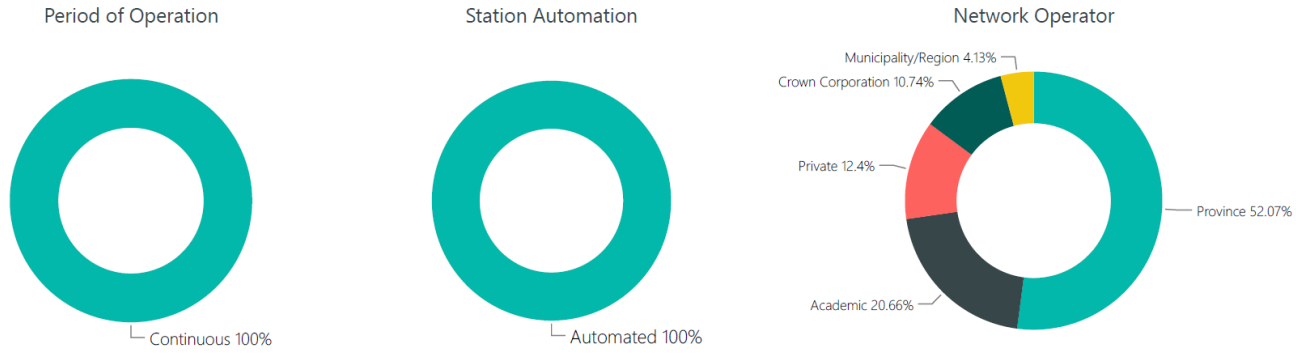


Figure 3.4.4.1 Overview of networks within Newfoundland and Labrador

A data sharing MoU is signed between the Government of Newfoundland and Labrador (including Environment, Climate Change and Municipalities; Fisheries, Forestry and Agriculture; and Transportation and Infrastructure) and ECCC. Monitoring priorities are widespread in NL due to the number and diversity of networks in the province. Water management, road safety, and fire forecasting are key priorities in the province, in addition to marine safety, regulatory requirements and severe weather forecasting.

Parameters vary per network, with over 75 stations measuring air temperature, wind and rainfall and less than 20 measuring air pressure, solar radiation and snow. Approximately 30 stations in the province are equipped to measure precipitation all-year round.

In 2018, the NL Climate Network Owners Working Group was established to provide a forum for discussion amongst climate network owners in Newfoundland and Labrador, to share knowledge on the operation and maintenance of climate stations and to act as a resource on issues relating to climate monitoring. Collaborative challenges in NL revolve around the wide variety of monitoring priorities, making it difficult to utilize data from other networks. Some network owners are reluctant to rely on external networks in order to meet their needs. The biggest operational challenge in the province is the lack of resources for operation and maintenance of networks.

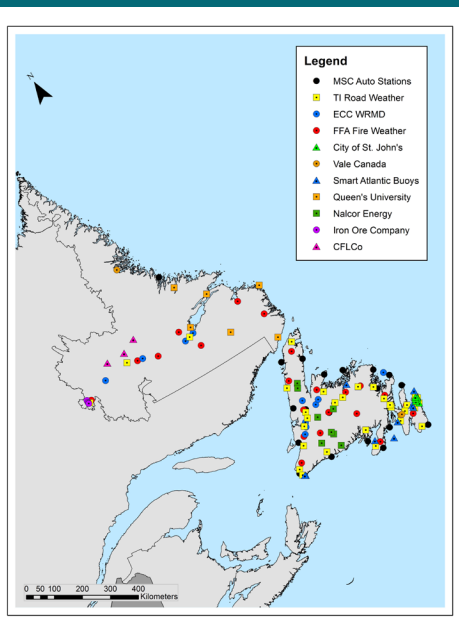


Figure 3.4.4.2 Map of Newfoundland and Labrador Surface Weather and Climate Networks

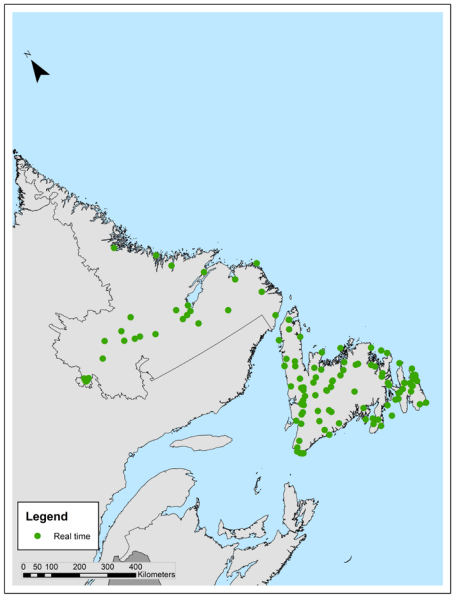


Figure 3.4.4.3 Map of Newfoundland and Labrador non-real time and real time stations

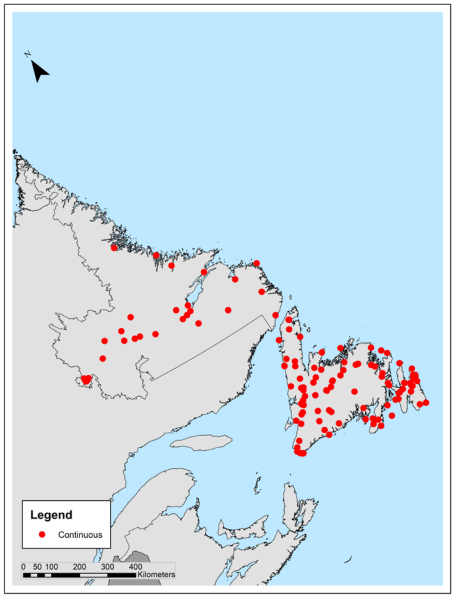


Figure 3.4.4.4 Map of Newfoundland and Labrador continuous and seasonal stations

3.4.5 Common Challenges in Eastern Canada

Monitoring in Eastern Canada comes with many challenges, from limited funding and resources to differences in data collection and management across networks. The following have been identified as the main challenges for surface weather and climate monitoring in Eastern Canada.

Operational Challenges:

Limited funding and resources to support new station installation and maintenance activities. This is a common issue across organizations that can limit the growth of surface weather and climate networks in Eastern Canada.

Limited access to data and dissemination tools. Access to data varies within each province, while some organizations do not have the capacity required to ingest data from other sources or to develop dissemination tools.

Lack of standardization in collection and management of data. Differing priorities, QA/QC processes and metadata collection leads to variability and inconsistency between networks in Eastern Canada. The considerable effort required to standardize also leads to a barrier for data sharing and greater collaboration.

Collaborative Challenges:

No formal governance mechanism to discuss common monitoring issues. With the exception of NL and NS, common issues and needs are not addressed collaboratively between networks and jurisdictions.

No common system for sharing data. While some organizations exchange weather and climate data, there is no common approach to standardize and share data between networks in any jurisdiction. However, NB has begun to develop a shared system for government networks within the province.

3.4.6 Gap Analysis for Eastern Canada

The density of surface weather and climate observations in Eastern Canada is generally higher than other parts of the country, however several microclimates have been observed which are not represented by the current network. Gaps in data availability are also caused by a lack of access to data from existing networks and stations. The most significant gap in the current network can be seen in northern/coastal Labrador.

3.5 Federal Partners

Current federal government networks that monitor weather and climate are depicted below in Figure 3.5.1.1.

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
CCG - Lighthouse Network	29	Temperature, Wind, Dew Point	Automated	Continuous	Real time
DFO - Drifting Buoy Network	58	Temperature, Humidity, Pressure, Marine	Automated	Continuous	Real time
DFO - Moored Buoy Network	9	Temperature, Humidity, Pressure, Wind, Marine	Automated	Seasonal	Real time
DND - AWOS (Automated Weather Observation System)	46	Temperature, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
MSC - Co-operative Climate Network	333	Temperature, Precipitation (rain), Precipitation (snow)	Staffed	Continuous	Non real time
MSC - Drifting Buoy Network	43	Temperature, Pressure, Wind	Automated	Continuous	Real time
MSC - Moored Buoy Network	43	Temperature, Pressure, Wind	Automated	Mixed	Real time
MSC - Radar Network	32		Automated	Continuous	Real time
MSC - Radiosonde Observation Network	30	Temperature, Humidity, Pressure	Mixed	Continuous	Real time
MSC - Surface Weather Network	583	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
Parks Canada	16	Temperature, Precipitation (snow), Wind	Automated	Continuous	Real time

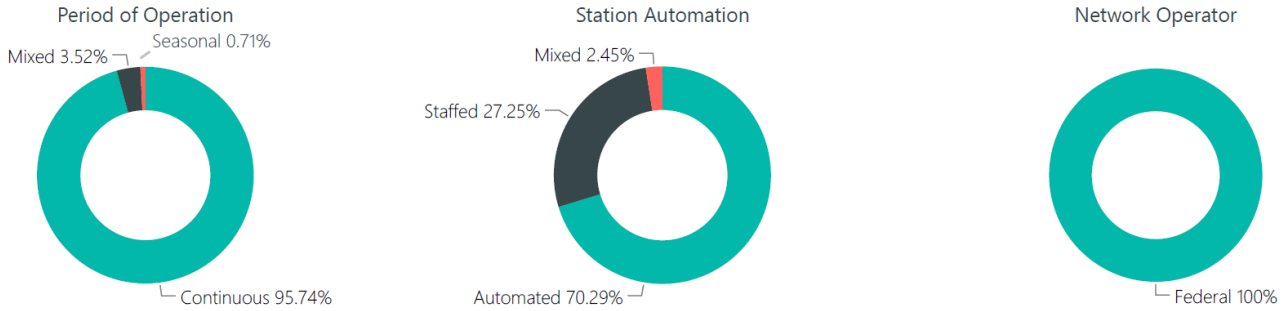


Figure 3.5.1.1 Overview of Federal Networks

Key monitoring priorities across federal departments include public safety, as it relates to marine, aviation and severe weather forecasting, as well as climate and research activities. Parameters are fairly consistent across all stations, but vary depending on network purpose. Networks include automated weather stations, manual volunteer stations, aviation stations and marine buoys.

Although there are active agreements and existing collaborative efforts between various federal departments, there is no standardized approach to collaborate on weather and climate monitoring. Departments have agreed there is a need for a whole of government approach, and see value in improved data access and information sharing for a variety of domains (upper air, permafrost, marine, etc.).

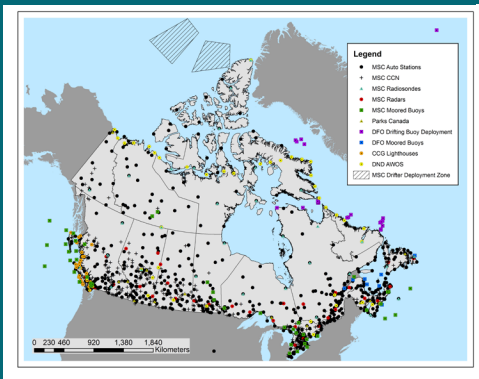


Figure 3.5.1.2 Map of Federal Surface Weather and Climate Networks

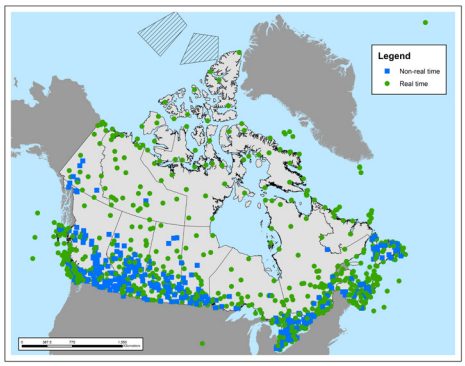


Figure 3.5.1.3 Map of Federal Surface Weather and Climate Networks and non-real time and real time stations

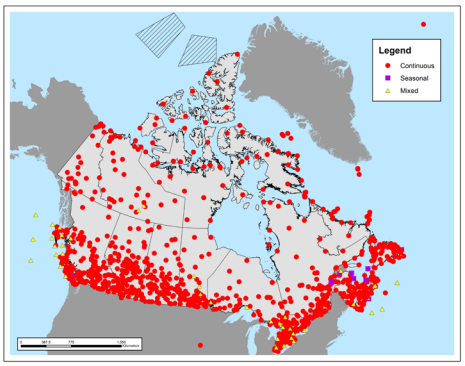


Figure 3.5.1.4 Map of Federal Surface Weather and Climate Networks continuous seasonal stations

3.5.1 Common Challenges for Federal Partners

The following have been identified as the main challenges for surface weather and climate monitoring amongst federal departments.

Operational Challenges:

Limited funding to support new station installation, long-term maintenance and life-cycle management. This is a common issue between all departments and limits the growth of surface weather and climate networks in Canada.

Decommissioning legacy data collection/management systems and transition to new systems. As technology improves and systems are consolidated, considerable effort is required to transition data management processes without disrupting day-to-day operations.

Delays due to lengthy departmental processes for procurement, real estate, etc. that impact timelines for maintenance and new station installation.

Collaboration Challenges:

No formal governance mechanism to discuss common monitoring issues. However, departments agree there is a need for a whole of government approach to weather and climate monitoring in Canada, and are working towards a collaborative agreement.

No common system for sharing data. While some organizations exchange weather and climate data, there is no common approach to standardize and share data between all federal departments. Dissemination of data to the public and other organizations is a challenge for some network operators.

3.5.2 Gap Analysis for Federal Networks

With a shared mandate for public safety, federally operated surface weather and climate networks are denser along the southern border of Canada where population density is the highest. There is a consensus among federal departments of the sparseness of data in Northern Canada as many often must use interpolated data to support their operations.

Section 4: National Data Management Strategy

Historically there has been no national program to support weather and climate monitoring in Canada resulting in a wide range of often incompatible data management practices and standards, and a fragmented system for the dissemination and exchange of data. Users are unable to access nationally produced, real-time or historical weathe and climate data and metadata from a single source, and network operators do not follow standardized practices for the collection, sharing, quality assessment, storage and distribution of this data and metadata. The lack of standardization in data management is a common challenge faced across Canada, which often creates a barrier to greater collaboration between network operators. Other common challenges include a lack of systems to share data, varying QA/QC protocols, and lack of funding to support data management related activities (see Appendix B for detailed definitions of data management terms).

Building upon initial efforts to aggregate weather and climate data through Collaborative Monitoring, a framework for a national data management strategy has been developed and endorsed by members at CWAC.

4.1 Vision

Develop and implement a national data management strategy for Canadian weather and climate data through collaboration of the Federal government, Provincial and Territorial governments, as well as other network operators/data owners (such as academia, Regional/Municipal governments and the private sector). The strategy wil build upon Canadian standards for weather and climate data and cover topics related to transmission, metadata collection, data quality, archiving, access and dissemination, and governance (see Appendix C for information on Canadian standards).

The national data management strategy will follow open data principles to ensure Canadians can find, understand and use all weather and climate information, data and metadata. Data resources are to be open by default and released to the public, unless subject to valid exceptions such as ownership, security, privacy and confidentiality. The strategy will also ensure that open data and information is released in accessible and reusable formats which caters to the accessibility issue aforementioned. Data will be properly attributed in all dissemination platforms so that it is clear who the rightful data owners are.

4.2 Strategic Pillars

The national data management strategy will include six key pillars: telemetry, metadata, quality, archiving, access and dissemination, and governance.

4.2.1 Telemetry

The objective for the telemetry pillar is to ensure continuity and improve the reliability and resiliency in Canadia monitoring network telecommunications. The telemetry pillar will provide guidance on the management of telemetry systems, including an inventory and risk assessment of those currently in use, mitigation strategies for long-term resilience and an evaluation of alternative or novel telemetry systems. It is expected that a coordinated approach to risk assessment and management will benefit data users and provide pertinent information for decision makers. This pillar will be developed in collaboration with the National Administrators Table for Hydrometric Monitoring to enhance the resiliency of both weather and water monitoring networks in Canada.

4.2.2 Metadata

The objective for the metadata pillar is to improve the collection, exchange and standardization of metadata for weather and climate stations and data. This includes both observational metadata, which describes observed variables, sensors, sampling period, site environment, etc., and discovery metadata, which facilitates discovery, access and retrieval of the data. The metadata pillar will align with the *Canadian metadata standard for hydrometeorological monitoring stations*, which includes the collection and public dissemination of metadata through the use and Canadian application of the WIGOS Metadata Standard and OSCAR/Surface.

4.2.3 Data Quality

The objective for the data quality pillar is to enhance the overall quality and utility of observations exchanged between network operators. The data quality pillar will be guided by a principle of known quality, which does not enforce a minimum quality standard but rather encourages sharing metadata and information for users to make informed decisions. It will also align with the national standard entitled *Data qualification for Canadian automated hydrometeorological monitoring stations* which is currently under development. This standar is expected to include a data quality rating system that covers both organizational and instrument specific parameters applicable for hydrometeorological stations in Canada. It will enable network operators to assess the quality of data they collect using a systematic and quantitative approach and make improvements where possible.

4.2.4 Data Archiving

The objective for the data archiving pillar is to improve accessibility and discoverability of historical weather and climate data and information across Canada. Key considerations include timely access to data and products, best practices to maintain long-term value, and forward-looking infrastructure that retains and provides access to non-real-time data and products. This pillar will take into account existing data archives to minimize duplication of effort and duplication of climate records as much as possible.

4.2.5 Data Access and Dissemination

The objective for the data access and dissemination pillar is to ensure Canadians to have the tools they need in order to find and access weather and climate information and data. Principles for this pillar include that all Canadians have access to a common set of tools to visualize data, the tools are developed according to user requirements, and that data is disseminated with proper attribution to its rightful owner. This pillar will draw upon recommendations from the *Data Access and Visualization Tools (DAVT) Committee Report* developed through CWAC. It will align with the data policy as well as the national standard, *Protocols for sharing automated hydrometeorological monitoring stations data and metadata,* which is currently under development.

4.2.6 Data Governance

The objective for the governance pillar is to support long-term strategic, efficient, effective and responsive data management practices for weather and climate data and metadata. Data governance is necessary to ensure there is a set of agreed upon priorities and work plans to support a national data management strategy. It will help obtain perspectives from both service providers and users/clients to guide essential decisions and establish consensus around potential benefits, risks or repercussions. This pillar will aim to utilize existing governance mechanisms and structures as much as possible.

Section 5: Conclusions and Recommendations

Through the coordinated efforts of CWAC, the collection and delivery of weather and climate data and information across Canada will continue to be optimized in support of regional, provincial, territorial and national service delivery, policy development and emergency management preparedness and response. Key common challenges which will be discussed and addressed through CWAC activities include:

Limited funding and human resources to support new station installation, long-term maintenance and life-cycle management. This is a common issue between all jurisdictions and limits the growth of surface weather and climate networks across Canada. Limited funding and resources also impede the ability for jurisdictions to collaborate and work towards common goals.

Lack of standardization in collection and management of data. Differing drivers, QA/QC processes, and data/metadata management lead to variability and inconsistency between networks across Canada. The considerable effort required to standardize also leads to a barrier for data sharing and greater collaboration between network operators.

Lack of formal governance mechanisms and common systems to share data. With the exception of some jurisdictions, common issues and needs are not addressed collaboratively between network operators. Most jurisdictions do not have a common approach or system for data sharing.

Limited capacity and differing objectives between organizations often create barriers to collaboration. Although information is shared between some networks, greater collaboration is often hindered when priorities or network standards do not align.

In an effort to address some of these common challenges, three key recommendations have been put forward for CWAC and member organizations in the short-term:

Finalize the National Data Management Strategy, starting with the development of a national metadata strategy and implementation plan. As articulated above, the lack of standardization in data management is a common challenge across Canada which often creates a barrier to greater collaboration between network operators. Finalizing the national data management strategy is the first step towards implementing a consistent, interoperable, and authoritative data resource for weather and climate observations. Developing the metadata pillar is the first step in finalizing the National Data Management Strategy, as it sets the foundation on which subsequent pillars can be built. It is recommended that the pillar align with the Canadian application of the WIGOS Metadata Standard as articulated through the Canadian metadata standard for hydrometeorological monitoring stations. Metadata uploaded through OSCAR/ Surface is both easily downloadable and updatable as well as fully described and attributed in accordance wit the international standard. Efforts are already underway to pilot the use of OSCAR/Surface for non-MSC stations which will help steer both the strategy and implementation plan.

Develop a national, publicly available resource of monitoring networks, access points and graphical tools to support broader data sharing and visualization. Limited funding and resources is the top challenge faced by network operators across Canada and the primary factor limiting the growth of monitoring networks. Expanding the discoverability of existing weather and climate information and enabling broader access to data will not only benefit Canadians, but support the operational data needs of network operators. By increasing awareness of other monitoring networks and more broadly collaborating with partners we can potentially maximize the volume of observational weather and climate data without greatly increasing operational costs. In line with recommendations from the Data Access and Visualization

Tools Working Group report, this inventory or catalogue would also inform users on what data is currently available and its intended use. It will build upon existing provincial and territorial efforts and those through the Collaborative Monitoring Initiative to collect information on networks across Canada.

Align efforts to improve IM/IT capacity and capabilities (quality assessment & correction, data marts & portals) to maximize the value of existing data resources in Canada. The ability to acquire, manage, store and disseminate weather and climate information requires robust IM/IT infrastructure. This includes improving data quality management functions to ensure continuity of data integrity and dependability, and streamlining dissemination capabilities to provide intuitive and seamless access to a variety of datasets. Collectively optimizing and aligning investments between weather and climate network operators will ensure sustainability and interoperability of Canadian data – whether it's collected from federal, provincial or territorial jurisdictions - now and into the future. It is recommended for CWAC to continue to support inter-jurisdictional coordination to maximize alignment of investment in IM/IT capacity. Congruent with the development of a national metadata strategy and implementation plan, collectively supporting the adoption of a common platform for sharing metadata such as OSCAR/Surface would be a significant first step. This recommendation is in line with the priorities articulated through bilateral engagements between PTs and the MSC.

References

[1] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON. 444 p.

[2] Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario

Appendix A: Weather and Climate Monitoring Networks in Canada

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
YT - Department of Highways and Public Works Road Weather Network	25	Temperature, Precipitation (all weather), Wind	Automated	Continuous	Real time
YT - Department of Environment Yukon Parks	3	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time
YT - Department of Environment Water Resources Network	6	Temperature, Humidity, Pressure, Precipitation (all weather), Wind, Radiation, Soil	Automated	Continuous	Real time
YT - Department of Environment Snow Survey Network	58	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time
YT - Department of Energy Mines and Resources Permafrost Outreach Program	7	Temperature, Soil	Automated	Continuous	Non real time
YT - Department of Energy Mines and Resources Abandoned Mines Network	3	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (snow), Wind	Automated	Continuous	Real time
YT - Department of Community Services Fire Weather Network	27	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Yukon Avalanche Association Avalanche Weather Network	4	Temperature, Humidity, Precipitation (snow), Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time
Yukon Energy	7	Temperature, Precipitation (all weather)	Automated	Continuous	Real time
NWT - Department of Environment and Natural Resources Fire Weather Network	42	Temperature, Humidity, Precipitation (rain), Wind, Radiation, Soil	Automated	Continuous	Real time
NWT - Department of Environment and Natural Resources Snow Survey Network	49	Snow Water Equivalent	Staffed	Seasonal	Non real time
NWT - Department of Environment and Natural Resources Water Management and Monitoring Network	13	Temperature, Humidity, Precipitation (rain), Snow depth, Wind	Automated	Continuous	Mixed
NWT - Department of Infrastructure Road Weather Network	1	Temperature, Humidity, Pressure, Precipitatio (all weather), Wind	Automated	Continuous	Real time

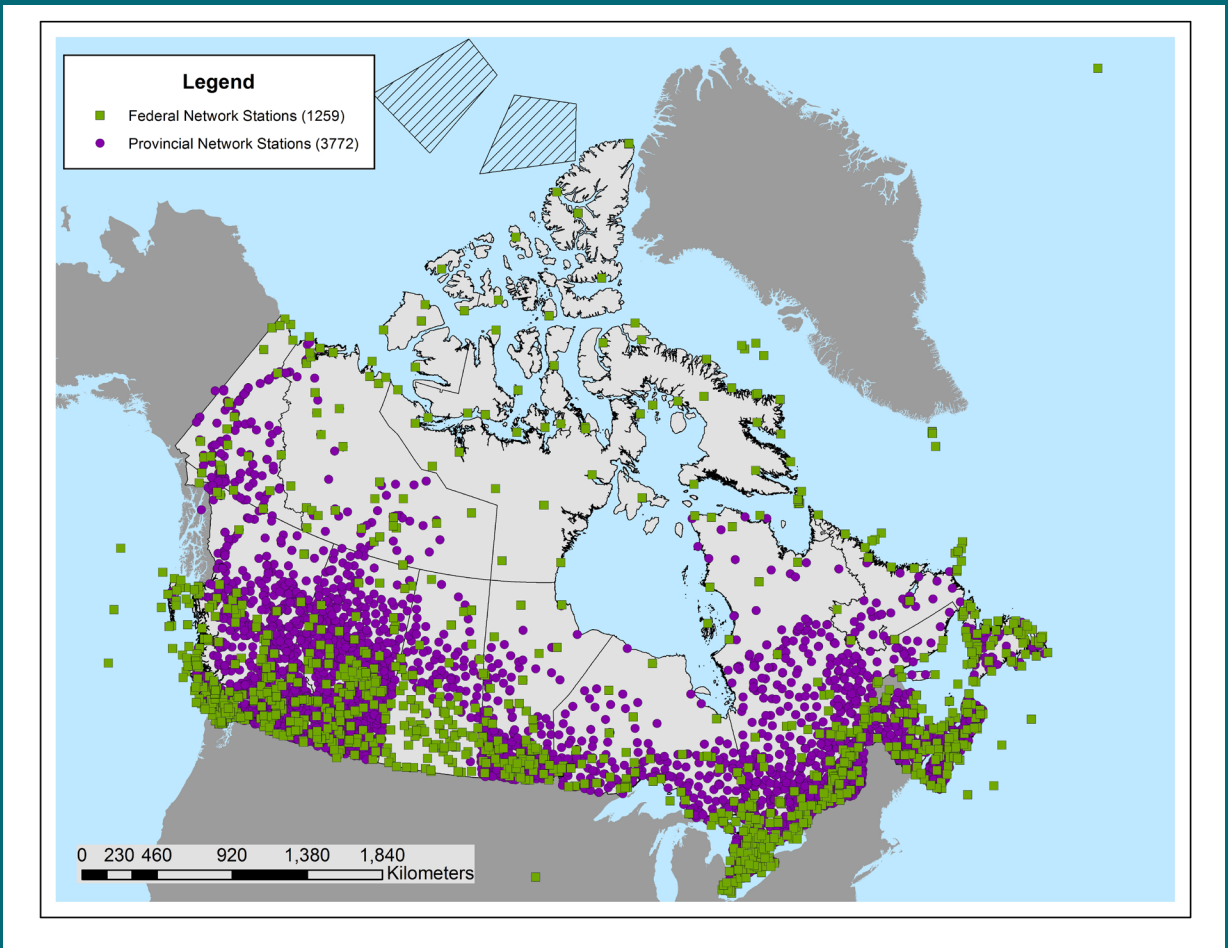
Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
BC - Ministry of Transportation and Infrastructure Avalanche & Road Weather Network	162	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (snow), Wind	Automated	Continuous	Real time
BC - Ministry of Forests Fire Weather Network	254	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Wind	Automated	Continuous	Real time
BC - Ministry of Forests - Forest Ecosystems Research Network	105	Humidity, Precipitation (all weather), Precipitation (snow), Wind, Radiation, Soil	Automated	Continuous	Real time
BC - Ministry of Environment and Climate Change Strategy Automated Snow Weather Network	46	Temperature, Precipitation (all weather), Precipitation (snow), Snow Water Equivalent	Automated	Continuous	Real time
BC - Ministry of Environment and Climate Change Strategy Air Quality-Met Network	54	Temperature, Humidity, Pressure, Precipitation (all weather), Wind, Air quality, Radiation	Automated	Continuous	Real time
BC – Ministry of Agriculture and Foods	27	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Rio Tinto	5	Temperature, Humidity, Precipitation (all weather), Precipitation (snow), Snow Water Equivalent	Automated	Continuous	Real time
Metro Vancouver Watershed Management Network	14	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Snow water equivalent, Wind	Automated	Continuous	Real time
Metro Vancouver Air Quality Network	29	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Capital Regional District	11	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
BC Hydro	100	Temperature, Precipitation (all weather), Snow depth, Snow water equivalent	Automated	Continuous	Real time
AB - Ministry of Transportation Road Weather Network	100	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
AB - Ministry of Environment and Parks Met Network	88	Temperature, Humidity, Precipitation (all weather), Wind	Automated	Continuous	Real time
AB - Ministry of Agriculture, Forestry and Rural Economic Development Fire Weather Network	166	Temperature, Humidity, Precipitation (rain), Wind	Mixed	Continuous	Mixed

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
AB - Ministry of Agriculture, Forestry and Rural Economic Development Ag-Weather Network	179	Temperature, Humidity, Precipitation (all weather), Wind, Radiation	Automated	Continuous	Real time
Saskatchewan Research Council Climate Reference Station Network	2	Temperature, Humidity, Pressure, Precipitation (all weather)	Automated	Continuous	Real time
Saskatchewan Public Safety Agency Fire Weather Network	89	Temperature, Humidity, Precipitation (rain), Wind, Dew point	Automated	Continuous	Real time
Saskatchewan Crop Insurance Corporation Ag-Weather Network	155	Temperature, Humidity, Precipitation (rain)	Automated	Seasonal	Real time
MB - Department of Natural Resources and Northern Development Fire Weather Network	45	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
MB - Department of Transportation and Infrastructure Road Weather Network	32	Temperature, Humidity, Pressure, Water quantity, Wind	Automated	Continuous	Real time
MB - Department of Agriculture Ag-Weather Development	109	Temperature, Humidity, Precipitation (rain), Wind, Radiation, Soil, Dew Point	Automated	Continuous	Real time
City of Winnipeg Rainfall Network	37	Precipitation (rain)	Automated	Continuous	Real time
Manitoba Hydro	9	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
ON - Ministry of Transportation Road Weather Network	148	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
ON - Ministry of Natural Resources and Forestry Surface Water Monitoring Network	122	Precipitation (rain)	Automated	Continuous	Real time
ON - Ministry of Natural Resources and Forestry Fire Weather Network	142	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Snow depth, Wind	Automated	Continuous	Real time
Toronto and Region Conservation Authority	39	Temperature, Precipitation (rain)	Automated	Continuous	Real time
Grand River Conservation Authority	27	Temperature, Precipitation (rain)	Automated	Continuous	Real time
Hydro-Québec Snow Weather Network	68	Precipitation (snow), Snow water equivalent	Automated	Continuous	Real time

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Snow Survey Network	107	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time
Société de protection des forêts contre le feu	69	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
QC - Ministère des Forêts, de la Faune et des Parcs	16	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
Rio Tinto	13	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Snow water equivalent, Wind	Automated	Continuous	Real time
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Automated Network	93	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Snow water equivalent, Wind	Automated	Continuous	Real time
Hydro-Quebec	80	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
QC - Ministère de l'Environnement et de la Lutte contre les changements climatiques Observer Network	157	Temperature, Precipitation (all weather), Precipitation (snow), Snow water equivalent, Weather phenomenon observation	Mixed	Continuous	Non real time
NB Power	4	Temperature, Precipitation (rain)	Automated	Continuous	Real time
NB - Department of Natural Resources and Energy Development Fire Weather Network	26	Temperature, Humidity, Precipitation (all weather), Precipitation (rain), Wind	Automated	Continuous	Real time
NB - Department of Agriculture, Aquaculture and Fisheries Ag-Weather Network	34	Temperature, Humidity, Pressure, Wind, Radiation, Soil	Automated		Real time
NB - Department of Transportation and Infrastructure Road Weather Network	46	Temperature, Humidity, Precipitation (all weather), Wind	Automated	Continuous	Real time
NB - Department of Environment and Local Government Snow Survey Network	58	Precipitation (snow), Snow water equivalent	Staffed	Seasonal	Non real time

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
NS - Department of Public Works - Road Weather Information System	51	Temperature, Humidity, Wind	Automated	Continuous	Real time
NS - Department of Natural Resources and Renewables - Fire Weather Network	31	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
NS - Department of Agriculture & Perennia - Farm Weather Network	100	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
NS - Municipality of the District of Digby - Coastal Management Network	5	Temperature, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
Nova Scotia Fruit Growers' Association - Smart Farm Network	10	Temperature, Humidity, Pressure, Precipitation (rain), Wind, Solar Radiation	Automated	Continuous	Real time
Cape Breton Mesonet	89	Temperature, Humidity, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
Nova Scotia Community College Ag-Weather Network	72	Temperature, Humidity, Precipitation (rain), Wind, Radiation	Automated	Continuous	Real time
PEI - Department of Transportation and Infrastructure Road Weather Network	5	Temperature, Humidity, Pressure, Wind, Dew Point	Automated	Continuous	Real time
PEI - Department of Agriculture and Fisheries Ag-Weather Network	13	Temperature, Humidity, Vapour Pressure, Precipitation (rain), Wind	Automated	Seasonal	Real time
UPEI Climate Research Lab	36	Temperature, Pressure, Precipitation (rain), Wind, Radiation, Marine	Automated	Continuous	Non real time
NL - Department of Transportation and Infrastructure Road Weather Network	28	Temperature, Precipitation (rain), Wind	Automated	Continuous	Real time
NL - Department of Fisheries, Forestry and Agriculture Fire Weather Network	23	Temperature, Humidity, Precipitation (rain), Wind	Automated	Continuous	Real time
Smart Atlantic Buoy Network	19	Temperature, Pressure, Wind	Automated	Continuous	Real time
Nalcor Energy	13	Temperature, Humidity, Precipitation (all weather), Wind, Snow Water Equivalent	Automated	Continuous	Real time
NL - Department of Environment and Climate Change, Water Resources Network	12	Temperature, Humidity, Pressure, Precipitation (rain), Precipitation (snow), Wind, Radiation, Snow Depth, Snow Water Equivalence, Dewpoint, Solar Radiation	Automated	Continuous	Real time

Network title	Number of stations	Category of reported elements	Station automation	Period of operation	Data feed frequency
Churchill Falls Labrador Corporation (CFLCo)	8	Temperature, Precipitation (rain), Wind	Automated	Continuous	Real time
Queen's University Coastal Labrador Weather and Climate Monitoring Program	6	Temperature, Humidity, Precipitation (snow), Precipitation (rain), Wind, Radiation, Soil	Automated	Continuous	Real time
City of St. John's	5	Temperature, Wind	Automated	Continuous	Real time
Iron Ore Company of Canada	4	Temperature, Humidity, Wind	Automated	Continuous	Real time
Vale Canada	3	Temperature, Humidity, Pressure, Precipitation (snow), Precipitation (rain), Wind	Automated	Continuous	Real time
MSC - Co-operative Climate Network	333	Temperature, Precipitation (snow), Precipitation (rain)	Staffed	Continuous	Non real time
CCG - Lighthouse Network	29	Temperature, Wind, Dew Point	Automated	Continuous	Real time
DFO - Drifting Buoy Network	58	Temperature, Humidity, Pressure, Marine	Automated	Continuous	Real time
DFO - Moored Buoy Network	9	Temperature, Humidity, Pressure, Wind, Marine	Automated	Seasonal	Real time
DND - AWOS (Automated Weather Observation System)	46	Temperature, Pressure, Precipitation (all weather), Wind	Automated	Continuous	Real time
MSC - Drifting Buoy Network	43	Temperature, Pressure, Wind	Automated	Continuous	Real time
MSC - Moored Buoy Network	43	Temperature, Pressure, Wind	Automated	Mixed	Real time
MSC - Radar Network	32		Automated	Continuous	Real time
MSC - Radiosonde Observation Network	30	Temperature, Humidity, Pressure	Mixed	Continuous	Real time
MSC - Surface Weather Network	583	Temperature, Humidity, Pressure, Precipitation (all weather), Precipitation (rain), Precipitation (snow), Wind	Automated	Continuous	Real time
Parks Canada	16	Temperature, Precipitation (snow), Wind	Automated	Continuous	Real time


Legend
Federal Network Stations (1259)
Provincial Network Stations (3772)
0 230 460 920 1,380 1,840
Kilometers

Appendix B: Definition of Key Terms

Data Archive: The long-term repository of climatological and meteorological data and information.

Data Quality: The combination of quality principles, quality assurance and quality control measures. Quality assurance is a system of planned and systematic management activities necessary to provide adequate confidence that data, products or services will fulfill quality requirements. Quality control is a system of operational techniques and activities that measure, assess and characterize the quality of data, products or services.

Governance: Coordination mechanism to enable decision-making, share information and ideas, and determine accountability.

Metadata: Information on the capabilities of observing stations/platforms and their instruments and methods of observation. Observational metadata should describe the observed variable, the conditions under which it was observed, how it was measured, and how the data has been processed, to provide users with confidence that the data is appropriate for their application.

Open Data: Data that is freely shared, used and built on without restriction.

Quality Assessment (Qa): An evaluation where data are subjected to quality check routines used to assess and characterize the quality of data. Techniques generally involve subjecting data to compliance criteria or algorithms, which may result in non-compliant or suspicious data being flagged with specific indicators to facilitate control measures, follow-up investigation/intervention, or providing cautionary metadata for users.

Quality Assurance (QA): A system of planned and systematic management activities necessary to provide adequate confidence that data, products or services will fulfill quality requirements. Quality Assurance includes the organization, planning, data collection, quality control, documentation, training plans, auditing, reporting, preventative measures to preclude non-conformance, and quality improvement to ensure that quality objectives are met. Quality Assurance activities establish the extent to which quality will be, is being, or has been, assured.

Quality Control (QC): A system of operational techniques and activities that measure, assess and characterize the quality of data, products or services, through error detection, statistical control, and remedial actions in response to non-conformance, in order to satisfy given quality requirements. Quality Control is an important component of total quality management and is a process for verifying standards, not creating them.

Quality Correction (Qc): The process in which a correction or adjustment is made to the data as remedial action in response to QC activities.

Appendix C: National Standards for Weather Stations and Data

CSA Group has been commissioned by the Standards Council of Canada (SCC) to develop four National Standards of Canada (NSC) focusing on data and metadata collected from hydrometeorological monitoring stations. The four standards include:

- **NSC 1:** the collection and public dissemination of metadata for hydrometeorological monitoring stations;
- **NSC 2:** siting, design and operations of hydrometeorological stations;
- **NSC 3:** an approach and criteria to evaluate quality of data collected at automated monitoring stations; and
- **NSC 4:** protocols for sharing hydrometeorological data sets across information systems.

These standards will promote consistency in the methods, procedures, techniques, and practices used for collecting and sharing hydrometeorological data and metadata in Canada. Standardization and improved best practices will help make more hydrometeorological observations become more easily accessible to a larger and better-informed audience.

The first standard, CSA R100:20, *Canadian metadata standard for hydrometeorological monitoring stations*, was published in late 2020. The standard is a Canadian adoption without modification of the WMO's OSCAR/ Surface tool, a global climate data reporting platform.

Development of the remaining standards is underway with expected publication by March 2023.