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Climate Observing During Canada's Empires, 1742–1871: People, Places and Motivations

Victoria Slonosky and Isabelle Mayer-Jouanjean

Abstract

A wealth of pre-Confederation weather and climate observations were recorded in Canada by individuals and institutions during both the French and British empires. This scientific heritage came about for a number of reasons. For instance, the Hudson's Bay Company wanted to reduce operating costs by having their posts in Canada's north-west become self-sufficient in agriculture. Others wished to save lives from cholera or shipwrecks, or to satisfy curiosity about the ever-present debate concerning anthropogenic climate change. Today, historical climate observations can be found in many diverse locations. Despite our rich scientific heritage, turning archival paper and ink observations into scientific data remains an enormous technical challenge. This challenge falls to our generation, both to use this heritage to investigate the historical context of current climate change and variability, and to use the digital resources in development today to safeguard our scientific heritage for future generations.

Keywords: Historical climatology, history of weather, history of climate, history of science, Canada, weather data rescue, climate change

Introduction

The climatic variations found in the Americas, ranging from the frigid northern and southern extremes to the humid tropics, have always fascinated and challenged human societies. Popular physical anthropologists[1] and cultural historians[2] have theorized that climatic extremes and a hazardous environment profoundly shaped human culture and society in the Americas from the times of earliest human occupation. In North America, including the territory now known as Canada, the first European explorers and colonizers were particularly puzzled and intrigued by the 'problem' of climate. Why were the seasons so much more extreme, and in particular the winters so much colder, than at similar latitudes in their home countries in Europe?[3] These differences were so startling and unexpected that descriptions of the weather and climate can be found in the earliest Canadian documentary records, though the 'climate shock' encountered can make evaluation of the descriptions therein difficult. Was the weather and climate described really extreme for the location, or did it only seem so to someone newly arrived from a generally milder climate? The situation is made more complicated still by the fact that the initial centuries of settlement of North America by Europeans were made during an exceptionally cold and unsettled climatic period.[4]

In Canada, therefore, we have documentary descriptions of weather and climate events dating back over four centuries.[5] Long-term instrumental meteorological records date back to 1742 for the St Lawrence Valley region,[6] with sporadic observations for the Hudson's Bay region dating back to the 1730s.[7] Canada has a rich, but largely unrecognized scientific heritage hidden in archives. As this heritage is usually in paper form, it is often unavailable for digital sharing or scientific analysis, a format that is necessary to evaluate climate change or hazardous extreme[8] events such as floods, ice storms or heat waves.

In this article we explore some of the various types of historical records relating to weather and climate in Canada. The first part looks at who kept weather- and climate-related records, where they were stored, and why people were interested in keeping such records. The second part describes how these records are being organized and who is using them today. Two historical data projects have recently been developed in Quebec: the AQUARISC (Quebec contribution for anticipation of floods and droughts risks in Canada) database[9] and the ACRE (Atmospheric Circulation Reconstruction over the Earth)–Canada collection.[10] The AQUARISC database is a collection of records including written documents, photographs, and instrumental data concerning all hydrological events on the southern shore of the St Lawrence River between Quebec City and Montreal to the US border since the beginning of the documentary period. ACRE–Canada is a project which undertakes the collection and transcription in digital format of original historical meteorological data from present-day Canada, from the period of the earliest instrumental records to the founding of the Meteorological Service of Canada (MSC) in 1871. The MSC is now part of the government entity known as Environment and Climate Change Canada (ECCC).

Historical Reasons for Recording and Preserving Weather Records

The European discovery of the New World and attempts at colonization by European settlers coincided with the Little Ice Age, a period of cold and variable climate between roughly the fourteenth and the early nineteenth century. The seventeenth century was particularly harsh in North America, as extensively documented by Sam White.[11] The prevailing European climatic theories in the sixteenth and seventeenth centuries were based on sciences little changed since the Classical period, which held that climate was determined by latitude. The Europeans, therefore, expected climates in North America to be similar to those of European regions at the same latitudes: Montreal, at 45°N, is approximately parallel with Bordeaux, France, while York Factory, the major fur-trading hub on the Hudson Bay, at 57°N, is parallel with Aberdeen, Scotland.

Explanations for the difference in climate between France and New France were sought by the curé Louis Cotte (1740–1815), who had published his *Treatise on Meteorology*[12] in 1774. In 1776, Cotte was tasked by the French *Société royale de médecine* (Royal Medical Society) with the creation of a worldwide meteorological observation network.[13] The opening up of trade routes,[14] especially between Europe and the Far East, meant that knowledge of meteorological conditions that could affect shipping and sailing times became commercially important information.

At the same time, weather records by individuals and institutions such as observatories and colleges were recorded in a spirit of scientific curiosity and enthusiastic interest in the natural world. The invention in the seventeenth century of instruments necessary for objectively measuring atmospheric conditions,[15] such as the thermometer, barometer, anemometer and rain gauges, gave meteorology a definitive scientific status. Over the course of the seventeenth and eighteenth centuries, these instruments allowed successive generations of scientists to define fundamental physical laws governing the atmosphere, which in turn led to a better understanding of the weather.

Practical Reasons for Recording and Preserving Weather Records

Self-Sufficiency and Agriculture

Keeping meteorological observations to help determine the local suitability of various crops and agricultural activities may seem to be self-evident. However, agricultural suitability is only one among many reasons cited in the eighteenth and nineteenth centuries for maintaining a record of weather observations.[16] In 1814, the Hudson's Bay Company (HBC), in partnership with the Royal Society of London (RS), supplied meteorological instruments to fur-trading posts. The HBC required meteorological observations to be kept with the aim of potentially making posts self-sufficient in agriculture, thus reducing the costs of supplying the posts by ship from the UK. 'An accurate comparison' between the climate of the Hudson Bay region and that of northern Europe was required.[17] Unfortunately, this attempt at self-sufficiency came in the second decade of the nineteenth century, possibly the coldest of the millennium.[18]

An example of a mandate to keep meteorological records with a view to becoming agriculturally self-sufficient is the HBC's 1814 directive described by Wilson.[19] These records could be described as institutional as there was not always one self-motivated observer for the entire length of the record. At the same time, there are several long-term records associated with HBC posts which appear to be partly self-motivated; by William Woods (possibly father and son; dates unknown) at York Factory from the 1820s to the 1880s, (Figures 1b and 1c) for which fragmentary records have been recovered, or by John Siveright (1779–1856) at Sault Ste Marie and Fort Coulonge from 1821 to 1833 (Figure 2a).

Knowledge of the climate as an aid for agriculture was cited as a motivational factor for the study of climatology. John Henry Lefroy (1817–1890) of the Royal Artillery and Director of the Toronto Observatory, wrote that 'Almost every house possesses a thermometer.'[20] The volunteer observers who sent their observations to the Smithsonian Institute did so on printed forms 'Adopted for the Commissioner of Agriculture for his Annual Reports' after 1860 (Figures 1c and 2b).[21]

Records kept specifically for agricultural purposes have not, so far, been widely found in Canadian archives with one or two exceptions. There is the journal by Robert Cleghorn (1778–1841), a professional plant nurseryman on the island of Montreal in the early nineteenth century.[22] Jean-François Gaultier (1706–1756) recorded Canada's first long-term instrumental daily weather record in 1742–54 while Thomas

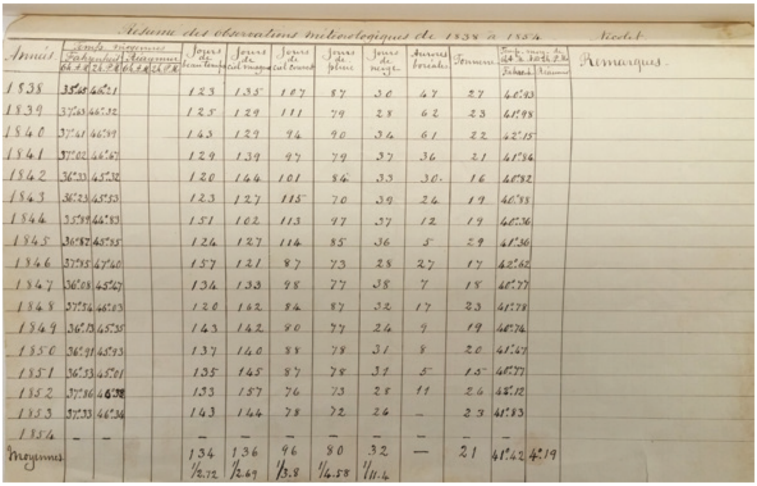
McCord (1750–1824) and Louis-Edmond Glackmeyer (1793–1881) kept phenomenological notes on the flowering of fruit trees, arrival of bird or insect species in the spring, harvest dates or river freeze-up and break-up.[23]

Medicine and Health

Medicine was another practical reason for keeping meteorological records in the era before Louis Pasteur's (1822–1895) germ theory.

Figure 1. Continued

e



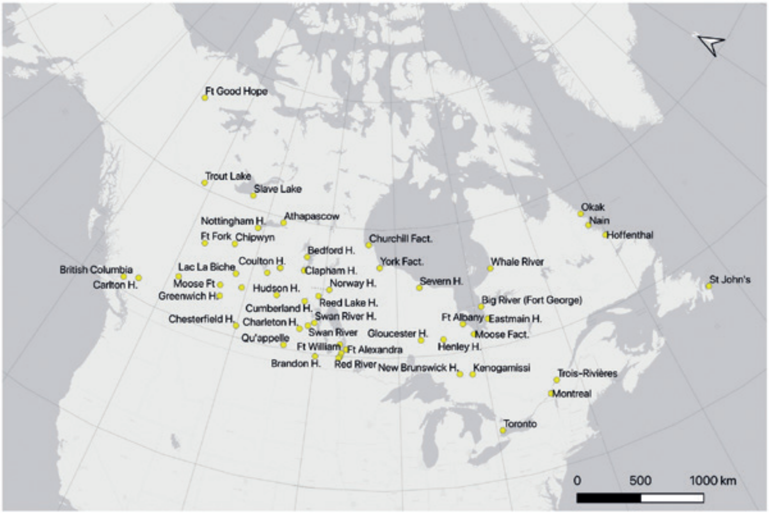
Résumé des observations météorologiques de 1838 à 1854. Nicolet.

Années	Temp. moyennes Fahrenheit 6h A.M.	Fahrenheit 2h P.M.	Réaumur 6h A.M.	Réaumur 2h P.M.	Jours de beau temps	Jours de ciel nuageux	Jours de ciel couvert	Jours de pluie	Jours de neige	Aurores boréales	Tonnerre	Temp. moy. de 6h à 2h P.M. Fahrent.	Réaumur	Remarques
1838	35°.65	46°.21			123	135	107	87	30	47	27	40°.93		
1839	37°.63	46°.32			125	129	111	79	28	62	23	41°.98		
1840	37°.41	46°.99			143	129	94	90	34	61	22	42°.15		
1841	37°.02	46°.67			129	139	97	79	37	36	21	41°.86		
1842	36°.33	45°.32			120	144	101	86	33	30.	16	40°.82		
1843	36°.23	45°.53			123	127	115	70	39	24	19	40°.88		
1844	35°.89	44°.83			151	102	113	97	37	12	19	40°.36		
1845	36°.87	45°.85			124	127	114	85	36	5	29	41°.36		
1846	37°.85	47°.40			157	121	87	73	28	27	17	42°.62		
1847	36°.08	45°.47			134	133	98	77	38	7	18	40°.77		
1848	37°.54	46°.03			120	162	84	87	32	17	23	41°.78		
1849	36°.13	45°.35			143	142	80	77	24	9	19	40°.74		
1850	36°.91	45°.93			137	140	88	78	31	8	20	41°.47		
1851	36°.53	45°.01			135	145	87	78	31	5	15	40°.77		
1852	37°.86	46°.38			133	157	76	73	28	11	26	42°.12		
1853	37°.33	46°.34			143	144	78	72	26	–	23	41°.83		
1854	–	–			–	–	–	–	–	–	–	–		
Moyennes					134 1/2.72	136 1/2.69	96 1/3.8	80 1/4.58	32 1/11.4	—	21	41°.42	4°.19	

f

Figure 1. Examples of archival weather information: (a)–(c): Meteorological records from York Factory on the western shore of Hudson's Bay for (a) 1773, (b) 1843 by William Woods, (c) 1875 from the Smithsonian collection; (d) January 1859 weather for Quebec City kept by the Royal Engineers; (e) Nicolet, Quebec; (f) photographs of ice dams causing flooding at Montreal between 1865 and 1875.
Source: (a) York Factory, 1778 from United Kingdom Meteorological Office (UKMO) Library and Archive (Private Weather Diary for Hudson's Bay, Canada (DCnn: 9HUB)); (b) York Factory, 1843 from MSC archives manuscript 1842C, UKMO Archive; (c) York Factory, 1875, NARA; (d) Quebec City, January 1859, graphs from MSC archives manuscript 1859A; (e) François Desaulniers, Séminaire de Nicolet, Centre d'archives regionales, AQUARISC database; and (f) Alexander Henderson, Montreal wharfs in winter, Montréal, QC, 1865–1875, MP-0000.1452.50 © McCord Museum/Musée McCord. AQUARISC database. Images used by permission.

a HBC posts and observations in Royal Society archives 1770–1830



b Locations of observers reporting to the Smithsonian Volunteer network and other 19th century Canadian observations from international archives

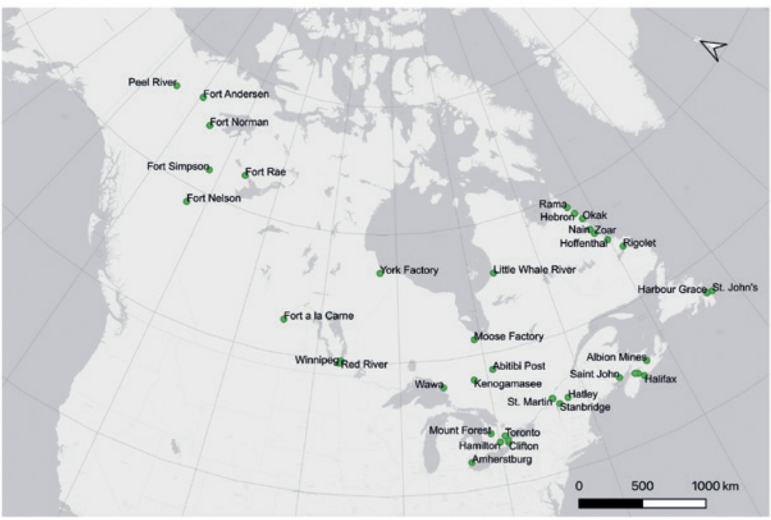
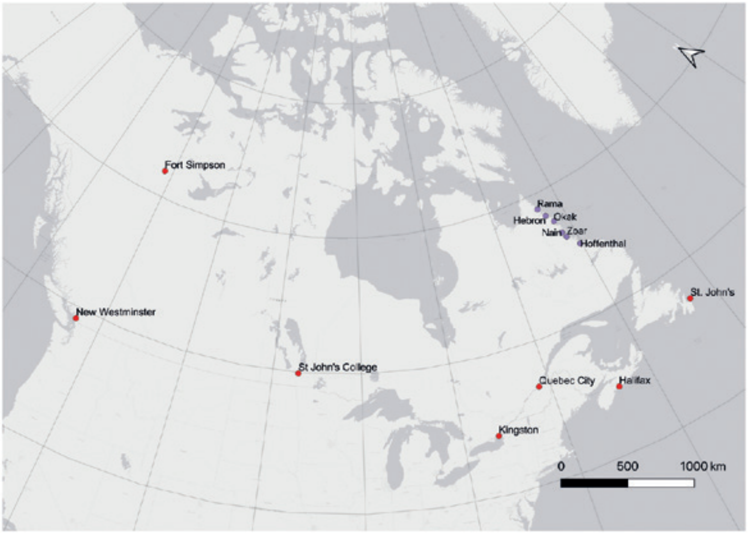


Figure 2. Maps showing locations where observers kept weather journals: (a) Hudson Bay Company posts where weather journals were recorded (information courtesy of Cynthia Wilson and Ken Devine); (b) records from NARA, largely collected from the Smithsonian Institute volunteer weather observing network; (c) weather-observing stations from European archives, such as the UK Royal Engineers and Army Medical Department and the Moravian missionaries in Labrador; (d) weather records from local, provincial and national Canadian archives.

(*Caption continued on next page*)

c Royal Engineers posts reporting daily weather and other locations from the European archives c.1850–1900



d Locations of meteorological observations in national, provincial and local Canadian archives 1760–1870

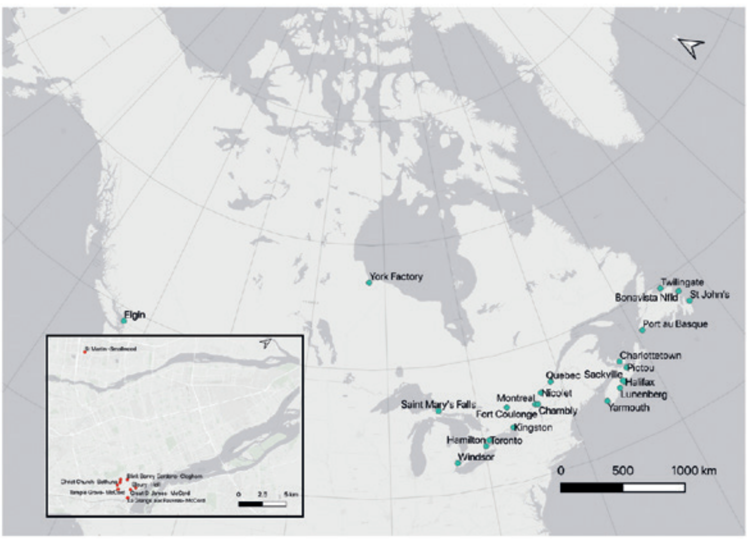


Figure 2. *Note*: Observers sometimes sent their observations to various collecting agencies over time, with the result that records from the same location are now often to be found in a variety of different archives, both within and beyond Canada. Many locations which are visible as a point on a national map contain complex series from multiple overlapping observers at cities such as St John's, Halifax and Montreal, shown in the inset.

Besides keeping descriptions of weather and prevailing diseases, Gaultier acted as King's Physician to the colony of Quebec, although he also kept careful note of agricultural conditions alongside them. A recurring concern of Gaultier's was malnutrition caused by poor harvests, often due to weather conditions unconducive to crop growth such as rainy autumns or early frosts. Throughout the nineteenth century, doctors were at the forefront of recording and publishing meteorological data. The neo-Hippocratic theory of disease was a seventeenth-century revival of the ancient ideas of Hippocrates that atmospheric conditions influenced disease.[24] This view was commonly held until Pasteur developed his germ theory in the late nineteenth century. Identifying connections between prevailing weather conditions and disease was the motivating factor behind the observation network set up by the French *Société royale de médecine* with Cotte in 1776. The terrifying epidemics of typhus and cholera that swept through the early- to mid-nineteenth-century world, especially Canada,[25] brought about a renewed interest in connections between weather, atmosphere and disease from doctors desperate to stem the tide of mortality. Canadian naturalist and geologist Charles Smallwood (1813–1873) intensively investigated the connection between atmospheric ozone and disease, especially cholera, as ozone, like chlorine, was seen to have bleaching and thus potentially disinfectant properties.[26]

Engineering, Navigation and Storm Warnings

A circular from the British government in Downing Street dating from 29 November 1838, and signed by Glenley (dates unknown), mentioned a study that had been recently written by Col. William Reid (1791–1858), entitled 'The Law of Storms'. Reid, who was a colonel in the Royal Engineers posted in the Bahamas, had just witnessed the devastation wrought by a tropical hurricane. The Downing Street circular, also bearing the title 'Laws of Storms' in reference to Reid's article, endorsed Reid's call for more meteorological observations to be made in order to 'develop with a view to practical uses in navigation the laws by which storms and variables winds are governed'.[27] Glenley 'therefore request[s] you to communicate with such officers or private individuals in the Colony under your government, as may appear to you best qualified to furnish information on the subject, pointing out to them the service which they would render to science by keeping journals'.

Richard Henry Bonnycastle (1791–1847), also of the Royal Engineers, wrote that in 1842, 'It is to be regretted that the British government have not established an observatory at St John's, which, with the one at Toronto in Western Canada, would very usefully maintain observers, not for astronomical purposes exclusively, but for meteorological science.'[28] He added to this a recommendation that engineering officers should be 'permitted to carry their libraries and instruments at the public expense and duty free'.[29]

It took nearly a decade before Bonnycastle's recommendations, both in general and in particular, were taken up. The Inspector-General of the Royal Engineers (Sir John Burgoyne) decided in 1851 that it would be 'highly useful to science' if the Royal Engineers were to undertake meteorological observations, especially if they were kept 'on one uniform system, under instructions and by authority'.[30] Instruments were sent out to 19 'Foreign and Colonial' stations in 1852 and observations started between 1852 and 1853. The Royal Engineers established twice-daily weather observations of 24 variables using 10 instruments in a number of Canadian locations, including St John's ('Newfoundland'), Halifax, Quebec City (Figure 1d) and Kingston. A post in New Westminster, British Columbia, started in 1859 with the arrival of the Royal Engineers on the West Coast. Observations continued into the 1870s with the Army Medical Department at Halifax and Quebec City (Figure 2c).

In August and September of 1853, the Maritime Conference held in Brussels was the first of the landmark international nineteenth-century meteorological conferences 'for the purpose of establishing a uniform system of observations at sea'.[31] Naval Captain Robert Fitzroy (1805–1865) of *Beagle* (Darwin) fame and US Navy Lt Maury (1806–1873) were pioneers in collecting wind and current observations, analysing them to construct navigational charts to improve safety and decrease voyage lengths. In Canada, the Atlantic Coast, St Lawrence River and the Great Lakes were the main transport and communication arteries of the country for much of the nineteenth century. Consequently, shipwrecks and their loss of lives and goods caused great concern. Storm warnings were one of the main justifications for the foundation of the MSC, after decades of lobbying, in 1871, under the auspices of the Department of Marine and Fisheries.

It appears from letters written by Lefroy that meteorological observations had been kept in military guardrooms in Upper and Lower Canada and the Atlantic provinces since the 1840s, including 'Queenston, Kingston, Toronto, London, Newfoundland, Fredericton and Halifax'.[32] Lefroy, and the Royal Artillery generally, were involved in the 'Magnetic Crusade' behind the founding of the Toronto Observatory.

Theory and Knowledge Seeking

Climate Change

The popular theory generally settled on by the mid- to late eighteenth century to explain differences between the New and Old World climate was the 'cultivation and climate improvement' theory.[33] This held that the increased climatic extremes in north-eastern North America, including the severe winter cold, was a consequence of the densely forested and 'swampy' nature of the terrain. As forests were cleared, swamps drained and land brought under cultivation, the theory claimed that the climate would correspondingly moderate.[34] This seemed to be regarded with some caution, if not outright scepticism, however, especially by observers in North America: Gaultier, John Samuel McCord (1801–1865), naval surveyor William Kelly (active in the early nineteenth century; dates unknown) and by European Enlightenment polymaths Daines Barrington (1728–1800) and Theodore Mann (1735–1809). In addition, William Kelly wrote vigorously against the climate improvement theory in 1838, comparing the records of a local observer in Quebec City, Mr Barr, with observations from early explorers such as Samuel de Champlain.[35] McCord attempted to investigate the climate improvement theory using his own observations as well as earlier instrumental records he found from other observers. His investigations led him to be dubbed the 'Pioneer of Canadian Meteorology'.[36] His nineteenth-century collection of weather records form a core component of Canada's historical climatology collection today.

Lefroy held that 'whether a … change of climate has occurred may be determined by our posterity if we will only take a little trouble in the matter.'[37] Gaultier also expressed the hope that his observations would be, if not of immediate use, helpful to posterity.[38]

The Enlightenment and the Magnetic Crusade

After Gaultier's work in 1742–54, the first official government-sponsored observatory in Canada, which later evolved into the MSC, was set up, not primarily for meteorological observations but for magnetical observations in 1839. The 'Magnetic Crusade' was a Humboldtian[39] enterprise to understand connections between different geophysical phenomena and to map variations in the Earth's geomagnetic field. Weather observations by military units started in 1840 with the founding of the Toronto Observatory by the Royal Artillery mainly for the purposes of magnetic observations. The story of the founding of the Toronto Observatory has been described in detail by Thiessen, Thomas, Zeller and one of the current authors (Slonosky).[40]

Some record keepers appear to have recorded meteorological observations more out of a desire for furthering knowledge or scientific curiosity than for immediate practical or public applications. This seems particularly true of religiously affiliated observers and those arising out of the Scottish Enlightenment tradition.[41] Presbyterian minister Alexander Spark (1762–1819), Anglican minister John Bethune (1791–1872) and the anonymous religious sisters from various convents in Quebec, who sent their precipitation records to the MSC headquarters in Toronto, may have been such knowledge seekers. Neither Spark nor Bethune appear to have published or even analysed their records in detail. Nevertheless, their records rank as among the best for consistency and quality of observations. They are used as benchmarks for other more professionally connected observers such as John Samuel McCord and Charles Smallwood, who was the first professor of meteorology at McGill. After the sisters stopped reporting their observations, Charles Carpmael, Deputy Superintendent of the MSC, lamented that 'good quality data was now hard to get'.[42]

Other observers who appeared to be driven mainly by curiosity include explorers affiliated with the HBC. Before the directive of 1814, they kept meteorological readings on their journeys more out of a spirit of scientific discovery.[43] It was in this spirit that the HBC co-operated with the RS on scientific ventures such as the expeditions to measure the transit of Venus in 1769 (Figure 1a).[44] The meteorological documents from Rupert's Land in the RS archives investigated by Cynthia Wilson, for example, contain over 75 manuscripts with daily observations between 1766 and 1853, and over 50 in the HBC archives between 1770 and 1823 (Figure 2a).[45] Ken Devine identified over 25 individuals among early Canadian observers in the Canadian Northwest (Figure 2a). Peter Fidler (1769–1822), active between 1789 and 1819, was outstanding for the geographical breadth of his observations and the three decades of his continued observations.[46]

Professors at institutes of learning such as Acadia College in Nova Scotia, Hudson Bay Company employees, doctors and other volunteer observers across Canada contributed to the Smithsonian Volunteer Weather Observers Network (Figure 2b). The later Canadian volunteer weather observing network may also have been motivated by knowledge seeking.

Historical Records

Where are the Records Today?

Where the records are located now depends to an extent on where the data were collated after they were recorded, who kept them, and why they were kept. Table 1 shows the data life cycle of different types of meteorological and climatological records. Personal records were largely kept in family records; a prime example of this is the McCord collection. John Samuel McCord not only kept meteorological records himself but also collected the journals and records of his contemporaries and, in some cases, those who came before him. Many of the early records of Canadian climate are available to us today due to quirks of personal circumstance. McCord's son, David Ross, had sufficient wealth inherited from his forebears to found a museum, in whose archives family papers, including his father's scientific papers, were conserved.

In other instances, observations were collected by organizations for specific purposes. Examples of these include the Hudson Bay Company and the Smithsonian volunteer observers' network. In these cases, original logbooks or copies of logbooks, such as monthly registers were sent to the main collecting agencies. These were often located outside Canada, including the Hudson Bay Company headquartered in London, England; the Smithsonian Institute in Washington, DC; and the headquarters of the various army departments (Table 1).

Other observations include those of interest to the local community. Weather records were often printed daily, weekly or monthly in local or regional newspapers. Indeed, instructions to observers were sent in 1851 with an original box of instruments to the observing stations of the Royal Engineers. As officers were 'recommended to furnish the editors of local papers with extracts from the registers',[47] such records were common in the coastal communities of St John's and Halifax. Some observers sent copies of their weather registers to several regions, resulting in the same information being widely disseminated. The Delaney family of St John's, Newfoundland, for example, were active weather observers during the middle of the nineteenth century. Not only were their meteorological observations printed in local newspapers, but they were also members of the Smithsonian volunteer network. In addition, copies of their observations can be found in the archives of the United Kingdom Meteorological Office (UKMO). From the observations sent to such centralized locations, nineteenth-century compendia of climatic observations such as Charles Schott's *Tables, distribution and variations of the atmospheric temperatures*

Table 1 Examples of historical Canadian climate data life cycle.

Observer	Location	Historical record location	Modern archival record location	Modern data rescue agency	Canadian databank	International databank and uses
Peter Fidler	York Factory, Rupert's Ld e.g. 1793–95	HBC Head quarters, London, UK	Manitoba Provincial Archives	Ken Devine (pers. comm. 2012; 2018)	In progress	In progress
John Bethune	Montreal (1838–69)	John Samuel McCord's personal papers	McCord Museum Archives	ACRE–Canada	ACRE–Canada	NOAA PaleoClimate Data Archive; ISTI; ISPD; 20CR
John Delaney and sons	St John's Newfoundland (1849–75)	Local newspapers; Smithsonian Institute; UK institutions	Local newspaper archives/microfilm; (US) National Archives and Records Administration (NARA); UKMO Archives	Environment and Climate Change Canada	In progress	–
Royal Engineers detachment	New Westminster, British Columbia (1859–65)	Chatham, UK	UKMO Archives	ACRE–Canada	In progress	–
François Desaulniers (Figure 1e)	Nicolet (1838–55)	Séminaire de Nicolet	Centre d'archives régionales	UQAM–Ouranos/ AQUARISC	AQUARISC	–

in the US and adjacent parts of America[48] disseminated abstracts of the observations still further. As can be seen in Figure 2, this can result in the same observations being located in several different archive collections.

Who is Recovering the Records?

There is considerable interest worldwide in recovering historical and archival weather records for scientific analysis. In Canada, work is ongoing at the MSC to recover data from the earliest period of its operation. Citizen scientists are currently working with the ACRE–Canada,[49] the national chapter of the international umbrella data rescue organization. They have transcribed over half a million observations from locations in eastern Canada in the eighteenth and nineteenth centuries; another 200,000 were transcribed by an ACRE partner, the University of Giessen.

ACRE–Canada has continued to identify and obtain digital images of records from across Canada, with thousands of pages of records from dozens of sites across the country still needing to be catalogued and transcribed (see Figure 2, Table 1). There are estimated to be at least 2 million observations still to be transcribed, with over half a million listed as a priority for climatic knowledge. It is hoped they will be transcribed using a web-based citizen science transcription app developed by the McGill DRAW (Data Rescue: Archives and Weather) project (Figure 3a).[50]

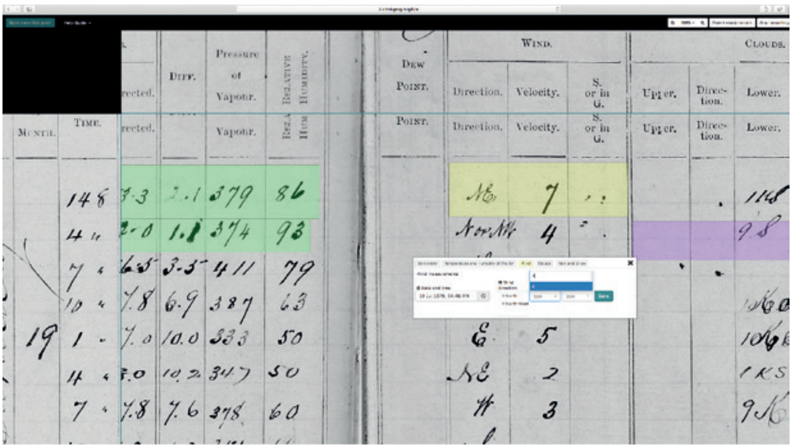
The AQUARISC project[51] aimed to develop understanding of flood and other hydrological risks by looking through archival records. Fifty archival and document conservation locations were visited or consulted (for example, Table 1). These include national, provincial and municipal archives, public and university libraries and historical societies. In total, 2,650 textual documents including books, reports, articles and correspondence were gathered into the database (Figures 1e and 1f). Also in the database were about 2,000 illustrative documents, such as photographs, lithographs and post cards. Thousands of data points encompassed meteorological records, hydrological observations and descriptions of the physical and social impacts of flooding or drought events painstakingly transcribed and documented (Figures 3b, 3c and 3d). Nevertheless, the database does not contain meteorological or hydrological records from government entities such as Environment and Climate Change Canada (ECCC).

Examples of similar regional projects funded by government agencies include the Climate Data Modernization Project in the United States, the Hist-Alp project in Europe, and ongoing data rescue within national meteorological agencies.[52] Other citizen science data rescue programmes include the Australian Weather Detectives and Belfield projects.[53]

Why are Historical Weather Records Being Recovered Today?

There are a number of reasons why historical weather data are now being rescued at an increased pace; one being the urgent interest in climate change. Indeed, how can we assess how the climate is changing

a



b

Informations supplémentaires	
Nom du champ	**Données**
Nature	Inondation
Type(s) d'inondation	Débordement de cours d'eau/masses d'eau
Cause(s) de l'inondation	Pluie abondante,Redoux (épisode)
Commentaires sur le(s) type(s) et/ou le(s) cause(s) de l'inondation	Malgré des conditions météos très douces pour un mois de janvier et une pluie plusieurs jours, le fleuve a fini par se boucher par les glaces. Crue extraordinaire des eaux.
Commentaire de la zone inondée	Faubourg Sainte-Anne et une partie des faubourgs Saint-Joseph et Saint-Antoine sous les eaux. Griffintown inondée.
Hauteur atteinte	Eau montée jusqu'au parapet du marché Bonsecours

Données hydrologiques	
Nom du champ	**Données**
Commentaire	Gelée survenue dans la nuit du 15 au 16 janvier, baisse du niveau d'eau d'un pied. 17 janvier: neige disparue à la suite d'un nouveau dégel et pluies de plusieurs jours. Glaces refoulées à l'île Sainte-Hélène. Crue "extraordinaire" du fleuve.

Données météorologiques	
Nom du champ	**Données**
Commentaire	Beaucoup de variations de température au mois de janvier. 31 déc 1847-1er janv 1848, on "laboure" à Montréal. Nuit du 2 au 3 janvier: orage électrique. Fleuve libre de glace. 5 janvier: froid. Température "capricieuse". 17 janvier: voitures d'été dans les rues, jamais vu ça. Neige disparue à la suite d'un nouveau dégel et pluies de plusieurs jours. Gelée survenue dans la nuit du 15 au 16 janvier. Température d'un mois de mars le 17 janvier. [[[Conditions météo post inondations: 27 janvier 1848: température variable, pas de neige. Pluie depuis le 26 janvier. Fortes gelées le 29-30 janvier alors que le printemps était déjà installé. 3 février 1848: 3 ou 4 pouces de neige. Dégel encore à craindre. 7 février 1848: neige en abondance, temps assez doux. 16 mars 1848: "froid très rigoureux". 6 avril: débâcle sans incident]]]

Figure 3. Continued

c

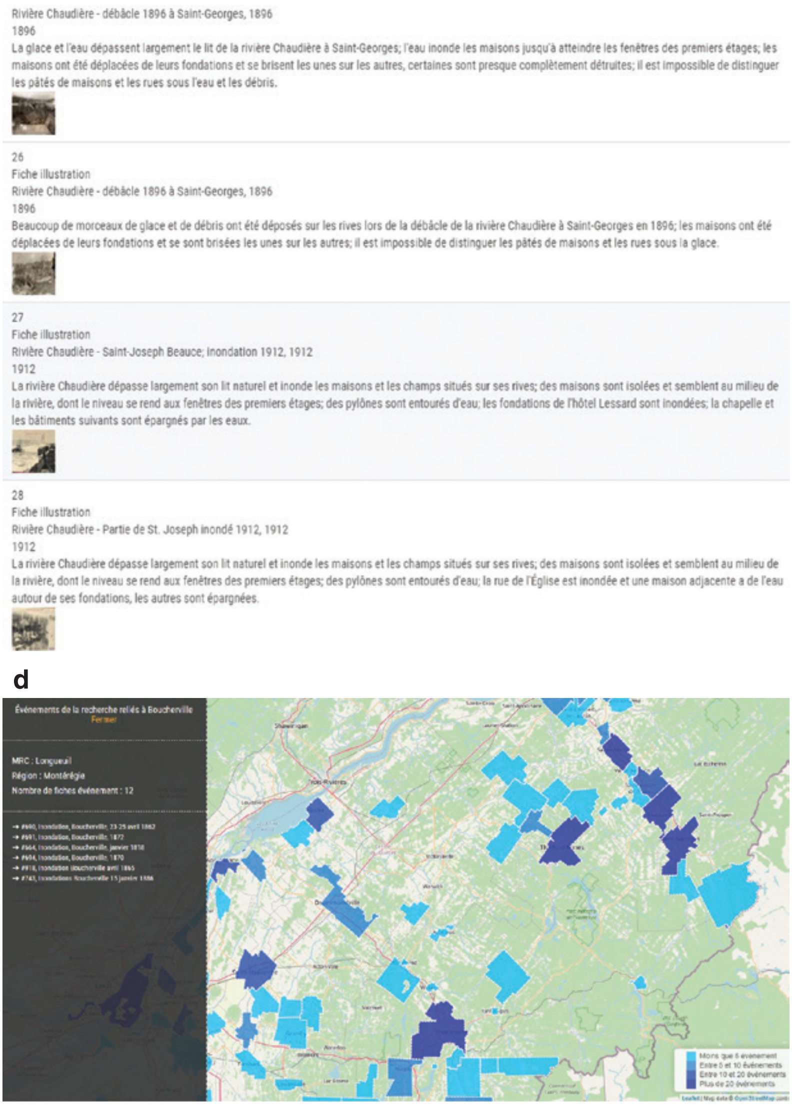


Figure 3. Capturing the data and making it machine readable for analysis: (a) an example of the DRAW transcription app; (b) database descriptor file; (c) photographs of floods document damages; (d) map of flooding events in Boucherville (Quebec).
Source: (a) developed at McGill University to capture the archival McGill Observatory weather observation with a citizen science project (www.citsci.geog.mcgill.ca) (b)–(d) from AQUARISC database.

unless we have accurate recordings of the past climate? A knowledge of past climates and extreme events gives us useful information to help us prepare for potential future changes. Details of the damage caused by floods over the past 500 years[54] or the recurrence of ice storms over the past 300 years[55] help sketch the boundaries of behaviour of the climate in a region. How often do ice storms recur? How common is flooding? Do such events tend to occur in clusters or in cycles? Two thousand flood events were identified as having taken place from 1642 to 2017 (Figure 4a). One hundred possible drought events from 1723 to 2016 were recorded in the AQUARISC database. These recordings directly testify to catastrophic climatic events and their consequences for society.

More particularly, historical data help us to understand the character, frequency and impact of extreme, and by their nature, rare but often devastating events such as storms, floods (Figure 4b), heat waves

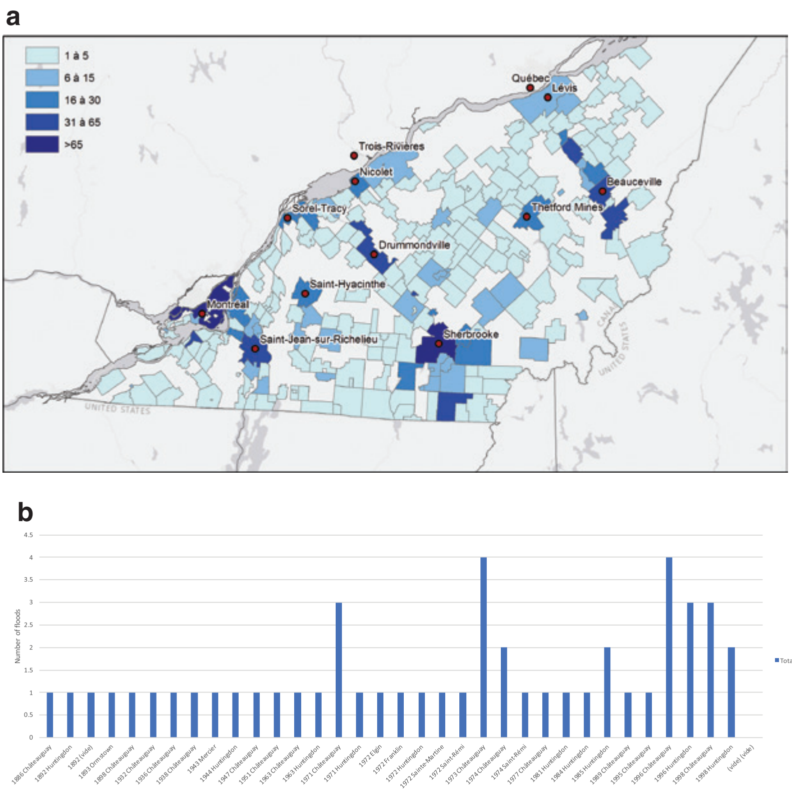


Figure 4. Continued

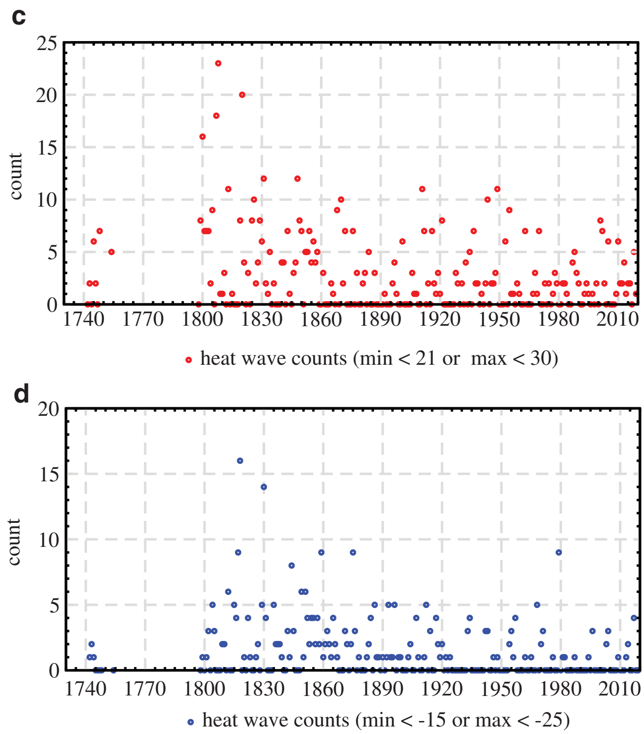


Figure 4. Examples of climatological analyses undertaken with historical documents from Canada showing the numbers of flood events for the Châteauguay River by year (a) and by town (b) for southern Quebec for 1642–2016. Annual counts of (c) heat waves and (d) cold spells in the St Lawrence Valley region.
Source: (a)–(b) AQUARISC database, Project 551013: Mayer-Jouanjean and Bleau. 'Historique des sinistres d'inondations et d'étiages et des conditions météorologiques associées' (2018); (c)–(d) updated and modified from Slonosky. 'Daily Minimum and Maximum Temperature in the St Lawrence Valley, Quebec: Two Centuries of Climatic Observations from Canada' (2014).

(Figure 4c), severe winters (Figure 4d), droughts and other weather-related natural hazards.[56]

These data are not only used in local and regional contexts[57] but also contribute to global climatic databanks such as the International Surface Pressure Databank[58] (ISPD) or the (United States) National Centres for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA), Paleoclimatology Data Bank (see Table 1).[59] The ISPD in turn is used to run atmospheric circulation reanalysis data-model hybrids including the Twentieth Century Reanalysis (20CR)[60] which form the basis of many climate change and impact studies.[61]

For example, the need for more Canadian data to give better results for northern Canada has been highlighted.[62] The latest version of the 20CR covers the globe from 1836 to 2015.[63]

Historical data are also important to verify the climate models which are used to predict the future behaviour of the climate. We need observations of how the climate has acted in the past to test our current theories of climate dynamics.[64]

But these scientific rationales are not the only reason historical records are now being 'rescued' and transformed into digital and machine-readable format. Advances in archival technology also stimulate interest in rescuing historical documents, as do the ravages of time; records in some locales are in danger of being irretrievably lost, through decay and neglect.[65] Only in the last decade or so have we acquired the technological capability of computerized high-speed processing, storing and evaluating vast quantities of information through high-resolution digital scanning and photography. We are now capable of using the high-speed internet to transfer data such as high-resolution digital images and of analysing the centuries worth of sub-daily observations resulting from the transcribed data.[66] Data rescue and digital initiatives are taking place across the sciences and humanities.[67]

Conclusion

There is no shortage of detailed information about the weather and climate of the past, although there are more gaps than we would like. We will never be able to retrieve the complete spatial and temporal data coverage of a country, for the simple reason that it does not exist, but we are nevertheless in many respects drowning in data. However, it takes enormous efforts to turn the vast quantities of paper and ink archival material that we do have into scientifically analysable data. We are often not sufficiently aware or appreciative of the richness of Canada's scientific heritage. Indeed, we are in danger of losing our knowledge of, and access to, an extensive historical geoscientific heritage data, even as great strides are being made to digitally transcribe federal government holdings since the formation of the MSC in 1874.

There are several examples of historical climatic events which would be interesting to examine in more detail should sufficient data surface to enable a detailed analysis. For instance, long-term weather records for the St Lawrence Valley region suggest that the summers of 1807 and 1808 were the warmest on record;[68] this finding merits an investigation of nearby areas should enough records be located. In contrast, the summers of the late 1830s, leading up to the rebellions of 1837 and 1838, were notably cool. While not stating that political events were driven by climatic determinism, nevertheless it would be interesting to reconstruct the weather patterns of these years in greater detail. Finally, the years after Confederation showed above average temperatures in Montreal, including the fire-plagued summer of 1868 followed by the exceptionally warm summer of 1870. This phenomenon included a 16-month run of above average temperatures relative to the isotherms for the time of December 1869 to June 1871 (the sole exception is January 1871). If the observations from the Royal Engineers, Army Medical Department and Smithsonian volunteers' network could be turned into analysable data through transcription, a greater understanding of the regional and even continental scale of climatic perturbations during these periods might be gained. Similarly, while the work undertaken for the AQUARISC project covers only a portion of Quebec's territory, nevertheless thousands of severe events with social impacts are documented. Comparable projects could be replicated across Quebec and Canada to better understand the social effects of climatic events.

These historical scientific observations are important for present-day questions and concerns about current climate change and because it falls to us, with our resources in digital technology, to safeguard and transmit our legacy to future generations. Technological change is continuous in the history of science. We are now approaching a situation involving a wholesale move to automatic weather observations combined with a dramatic reduction in the number of observing stations. Consequently, we risk breaking our centuries-long tradition of maintaining Canadian records capable of forming comparable series. Canadians may not be able to compare present and future observations with past records. Our ability to place the present in the context of the past is at serious risk.

List of Abbreviations

20CR	Twentieth Century Reanalysis project
ACRE	Atmospheric Circulation Reconstructions over the Earth

AQUARISC	Quebec contribution for anticipation of floods and droughts risks in Canada
DRAW	Data Rescue: Archives and Weather
ECCC	Environment and Climate Change Canada
HBC	Hudson's Bay Company
ISPD	International Surface Pressure Databank
ISTI	International Surface Temperature Initiative
MSC	Meteorological Service of Canada
NARA	National Archives and Records Administration
NCEI	National Centres for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
RA	Royal Artillery
RE	Royal Engineers
RS	Royal Society
UKMO	United Kingdom Meteorological Office

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Notes

1 Diamond, *Guns, Germs and Steel*.
2 Watson, *The Great Divide*.
3 Kupperman, 'The Puzzle of the American Climate'; White, 'Unpuzzling American Climate': 544–66.
4 White, *A Cold Welcome*; Parker, *Global Crisis*.
5 Thomas, *A Bibliography of Canadian Climate*.
6 Duhamel du Monceau, 'Observations botanico-météorologiques': 135–55.
7 Middleton, 'Observations on the Weather': 76–8.
8 'Extreme' in the technical climatic sense relates to rare events which can sometimes be classified as being in the 1st, 5th, 95th or 99th percentile of data distributions for continuously measured variables such as temperature or precipitation.
9 AQUARISC, https://aquarisc.ouranos.ca.
10 Slonosky, 'Canadian Historical Weather Data': 166–72.

11 White, *A Cold Welcome*.
12 Cotte, *Traité de météorologie*, 607–9.
13 Caudron, 'Les correspondants météorologistes'.
14 Mayer-Jouanjean, 'Des observations empiriques des cyclones': 246–57.
15 For more on meteorological inventions and meteorologists, see Fierro, *Histoire de la météorologie*.
16 Such as can be found in the remarks on the impact of weather on agricultural productivity made by Jean-François Gaultier ('Journal des observations météorologiques') or as shown by the diary of weather observations kept by professional gardener Robert Cleghorn ('Copies of Weather Diaries').
17 Wilson, *The Summer Season*, 82.
18 Briffa et al., 'Influence of Volcanic Eruptions': 450–5.
19 Wilson, *The Summer Season*, 4–6.
20 Lefroy, 'Remarks on Thermometric Registers': 30.
21 See, for example, the forms for Wolfville (Acadia College) Nova Scotia, NARA Records Group 27, Collection M1958, 'Surface Land Observations Outside the United States, 1843–87'.
22 Cleghorn, 'Copies of Weather Diaries'.
23 For example, Gaultier, 'Journal des observations météorologiques'; McCord and McCord, 'McCord's Meteorological Register'; Glackmeyer, 'Meteorological Observations'.
24 Glacken, *Traces on the Rhodian Shore*, 567, 604, 621; Démarée, 'The Ancien Régime Instrumental Meteorological Observations': 13–41; Fleming, *Historical Perspectives on Climate Change*, 21–3.
25 The death toll from the first cholera epidemic in 1832 in Lower Canada is estimated at 8,000 people; the epidemic hit Lower Canada especially hard for reasons that are still unknown. Bilson, 'The first epidemic of Asiatic cholera in Lower Canada': 411–33.
26 Smallwood, 'On Ozone'. *Proceedings of the American Association for the Advancement of Science*, 190–6; Charles Smallwood, 'On Ozone'. *Canadian Naturalist and Geologist*: 169–72, 343–5, 409–10.
27 Dispatches from the Colonial Office, dates April 1838 to December 1839. Circular. Glenley, 29 November 1838. Box G18. National Archives of Canada.
28 Bonnycastle, *History of Newfoundland*, 364–5.
29 Bonnycastle, *History of Newfoundland*, 365.
30 James, 'Notice of the Arrangements': 101–19, 161.
31 James, *Abstracts from the Meteorological Observations*, 3.
32 Morrison, 'Seasons, Storms and Time', 5.
33 Glacken, *Traces on the Rhodian Shore*, 600, 658–9.
34 Duhamel du Monceau, 'Observations botanico-météorologiques': 88–97; Barrington, 'An Investigation of the Difference', 58; Williamson, 'An Attempt to Account for the Change of Climate', 272–80; Mann, *Mémoire sur le changement successif*, 24; Bonnycastle, *History of Newfoundland*, 333–7; Fleming, *Historical Perspectives*, 13, 48–9.
35 Slonosky, *Climate in the Age of Empire Weather Observers*.
36 Smallwood, 'Contributions to Meteorology'.
37 Lefroy, 'Remarks on Thermometric Registers', 30.
38 Gaultier, 'Journal des observations météorologiques'.
39 Alexander von Humboldt (1769–1859) introduced a holistic view of science in which all phenomena were interconnected.
40 See, for example, Thiessen, 'The Founding of the Toronto Magnetic Observatory' and the 14 subsequent papers published between 1941 and 1946 in the *Journal of the Royal Astronomical Society of Canada*; Zeller, *Inventing Canada*; Thomas, *The Beginnings of Canadian Meteorology* ; Slonosky, *Climate in the Age of Empire*.
41 Allison, *Driv'n by Fortune*; Binnema, *Enlightened Zeal*.
42 Kingston, 'Reports on the Meteorological', x.
43 Binnema, *Enlightened Zeal*.
44 Dymond and Wales, 'Observations on the State of the Air'; Wulf, *Chasing Venus*.
45 Wilson, personal communication, 2003.
46 Devine, personal communication, 2012, 2019.
47 James, 'Notice of the Arrangements', 112.
48 Schott, *Tables, Distribution and Variations*.
49 Allan et al., 'The International Atmospheric Circulation'; Slonosky, 'Canadian Historical Weather'.
50 https://citsci.geog.mcgill.ca.
51 Mayer-Jouanjean and Bleau, 'Historique des sinistres'.
52 Dupigny-Giroux et al., 'NOAA's Climate Database Modernization Program'; Westcott et al., 'Quality Control'; Ingeborg et al., 'HISTALP'; Kaspar et al., 'Data Rescue': 57–61.

53 Ashcroft et al., 'Current Climate Data Rescue'.
54 Mayer-Jouanjean and Bleau, 'Historique des sinistres'.
55 Slonosky, 'Hazardous Weather Event'.
56 Mock et al., 'The Winter of 1827–1828'; Ashcroft et al., 'Historical extreme rainfall events'; Brázdil et al., 'Documentary Data'; Kaspar et al., 'Data Rescue'; Compo et al., 'The Twentieth Century Reanalysis Project'; Veale et al., 'Dealing with the Deluge of Historical Weather Data'.
57 Ansell et al., 'Daily Mean Sea Level'.
58 Cram et al., 'The International Surface Pressure Databank Version 2' (2015).
59 https://www.ncdc.noaa.gov/paleo-search/study/16336.
60 https://reanalyses.org; Compo et al., 'The Twentieth Century Reanalysis Project'.
61 Wang et al., 'North Atlantic Wave Height'; Brönnimann et al., 'Historical Weather Extremes', 7–17.
62 Brönnimann et al., 'Historical Weather Extremes'.
63 Slivinski et al., 'Towards a More Reliable Historical Reanalysis': 2876–2908.
64 Allan et al., 'Toward Integrated Historical Climate Research': 164–74; Kaspar et al., 'Data Rescue'; Griffin and CODATA Task Group 'Data At Risk': 92–7.
65 Griffin, 'Rescuing and Recovering': 21–6; Griffin and CODATA, 'When Are Old Data New Data?'.
66 Chandler et al., 'Building Trust in Climate Science': 373–81; Veale et al., 'Dealing with the Deluge'.
67 Griffin, 'Rescuing and Recovering'; Griffin and CODATA, 'When Are Old Data New Data?'; Hill et al., 'The Notes from Nature Tool': 219–33; Love, Hayakawa and Cliver, 'On the Intensity of the Magnetic Superstorm': 37–45; Reese, 'Transcribing the Past'.
68 Slonosky, 'Daily Minimum and Maximum Temperature': 1662–81; Slonosky, *Climate in the Age of Empire*.

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Conflict of Interests

The authors declare that there are no conflicts of interests with this work.