Study in Documents
From Meteorological Registers to Climate Data: Information Gathering in the Early Years of the Meteorological Service of Canada[1]

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RÉSUMÉ Cet article explore l'évolution de la tenue de documents scientifique et de la gestion de données dans les premières années du Service météorologique du Canada, qui a été établi en 1871. Il débute en donnant un compte rendu des pratiques météorologiques contemporaines de « réduction » et d'« abstraction » de données, qui ont eu un impact sur le premier surintendant du service, George Templeman Kingston, qui occupa ce poste jusqu'à sa retraite en 1880. Il examine aussi les différentes façons de traiter les données déterminantes et les remarques générales au sujet du temps et des phénomènes atmosphériques ou saisonniers, qu'on qualifie maintenant dans le contexte climatologique de données « quantitatives » ou « qualitatives ». Cet article examine les tentatives de Kingston de créer un dépôt canadien de données climatiques conçu à partir d'un système de stations d'observation distinctes et de formulaires de documents reliés. De plus, il présente en détail les aspects documentaires et relatifs à la tenue de documents de son manuel classique de 1878, *Instructions to Observers Connected with the Meteorological Service of Canada*. Enfin, cet article montre que, malgré le manque continuel de ressources qui lui étaient disponibles, Kingston réussit à jeter les fondations d'un système robuste de gestion de documents lié à l'observation, quoi que ce système ne sut exploiter pleinement les données du service avant la fin du XX^{e} siècle.

ABSTRACT This article explores the evolution of scientific recordkeeping and data management in the early years of the Meteorological Service of Canada, which was established in 1871. It begins with a review of the contemporary meteorological data "reduction" and "abstraction" practices that had an influence on the service's first superintendent, George Templeman Kingston, who held the position until his retirement in 1880. Also examined are the different treatments of instrumental data and general remarks about weather and atmospheric or seasonal phenomena, which we now refer to as "quantitative" and "qualitative" data in the climatological context. The article surveys Kingston's attempts to create a Canadian climate data repository built upon a system of differentiated observation stations and associated document forms.

1 I would like to thank Professor Alan MacEachern of Western University in London, Ontario, for reading an early version of this article.

In addition, it reviews in detail the documentary and recordkeeping aspects of his 1878 textbook, *Instructions to Observers Connected with the Meteorological Service of Canada*. The article demonstrates that, despite a persistent paucity of resources available to him, Kingston succeeded in laying the foundation of a robust observation recordkeeping system, albeit one that would not fully exploit the service's data until the late 20th century.

The Dominion of Canada took responsibility for a national system of meteorological observations in 1871 by allocating funds to the Meteorological Service of Canada. This service reported to the Department of Marine and Fisheries. It inherited staff and facilities from various observatories across Canada, most importantly the Toronto Magnetic and Meteorological Observatory, which had been established by the British military in 1839 and was subsequently taken over by the Province of Canada and the University of Toronto in 1853. The observatory evolved from an outpost of British imperial geomagnetic science to one of only a few well-equipped and professionally staffed meteorological stations in British North America. During this period of evolution, staff of the observatory dealt extensively with their American counterparts on questions of both theory and practice.[2] The Toronto observatory formed the foundation of the Central Office of the Meteorological Service when it was established in 1871.

The Meteorological Service's first superintendent, George Templeman Kingston, had been urging the Dominion government to create such a service from the time it agreed to subsidize the Toronto observatory in 1867. During the late 1860s, he set about instituting an information-gathering system that would lay the groundwork for a national forecasting system and climate data repository.

This article explores the influences on Kingston's practice prior to his superintendence of the Meteorological Service and examines the documentary forms and associated instructions that Kingston devised over the course of the 1870s to lay the foundation for a national meteorological registry and climate data archive. Studying the evolution and codification of these forms enables the exploration of the influence of both personal experience and professional relationships on the development of this scientific recordkeeping system. Another aim of this exploration is to probe the interconnection between the meteorological recordkeeping system Kingston developed and the climate data extracted from it.

2 Regarding the evolution of the Toronto observatory's American contacts prior to Confederation, see Gregory Good, "Between Two Empires: The Toronto Magnetic Observatory and American Science before Confederation," *Scientia Canadensis: Canadian Journal of the History of Science, Technology, and Medicine* 10, no. 1 (1986): 34–52.

The Role of Records and Data in 19th-Century Meteorology

At the outset of his work as superintendent of the Meteorological Service of Canada, Kingston was able to draw on nearly two decades of experience and precedent. He had served as the head of the Toronto observatory since 1855, during which time he maintained the observatory's strong connections to American meteorologists by joining the American Association for the Advancement of Science in 1857.[3] During his tenure, he also continued the meteorological practice of registering and "reducing" (i.e., summarizing and tabulating) data inherited from his predecessors at the observatory.[4] Beginning in 1864, Kingston resumed the publication of data "abstracts," which summarized the observational records from Toronto. Like his colleagues elsewhere, he believed very strongly in the principle that reduced meteorological observation data should be published for both scientific and practical ends and so that "people might learn the peculiarities of the Canadian climate."[5] In other words, observers created meteorological registers in order that researchers would eventually use abstracted versions of this data to study the evolution of the Canadian climate and its relationship to that of the United States.

Toward the middle of the 19th century, meteorology matured into a stricter science. It began to rely on improved instruments for measuring vast quantities of data gathered from multiple locations, especially in countries as large as Canada and the United States. To support this effort, meteorologists developed standardized systems of data gathering and reporting, and attendant uniform systems of instructions and forms.[6]

The earliest meteorological observers tended to be well-intentioned amateurs working with inconsistent procedures and equipment of variable quality. In her study of 18th- and 19th-century St. Lawrence Valley temperature data, climate scientist Victoria Slonosky draws a clear line regarding the quality of climate data when analyzing observation records:

> "Historical data" will refer to the individual, largely amateur, records kept in the eighteenth and nineteenth centuries before the establishment of the professional MSC [Meteorological Service of Canada], while "modern" data will refer to the data collected by professional meteorologists after the foundation of the MSC in 1871.

3 Ibid., 39.

4 Morley K. Thomas, *The Beginnings of Canadian Meteorology* (Toronto: ECW Press, 1991), 47. Scientists now generally refer to this practice as "compilation" and "derivation" of raw data acquired through observation. See Tracey P. Lauriault, Barbara L. Craig, D.R. Fraser Taylor, and Peter L. Pulsifer, "Today's Data Are Part of Tomorrow's Research: Archival Issues in the Sciences," *Archivaria* 64 (Fall 2007): 146.

5 Thomas, *The Beginnings of Canadian Meteorology*, 204–5.

6 James Rodger Fleming, *Meteorology in America, 1800–1870* (Baltimore, MD: Johns Hopkins University Press, 1990), xviii.

Changes in observing practice, instruments, standards of exposure of the instruments to the atmosphere and changes in the local environment often introduce bias into the measurements, such that the effect of these on climatological measurement biases could obscure, exaggerate or distort any climatic signals.[7]

Straddling this line was one of Slonosky's Montreal observers, Charles Smallwood, who was well equipped and educated. He compiled useful long-term data sets for the period 1849 to 1873, especially at his McGill University observatory, which was established in 1863.[8] Smallwood and Kingston were in the Canadian vanguard of a new meteorological concern with precision, numbers, and statistics. This was typical of the Victorian scientific method.

Historian Suzanne Zeller categorizes this method as "inventory science" and traces its origins to the work of the Scottish statistician Sir John Sinclair in the 1790s.[9] Zeller argues that meteorology played a crucial role in the development of a Canadian scientific identity between 1840 and 1867. For instance, the Canadian Institute, founded in 1851 to support the physical sciences and manufacturing, established a meteorological committee in 1856, chaired by Kingston.[10] Moreover, Zeller elaborates on educator Egerton Ryerson's argument that science was a "unifying social force" while he instituted a grammar school observatory network in Canada West in 1858.[11] Zeller concludes that the idea of a chain of meteorological observatories played an important part in the development and expansion of the nation.[12]

Inventory science was not unique to Canada. The leading American scientific organization was the Smithsonian Institution in Washington. The Smithsonian, under the leadership of its secretary, Joseph Henry, had begun a volunteer observatory program in 1849 and deemed it necessary to acquire data from Canadian observers to understand North American weather patterns. Henry began to send data-gathering forms and instructions to Kingston in 1856.[13] In 1853, the Smithsonian had issued a revised "daily register" form for meteorological observations taken three times a day – at 7 a.m., 2 p.m., and 9 p.m. The register recorded data from instruments used to read temperature,

7 Victoria Slonosky, "Historical Climate Observations in Canada: 18th and 19th Century Daily Temperature from the St. Lawrence Valley, Quebec," *Geoscience Data Journal* 1, no. 2 (November 2014), 104, doi:10.1002/gdj3.11.

8 Victoria Slonosky, "Daily Minimum and Maximum Temperature in the St-Lawrence Valley, Quebec: Two Centuries of Climatic Observations from Canada," *International Journal of Climatology* 35, no. 7 (15 June 2015), 1666, doi:10.1002/joc.4085.

9 Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Toronto: University of Toronto Press, 1987), 4.

10 Ibid., 165.

11 Ibid.

12 Ibid., 179.

13 Thomas, *The Beginnings of Canadian Meteorology*, 54; Western University, Western Archives, Environment Canada Collection, Superintendent's Letter Books, box EC893.

barometric pressure, relative humidity, precipitation, and wind speed. Because of the Smithsonian's interest in natural history, its observers were asked to record "casual phenomena," i.e., remarks upon atmospheric and seasonal occurrences such as rainbows, auroras, frosts, ice breakups, etc. From the earliest days, then, meteorologists drew a distinction between quantitative and qualitative data, the former originating with instruments read by human eyes and the latter with phenomena seen by them.

Both methods were prone to human error. In 1855, the meteorologist in charge of data reduction at the Smithsonian, Henry Coffin, found much that was lacking in this nascent system:

> The diversity now existing, each observer supposing that his own peculiar marks & mode will be understood by others, is a source of endless perplexities in reducing the observations as it renders it impossible for me to give general directions to my assistants without exposing them to run into frequent errors – such as it has taken a large share of the time I have been able to devote to the work to ferret out & correct.[14]

By 1865, Joseph Henry had begun to realize just how challenging it was to gather accurate climate observation data, something that Kingston would confront over the next decade in Canada. In his yearly *Smithsonian Report*, Henry commented that

> there is, perhaps, no branch of science relative to which so many observations have been made and so many records accumulated, and yet from which so few general principles have been deduced. This has arisen, first, from the real complexity of the phenomena, or, in other words, from the number of separate causes influencing the production of the ordinary results; second, from the improper methods which have been pursued in the investigation of the subject, and the amount of labor required in the reduction and discussion of the observations.[15]

Reducing meteorological records required a labour-intensive and rigorous effort to summarize and average meteorological data over periods of months and years. The Smithsonian's experience with data gathering had a significant influence on Kingston's system as he would establish it over a decade later. The Toronto observatory and other Canadian locations participated in the Smithsonian program until the late 1860s and early 1870s, at which point the United States government took over from the Smithsonian the function of data gathering.[16] For instance, Charles Smallwood of Montreal and Gilbert Murdoch of Saint

14 Ibid., 83.

15 Smithsonian Institution, Board of Regents, United States National Museum, *Annual Report of the Board of Regents of the Smithsonian Institution* (Washington, DC: Government Printing Office, 1866), 50, accessed 15 September 2017, https://archive.org/details/annualreportofbo1865smit.

16 Thomas, *The Beginnings of Canadian Meteorology,* 103.

John, New Brunswick, had been in contact with the Smithsonian between 1852 and 1862, and between 1859 and 1873, respectively. They began to correspond with Kingston as the Smithsonian program wound down and would eventually serve as two of his key lieutenants.[17]

Early Practices at the Meteorological Service of Canada

It was difficult for Kingston to secure both authoritative and reliable resources to collect data beyond his immediate Toronto responsibility. However, after 1866, he started to make progress in his efforts to establish a climate data centre. In that year, he began to receive records from a network of grammar school observatories that the Province of Canada had established in 1858 in what is now Ontario. He had attempted on several occasions to receive and verify the observational records for publishing purposes but had little success before the late 1860s.[18] Even more important, however, was the opportunity to build a national system beyond Ontario. To this eventual end, Kingston pursued his contacts with several other well-organized observers in other provinces, including Smallwood in Montreal, Murdoch in Saint John, and Frederick Allison in Halifax. In 1869, Kingston began to retain observation registers from these and other stations in an informal network.[19]

Following its establishment in May 1871, Kingston's Meteorological Service expanded rapidly. Much of the impetus for its funding and development was the prospect of improvement in weather communication and forecasting through telegraphy. Telegraphy allowed for immediate communication of conditions to the central office in Toronto. The service set up a handful of telegraph stations around the lower Great Lakes to track storms. It shared this information with the American meteorologists in Washington for weather forecasting. By 1876, the Canadian service was issuing its own forecasts.[20]

Despite the technological promise represented by telegraphy, observers transmitted most climate records to Toronto via the mail service. In 1871, as an organizational precondition to the establishment of a registration and data-reporting system, Kingston divided these observers into categories. "Chief stations" were those, like the Toronto observatory, in which a full set of observations would be taken up to eight times a day to provide a more complete and accurate data set.[21] The Dominion government usually paid the staff of chief stations. Between July 1871 and January 1874, chief stations were established

17 Ibid., 134.
18 Ibid., 67.
19 Ibid., 74–75.
20 Ibid., 197.
21 Ibid., 140.

in Halifax and Sydney, Nova Scotia; Saint John and Fredericton, New Brunswick; Montreal; Woodstock and Kingston, Ontario; Winnipeg; and Spence's Bridge, British Columbia.[22] In effect, chief stations were to serve as regional replicas of the well-equipped and professional Toronto observatory with which Kingston was most familiar.

"Ordinary stations" were those where volunteers served as observers. These were divided into three classes: class I stations at which all usual meteorological elements were measured three times a day; class II stations at which temperature and precipitation were measured up to three times a day; and class III stations at which only records of rain and snowfall were kept.[23] After an ambitious planned start of 122 ordinary stations, the actual number of reporting stations was only 72 as of 1874. Kingston's initial estimates of the number of volunteer participants were too rosy, as many did not actually participate.[24] Several other observers presumably lost interest and could not keep up with the regimen that Kingston imposed. By the late 1870s, however, the number of participants rose to nearly 120 as more volunteers in Ontario came forward and Canada began to expand gradually westward.[25] The ordinary-station network closely resembled the Smithsonian network in its informality and fluidity.

Kingston had begun to accumulate registers and abstracts from his informal network of observers in the late 1860s. With his new authority after 1871, Kingston standardized the daily registration forms in 1872 and included printed instructions as to their use.[26] These early forms included a "Weekly Register (Form 1)" for class I ordinary stations, a "Monthly Register (Form 2)" for class II ordinary stations, and a "Monthly Register (Rain/Snow Form)" for class III ordinary stations. He also provided a separate form for reporting telegraph stations.[27] His central office staff began to summarize data, which carried a significant workload:

> All written weekly, monthly, and occasional reports were acknowledged, examined for completeness and accuracy and the observer notified of any discrepancies and the need for improvement. In 1875 the volume of these reports was ten thousand pages of tabular data and sixteen hundred storm reports, which required the preparation and mailing of about twenty-five hundred acknowledgement cards.[28]

22 Ibid., 153.
23 Ibid., 150.
24 Ibid., 152.
25 Ibid., 154.
26 Ibid., 151.
27 Western University, Western Archives, Environment Canada Collection, Meteorological Registers, Albion, Ont., box EC65; Point Clark, Ont., box EC219; Port Dover, Ont., box EC223.
28 Thomas, *The Beginnings of Canadian Meteorology*, 204.

Nevertheless, throughout the period, Kingston published data in each of his voluminous annual reports.[29]

In addition to being busy with reduction, Kingston's staff also had to deal with problems with both data quantity and quality from the volunteer observers. In his annual report for 1875, the superintendent stated:

> It is estimated that about 8400 pages of tabular matter are received at the office from stations in the year. The mere transcription and collation of this mass, apart from drawing deductions from it, would be a heavy task, if all the reports were to come to hand in a perfect state; but, before these reports are turned to any use, it is the practice to examine each carefully, and to call the attention of the sender to any faults which the examination may have revealed. This correction and instruction by letter, is sometimes repeated, again and again to the same person, with reference to the same fault, in consequence of misconceptions, many of which the visits of an inspector would easily remove.[30]

These problems arose because a significant number of volunteers were new to the service, but also because they were not receiving regular in-person inspection and instruction, a weakness that Kingston lamented.[31] In addition, he had discovered that there were flaws built into the observation forms; these flaws (described in detail below) related to the exclusion of uncorrected instrumental observation data. Kingston felt the forms had to be revised to ensure retention of reliable data,[32] and consequently, in late 1876, he announced that he would send entirely new forms to all observers, along with a complete set of published instructions.[33]

At the same time, Kingston came under pressure for the cost of data reduction and publication. When questioned about the sheer volume of published tabulations in 1877, Kingston made his case in a letter to the Deputy Minister of Marine and Fisheries:

> Although persons engaged, as are the officers of this establishment, in drawing conclusions from day to day regarding current weather, do much towards the advancement of the art of prognostication, it is extremely desirable that not only the data on which our predictions are based, but that which reaches us from all our stations, should be made available to men of leisure, and at the same time of high scientific

29 See Canada, Parliament, House of Commons, *Annual Reports of the Meteorological Service of Canada* (Ottawa), beginning in 1872.

30 Canada, Parliament, House of Commons, *Annual Report of the Meteorological Service of Canada, 1875*. (Sessional Papers 1875, No. 5), 3.

31 Ibid., 2.

32 G.T. Kingston, *Instructions to Observers Connected with the Meteorological Service of the Dominion of Canada* (Toronto: Copp, Clark, 1878), 163.

33 Western University, Western Archives, Environment Canada Collection, Superintendent's Letter Books, box EC907, George T. Kingston to William Wylie, 4 September 1876.

culture, throughout the world, in order that they may bring their great and special attainments to bear upon the laws concerning atmospheric changes and their influence which officers [such as those at the Toronto Forecast Office] do not have the leisure to pursue.[34]

Kingston's objections must have had an impact, as the observations continued to be published.

Instructions to Observers

In January 1878, Kingston issued the service's first published set of *Instructions to Observers*. Most of this 190-page volume served as a textbook on the practices of accurate use of instruments to capture data such as temperature, relative humidity, and barometric pressure, as well as amounts of rain and snowfall. In addition, he devoted several dozen pages to the accurate registration of meteorological observations. Kingston's instructions in this area are a balance of scientific classicism and practical reflection about what had been done well and what had been done poorly since the service was established in 1871. For instance, Kingston initially had great hopes that the primarily paid chief station observers would form the backbone of the service by taking hourly readings over many years.[35] Nevertheless, by the mid 1870s, he accepted that most of his observers were inexperienced volunteers in ordinary locations and so his instructions primarily targeted their needs while still considering the needs of chief station staff. It may also suggest that Kingston had begun to see the benefits of a wide system of observations that could help validate the expert data acquired from a handful of chief stations.

Kingston went into considerable detail about the forms and methods required for accurate recording of the observations, as well as for summarizing or abstracting these observations into publishable data tables. Kingston wrote in the introduction to the section "On Forms for Registering Observations":

For recording the primary meteorological elements and phenomena obtained by observation at a station, and for arranging the numbers which express their intensity or frequency in such a manner as to admit of the convenient intercomparison of like quantities or numbers (or averages derived from them) in different hours, different days, different months, and different years, four kinds of form are required.[36]

Kingston's introduction makes clear that his ideal system was a complex one in which multiple forms would be required in order to facilitate not only the

34 Western University, Western Archives, Environment Canada Collection, Superintendent's Letter Books, box EC905, George T. Kingston to William Smith, 4 September 1876.
35 Thomas, *The Beginnings of Canadian Meteorology*, 140.
36 Kingston, *Instructions to Observers,* 156.

collection of data but also its manipulation for purposes of data abstraction. In other words, he built abstracting right into the recordkeeping system. Kingston outlined several different categories of idealized forms that progressed through stages of refinement. While chief stations recorded up to eight observations a day, ordinary station observers took only three daily readings. What the two had in common was the use of a daily register. The daily register was a record whose purpose had been set in the Toronto observatory and stations like it throughout North America for decades. Some variations occurred based on the number and frequency of observations being made. Nevertheless, in Kingston's words, the ideal daily register was a form "in which all elements or other numbers obtained from observation at the same hour are placed side by side in the same horizontal line, while like numbers obtained by observation at different hours are written in vertical columns."[37] Each column of observations was summarized and averaged at the foot of the form. A daily register that recorded hourly observations was referred to as Form A.[38]

By contrast, a monthly abstract (Form B) was a document "in which the numbers recorded in the daily register are re-arranged in such a way that like numbers, obtained at different hours in the same day, are placed in horizontal lines, and those at the same hours in different days in vertical columns, *so as to facilitate the computation of monthly averages*."[39] Abstracts for those making hourly observations on a daily basis documented only one element (e.g., temperature) per form. This focus on each element facilitated the publication of annual data, which Kingston compiled for each of the service's annual reports, beginning in 1872.[40] In his instructions, Kingston went on to describe an annual abstract (Form C, showing the averages of measurements for each year) and a secular (multi-year) abstract (Form D, showing averages for the same month over several years).[41]

Although he preferred the chief station model, whereby hourly readings were taken on a daily basis, Kingston acknowledged that each of these idealized forms could be modified for the use of the more numerous ordinary stations. For instance, he allowed that a combination of daily registers and monthly abstracts could be used where fewer (usually three) observations of only a few elements were taken over the course of a day.[42] These would track the daily observations over the course of an entire month, as well as provide summary and averaged data. This concession suggests that Kingston had learned a

37 Ibid.
38 Ibid.
39 Ibid. (emphasis added).
40 Canada, Parliament, House of Commons, *Annual Report of the Meteorological Service of Canada* (Sessional Papers).
41 Kingston, *Instructions to Observers*, 159–60.
42 Ibid., 162.

valuable lesson: data abstraction was a laborious task that should be made as easy as possible to those undertaking it, especially the volunteer observers who were tracking relatively few elements of data.

Despite his concessions in some areas, Kingston continued to feel strongly that combining forms would be counterproductive for the observers using barometers, who had to include uncorrected observations.[43] One had to correct certain data to account for various factors such as elevation and variations from the freezing point. Prior to 1877, he had sent to his class II volunteer observers a combined Monthly Register (Form 2, noted above) that did not provide room for uncorrected observations. Kingston's instructions now required the inclusion of both observed (i.e., uncorrected) and corrected data. He disapproved of performing these corrections mentally beforehand.[44] Including uncorrected information reduced the risk of errors and allowed for central office staff to correct any errors that may have occurred. To regulate data quality further, he tolerated no ambiguity in notation.[45] For instance, he permitted only the use of decimal fractions, and he forbade the repetition of numbers with a dash or any other sign. Furthermore, Kingston expressed strong disapproval for the use of conjecture to substitute for an accidental omission of information.[46]

Kingston's instructions also described the types of forms *in use* as of 1877, forms that he had introduced over the previous year to chief and ordinary class I stations. Distinguishing between different types of forms allowed him to tailor his ideal requirements (described above) to the actual circumstances of the service. The better equipped of the volunteer observers were to use the Weekly Register (Form 1) to record three daily readings of the full range of elements over the course of a week. (See figure 1, Weekly Register/Form 1, Ottawa, Ontario, 1877.) This form had been designed to meet the requirements of issuing daily synchronous (i.e., at the same time throughout North America) reports to satisfy the needs of the weather telegraph system.[47] The Weekly Form A was a rarer variation that allowed for the recording of up to eight or nine daily observations (i.e., at chief stations). (See figure 2, Daily Register/Form A, Winnipeg (St. John's College), 1878.) The Monthly Form 17 provided for recording three daily observations of fewer elements over the course of a month and so the service expected its class II ordinary stations to use it.[48] (See figure 3, Daily Register/Form 17, Point Clark, Ont., 1876.)

43 Ibid., 163.
44 Ibid.
45 Ibid., 186.
46 Ibid., 187.
47 Western University, Western Archives, Environment Canada Collection, Superintendent's Letter Books, box EC907, George T. Kingston to Cassidy Cranbourne, 17 April 1877.
48 Kingston, *Instructions to Observers,* 163–64.

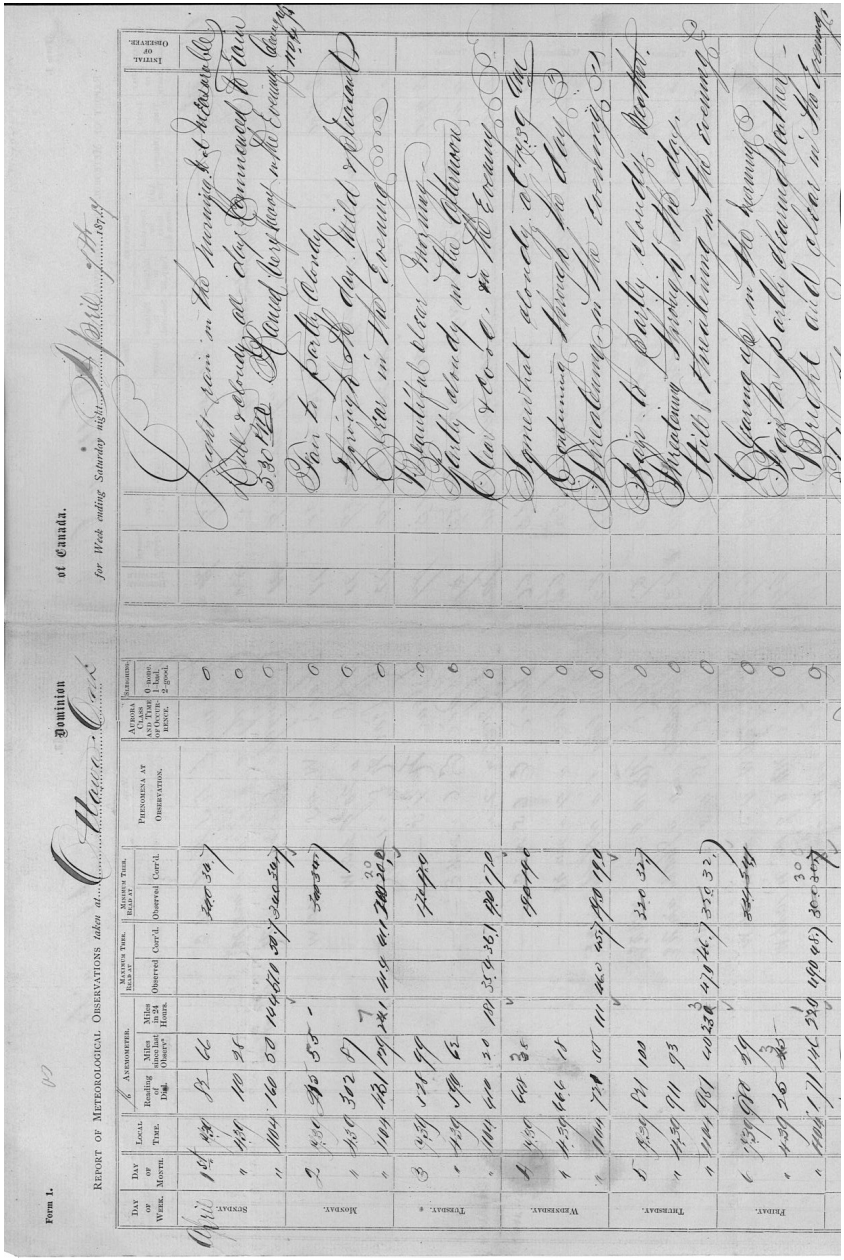
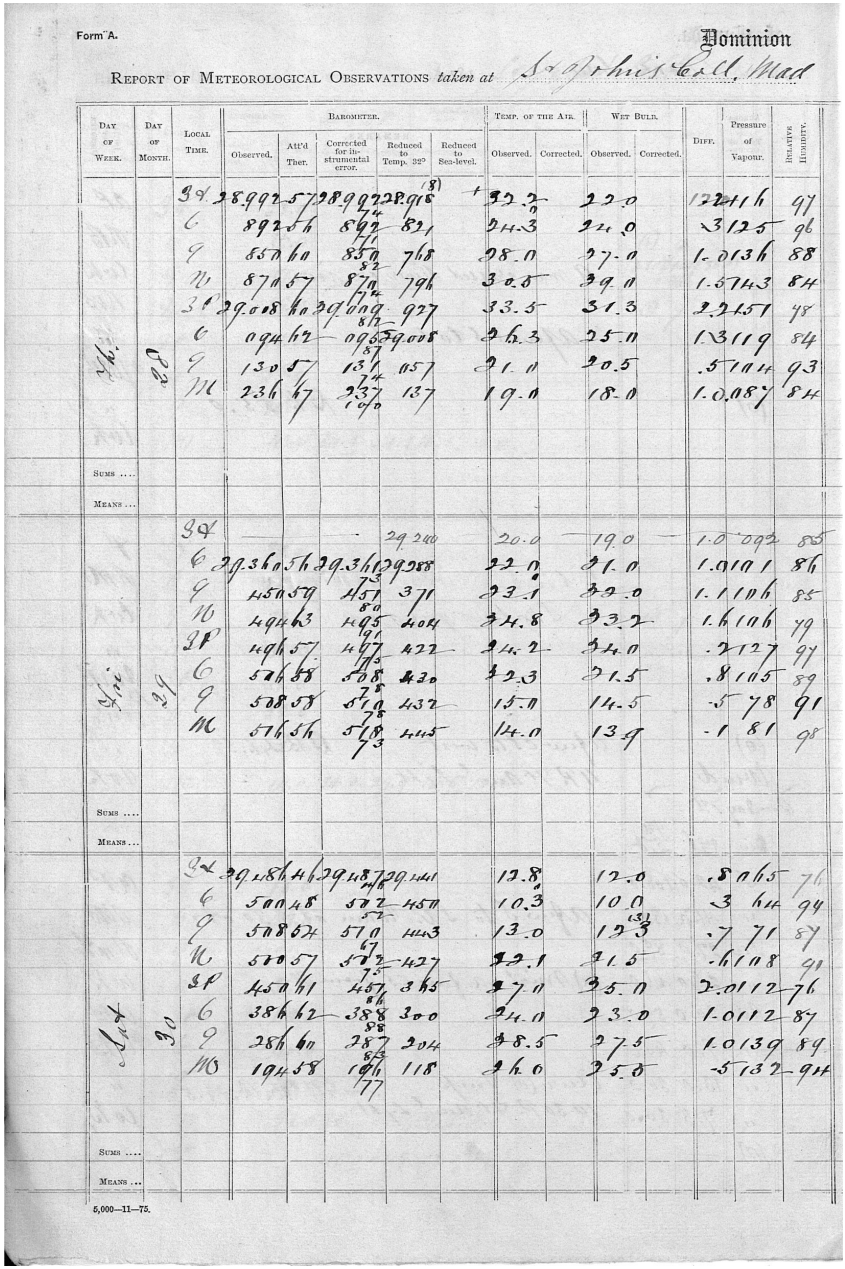


Figure 1: Weekly Register (Form 1), Ottawa, April 1877.



Form A. Dominion

REPORT OF METEOROLOGICAL OBSERVATIONS *taken at* St Johns College, Man

Day of Week	Day of Month	Local Time	Barometer. Observed.	Att'd Ther.	Corrected for instrumental error.	Reduced to Temp. 32°	Reduced to Sea-level.	Temp. of the Air. Observed.	Corrected.	Wet Bulb. Observed.	Corrected.	Diff.	Pressure of Vapour.	Relative Humidity
		9	28.992	57	28.992	28.918		22.2		22.0		122	411	97
		6	892	54	892	831		24.3		24.0		3125		96
		9	850	60	850	768		28.0		27.0		1.0136		88
		12	870	57	870	796		30.5		29.0		1.6743		84
	30	3	29.008	60	29.009	927		33.5		31.3		2.2451		78
		6	094	62	095	29.008		26.3		25.0		1.3119		84
		9	130	57	131	057		21.0		20.5		.5104		93
		12	236	67	237	137		19.0		18.0		1.0087		84
Sums														
Means ...														
		3				29.240		20.0		19.0		1.0092		85
		6	29.360	56	29.361	29.288		22.0		21.0		1.0101		86
		9	450	59	451	371		23.1		22.0		1.1106		85
		12	494	63	495	404		24.8		23.2		1.6106		79
		3	496	57	497	422		24.2		24.0		.2127		97
		6	526	58	528	430		22.3		21.5		.8105		89
Sun	24	9	508	58	510	432		15.0		14.5		.578		91
		12	576	56	578	445		14.0		13.4		.181		98
Sums														
Means ...														
		3	29.486	46	29.487	29.411		12.8		12.0		.8065		76
		6	500	48	502	458		10.3		10.0		.364		94
		9	508	54	510	443		13.0		12.3		.771		87
		12	520	57	522	427		22.1		21.5		.6108		91
		3	450	61	451	365		27.0		25.0		2.0112		76
Sat	30	6	386	62	388	300		24.0		23.0		1.0112		87
		9	286	60	287	204		28.5		27.5		1.0139		89
		12	194	58	194	118		26.0		25.0		.5132		91
Sums														
Means ...														

5,000—11—75.

Figure 2: Daily Register (Form A), Winnipeg (St. John's College), 1878.

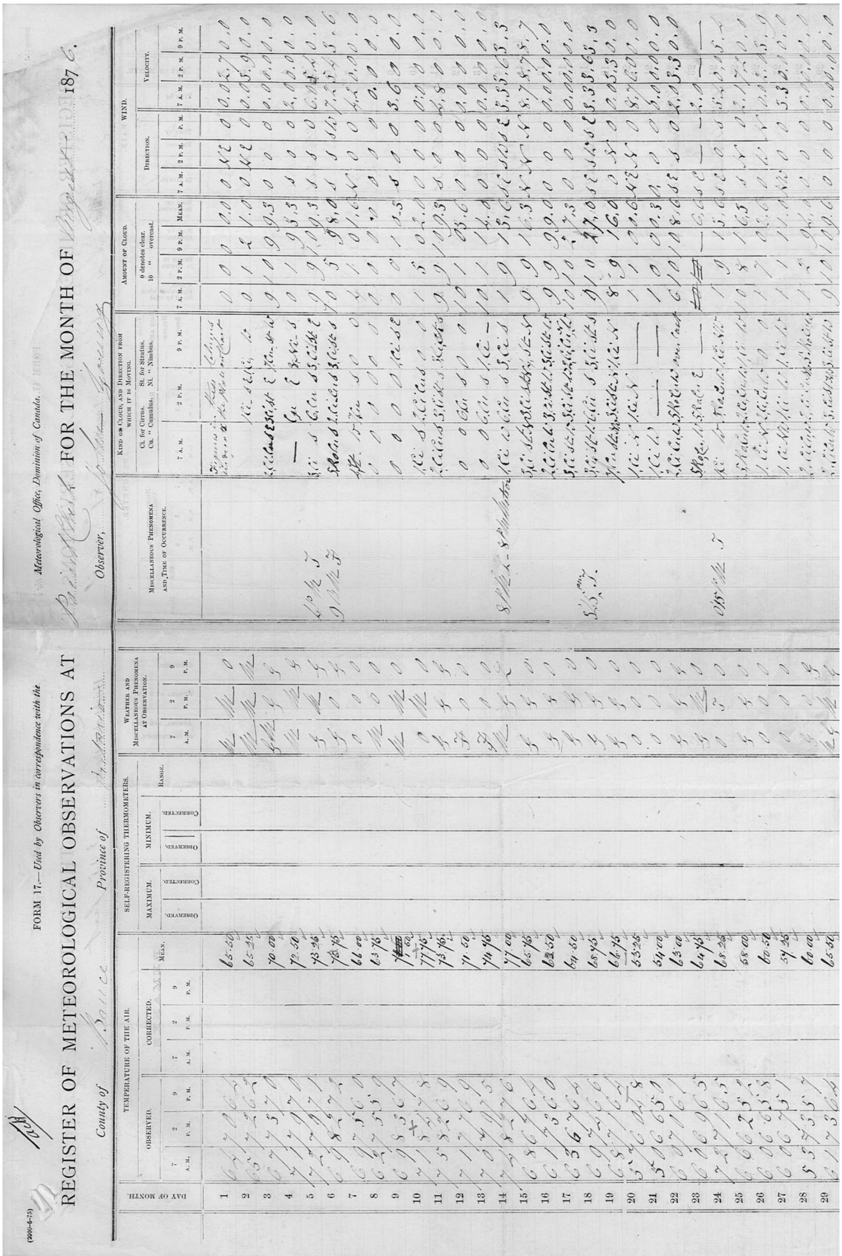


Figure 3: Daily Register (Form 17), Point Clark, Ontario, 1876.

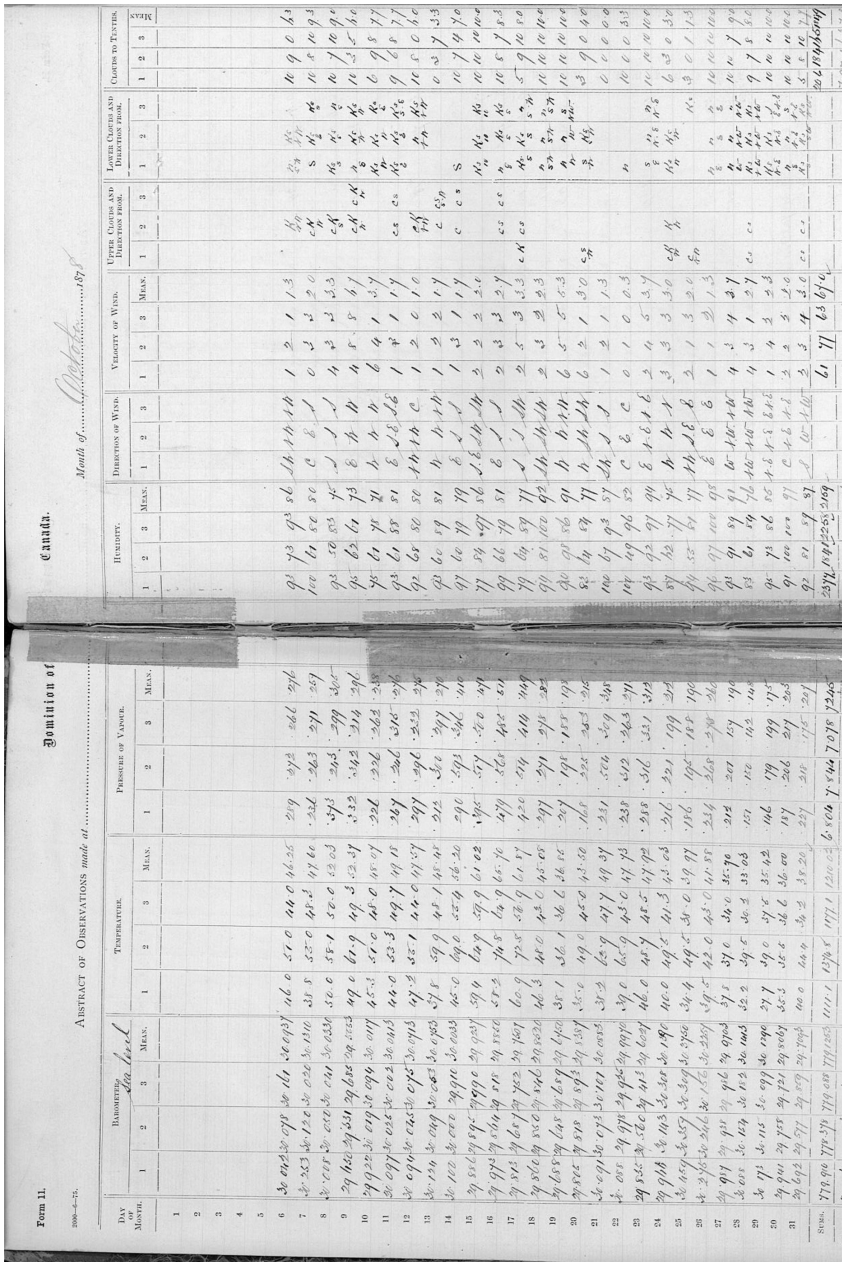


Figure 4: Monthly Abstract (Form 11), Ottawa, 1878.

Given that most observers were of the class I ordinary type, Kingston provided detailed instructions about entry of information into Weekly Register Form 1. These could be adapted with slight modifications for those using forms A or 17. First, he reiterated that both observed and corrected information should be entered where relevant because of the data quality and labour concerns described above. When describing the recording of information from instruments, Kingston made passing references to the use of a "pocket book" as a means of quickly noting data that observers could subsequently copy over to a Weekly Register Form 1.[49] When the Meteorological Service issued a new set of instructions in 1930, the "pocket register" had become a standard tool.[50] The service also provided rain and snowfall forms and a separate set of instructions for those class III observers whose only job was to record precipitation and the general state of the weather and miscellaneous phenomena.[51] These observers used the prescribed Form 23 (Register of Rain, Snow, Weather and Miscellaneous Phenomena) and the later variant Form 27 (which included a section for extremes of temperature).

Kingston expected all observers to complete daily registers or rain/snow forms and send loose copies of them to the central office.[52] He invited certain observers with the ability and time to begin the reduction of data (usually at class I ordinary stations) by creating and submitting monthly abstracts.[53] Monthly Form 11 provided an abstract (i.e., excluding uncorrected numbers) of the Form 1 daily observations for the entire month (see figure 4, Monthly Abstract/Form 11, Ottawa, Ontario, 1878). Monthly abstract forms B and C were used to abstract one element at a time on each page, primarily for those observations made eight times a day, and were consequently only used in chief stations utilizing register Form A.

Kingston went on to describe a very precise methodology for recording the general state of the weather in the daily and weekly register forms. He outlined a combination of letters and symbols that had been devised by Admiral Francis Beaufort and the 1873 Vienna Congress of Meteorologists. These notations were to be used to describe general weather states (e.g., ∞ for haze), types of precipitation (e.g., * for snow), clouds, and wind.[54] Similarly, like his predecessors and colleagues at the Smithsonian, Kingston prescribed the remarking of certain seasonal phenomena, such as the first snow, ice breakup, bird

49 Ibid., 172.

50 Canada, Meteorological Service, *Instructions to Observers in the Meteorological Service of Canada* (Ottawa: F.A. Acland, 1930).

51 G.T. Kingston; Canada, Meteorological Service, *Instructions for Recording Rain, Snow, Weather and Miscellaneous Phenomena: With a Supplementary Chapter on Temperature of the Air* (Toronto: Copp, Clark, 1878).

52 Kingston, *Instructions to Observers*, 185.

53 Ibid., 166–67.

54 Ibid., 174.

migrations, and agricultural cycles. For example, one of the elements to be tracked was "sleighing," intended to record the general state of the roads in the vicinity. Kingston prescribed a "remarks" column to allow observers to note these general phenomena as well as equipment problems.[55] Unlike the quantitative data, which observers usually recorded consistently (if not always accurately), this kind of qualitative data was not always recorded.

In contrast to the Smithsonian, which published the qualitative data it collected, Kingston never did.[56] Kingston's instructions do not indicate why data was not published. One possible explanation might be that this information was not regularly, or in some cases even legibly, written down in the daily registers. Alternatively, it might have been because, as noted above, Kingston and his immediate successors struggled to obtain funding for staff for the task of reduction, so they focused instead on the easier figures to interpret and manipulate.[57] Under the circumstances, the statistical/numerical bias of inventory science had begun to outweigh – in Kingston's mind – the more balanced approach used by the Smithsonian. In any case, it was not until the early 20th century that the service began to publish some of this "phenological" data in its annual reports.[58]

Kingston concluded his section on registering observations by explaining how these forms should be checked for quality and communicated to the central office. Returns were to be exact transcripts from daily register. As soon as one sheet (e.g., a week's worth of entries) was completed from the daily register, staff were to forward a copy to Toronto. Weekly Form 1 was to be mailed on the Monday of the following week. Monthly Form 17 and the Rain/Snow Form were to be sent at the beginning of the following month. Returns were always to be compared with originals by two persons, one of whom was to read aloud while the other made corrections, another measure taken to prevent errors.[59]

Kingston's Impact on Later Meteorological and Climate Recordkeeping

Kingston's instructions formed the basis of the standardized meteorological registry system that the Meteorological Service of Canada continued to develop after he abruptly retired in 1880 because of illness. Over the ensuing two to three decades, this registry evolved into a repository of climate data large and

55 Ibid., 182.

56 United States, Patent Office, *Results of meteorological observations: Made under the direction of the United States Patent Office and the Smithsonian Institution from the year 1854 to 1859, inclusive* (Washington: Government Printing Office, 1861).

57 Canada, Parliament, House of Commons, *Annual Report of the Meteorological Service of Canada, 1875* (Sessional Papers 1875, No. X), 3.

58 The annual reports for the years 1905–1910 contain short tables of summarized phenological data, which was gathered in co-operation with the Royal Society of Canada.

59 Kingston, *Instructions to Observers*, 185–86.

reliable enough to merit systematic study.[60] The vast majority of these registers and abstracts remain in the climate data archive of Environment Canada (EC) [now Environment and Natural Resources].[61] The registers and abstracts date primarily from the early 1870s, as would be expected, although there are some earlier records that Kingston inherited from Ontario grammar schools and other places, many of which predate Confederation.[62]

Records dating from 1871 to at least 1920 in the EC archive are a mixture of registers and abstracts from all types of stations in existence during this period. With only some minor changes in numbering, the extant forms for this period conform in structure to Kingston's 1878 instructions.[63] The clear majority are records of ordinary stations, which made observations only three times a day. Most of the records of these stations are either registers of the Monthly Form 17 type or abstracts of the Monthly Form 11 type, which document these three observations. In general, monthly abstracts do not contain a great deal of qualitative data such as atmospheric or seasonal phenomena, because these were primarily intended to be used for data reduction and publishing purposes.

As there were very few chief stations in Canada during this period, there are not very many examples of forms A, B, and C, which documented up to eight daily observations. However, one can find them among the records of the few chief stations that lasted beyond the year 1900 – in Saint John, Montreal, Winnipeg, and Esquimalt, British Columbia.

Numerical climate data from these records continued to be abstracted manually by clerical staff until the service began to acquire tabulating equipment in 1950.[64] Subsequently, after 1950, numerical data were migrated, and one can now search climate statistics as far back as 1840 via the Environment and Natural Resources website.[65]

60 Thomas, *The Beginnings of Canadian Meteorology*, 205.

61 Registers and abstracts dating up to 1960 are currently on long-term loan to Western University in London, Ont., and are stored and accessible in its Archives and Research Collections Centre. A smaller body of material at Library and Archives Canada (LAC) fills in gaps in the EC holdings of observation records for areas of eastern Canada. For instance, the Weekly Form 1 records for the Ottawa station in January 1875 are found at LAC, whereas the corresponding monthly abstract Form 11 records reside in the EC collection.

62 It should also be noted that many pre-Confederation meteorological registers are held in other Canadian repositories. For example, see Victoria Slonosky's analysis cited above. Many of the sources she utilizes are from McGill University Archives in Montreal.

63 The author examined abstracts and registers from several chief and ordinary stations for the period 1871–1920, held at Western University. The only significant post-Kingston addition to the suite of forms was Form 27, used at least as early as 1902 by stations that recorded only extremes of temperature, as well as precipitation and the general state of the weather.

64 B.S.V. Cudbird, *Modern Techniques in Canadian Climate Data Processing* (Toronto: Canada, Department of Transport, Meteorological Branch, 1968), 1.

65 For instance, see Environment and Natural Resources, "Weather, Climate and Hazard: Past Weather and Climate," http://climate.weather.gc.ca/historical_data/search_historic_data_e.html, for hourly, monthly, and yearly data. It should be reiterated that qualitative data are not

Conclusion

From the earliest days of 19th-century meteorology, observers kept records of raw data. Some observers transformed ("abstracted") this data into published tables. Most, but not quite all, of this abstracted data consisted of numbers produced by instrumental observations. The earliest Canadian observers also kept qualitative information (i.e., remarks or notes about phenomena), which was kept inconsistently and never published. As the accuracy of instruments and observers improved, the quantitative data became much more voluminous and reliable to meteorologists than general remarks about the weather or seasons.

By the late 1860s, G.T. Kingston had already begun to gather observation records with the intent of abstracting them into data to meet scientific needs. His efforts to establish a climate information bank had achieved some initial success in the period 1869–1870 as he began to collect and analyze registers from many observers before the new national program came into formal existence.[66]

By the time Canada established its Meteorological Service in 1871, Kingston's own experience and those of his predecessors at the well-equipped and professional Toronto observatory had heavily influenced his approach to information gathering and recordkeeping. This resulted in his preference for highly structured, detailed, and integrated registers and abstracts. In this regard, Kingston was at the leading edge of meteorological practice. However, the Smithsonian Institution's volunteer-based and simpler registry system had an equal impact on him. In a science such as meteorology, this influence easily crossed the border between the United States and British North America.

Victorian inventory science gave impulse to both approaches because they were both focused on careful fact gathering. Regardless, the Smithsonian built its American system on a network of amateurs. By contrast, Kingston started out in 1871 with high hopes for a robust Canadian network of professional chief stations and associated record types. However, the increasing dominance of volunteers in Kingston's Canadian observing system in the early 1870s led him to write his 1878 instructions, in which he clearly attempted to balance the strengths and weaknesses of each approach.

During this period, Kingston struggled to obtain sufficient resources to ensure both a large quantity and the high quality of abstracted data. Understandably, he focused on building the organizational base of the service, which consisted largely of a network of enthusiastic amateurs. Equally during this period, he concerned himself with the practical question of weather forecasting

included and remain available for the time-being only in the original registers and abstracts. Research is currently under way in the History Department at Western University to extract this qualitative data on seasonal and other phenomena from these registers and abstracts.

66 Thomas, *The Beginnings of Canadian Meteorology*, 133.

based on telegraph data, as opposed to data about longer time climate changes. He spent the scarce resources of the new service on the most pressing practical needs, such as storm warnings for navigators and weather forecasts for farmers. Consequently, he encountered institutional skepticism from his own minister about the purpose of vast quantities of climate data. Despite his immediate focus on telegraphy and forecasting, he vigorously made the case for the accumulation of longer-term data.

His 1878 instructions served as a blueprint for improving the quality of Canada's meteorological data, but he did not see full results of their implementation because of his abrupt retirement in 1880 and death in 1886. The organizational and recordkeeping system that Kingston formalized in his instructions survived well beyond his tenure. The Meteorological Service did not release new instructions until 1930. Furthermore, Environment and Natural Resources' data archive of climate registers makes clear that the service did not significantly change its forms until well into the 20th century.[67] By the 1950s, the Meteorological Service had begun to move much of the historical climate data to computerized platforms. Kingston had laid the groundwork for the Canadian climate data archive that came into full operation in the second half of the 20th century.

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67 The author examined abstracts and registers from several chief and ordinary stations for the period 1871–1920, held at Western University. Apart from minor numbering changes to forms, Kingston's system remained intact over this period.

Appendix A: Kingston's "ideal" forms.

DAILY REGISTER (Temperature)		
Hours	Observed	Corrected
1 a.m.		
2 a.m. etc.		
12 a.m.		
MONTHLY ABSTRACT (Temperature)		
	Hours of Day	
Days	1 a.m.	2 a.m.
1		
2 etc.		
31		
ANNUAL ABSTRACT (Temperature)		
	Days of Month/ Hours of Day	
Months	1	2
January		
February etc.		
December		
SECULAR ABSTRACT (Temperature)		
	Days of Month	
Years	1	2
1873		
1874		
1875 etc.		

Adapted from G.T. Kingston, *Instructions to Observers Connected with the Meteorological Service of the Dominion of Canada* (Toronto: Copp, Clark, 1878), 157–62.

Appendix B: Kingston's forms "in use at Canadian stations."

CHIEF STATIONS

WEEKLY REGISTER FORM A	Barometer – Observed	Attached Thermometer	Corrected for Index Error	Etc.
Day of Week/Month				
Sunday Time 1 Time 2 Time 3 Time 4 Time 5 Time 6 Time 7 Time 8				
Monday etc.				
Saturday				
MONTHLY ABSTRACT FORM B	One Element (e.g., Barometer) up to 8 times daily			
Day of Month				
1 Time 1 Time 2 Time 3 Time 4 Time 5 Time 6 Time 7 Time 8				
2 etc.				
31				
MONTHLY ABSTRACT FORM C	One Element (e.g., Extremes of Temperature) once daily			
Day of Month				
1				
2 etc.				
31				

ORDINARY STATIONS

WEEKLY REGISTER FORM 1 (Class I)	Barometer – Observed	Barometer – Corrected	Pressure of Vapour	Etc.
Day of Week				
Sunday Time 1 Time 2 Time 3				
Monday etc.				
Saturday				
ABSTRACT FORM 11 (Class I)	Temperature – Corrected	Barometer – Corrected	Pressure of Vapour	Etc.
Day of Month				
1 Time 1 Time 2 Time 3				
2 etc.				
31				
REGISTER FORM 17 (Class II)	Temperature – Observed	Temperature – Corrected	Weather and Miscellaneous Phenomena	Etc.
Day of Month				
1 Time 1 Time 2 Time 3				
2 etc.				
31				
REGISTER FORM 23 (Class III)	Rainfall	Snowfall	Weather	Phenomena

Adapted from G.T. Kingston, *Instructions to Observers Connected with the Meteorological Service of the Dominion of Canada* (Toronto: Copp, Clark, 1878), 163–64; and G.T. Kingston and Canada, Meteorological Service, *Instructions for Recording Rain, Snow, Weather and Miscellaneous Phenomena: With a Supplementary Chapter on Temperature of the Air* (Toronto: Copp, Clark, 1878), 14.

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