1.2 CALCULATION OF THE 1971 to 2000 CLIMATE NORMALS FOR CANADA

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1. INTRODUCTION

Climate normals in their most basic form are monthly and annual means and totals of daily temperature and precipitation to form a base reference for characterizing the climate of a location or region. The World Meteorological Organization (WMO) recommends that countries prepare climate normals for the official 30-year normals periods ending in 1930, 1960 and 1990, for which periods the WMO published World Climate Normals. In addition WMO recommends the updating of climate normals at the end of every decade. WMO-TD/No. 341(March 1989). Temperature and precipitation and their seasonal distribution are the basic elements that define the climate of a location or region and are basic to the Koppen climate classification system, for instance. Climate normals are often used as basic information to classify a region's climate and make decisions for a wide variety of purposes involving, for instance, basic habitability, agriculture and natural vegetation, energy use, transportation, tourism, and research in many environmental fields. Normals are also used as a reference for seasonal monitoring of climate temperature and precipitation for basic public interest, and for monitoring drought or forest fires risk.

The Meteorological Service of Canada has prepared climate normals for 30-year periods ending at end of each decade since 1920, including the most recent period 1971-2000. This paper describes the development of the 1971-2000 Canadian Climate Normals.

2. DATA AND OBSERVING STATIONS

The normals elements of greatest interest are temperature and precipitation but other elements were also calculated, as listed in *Table 1*.

The basic elements are the daily values of maximum and minimum and mean temperature (deg C), rainfall (mm), snowfall (cm) and total precipitation(mm). Mean temperature is the average of the daily maximum and minimum temperature. In Canada, rainfall and snowfall are observed separately and the rain and water equivalent of the snowfall are added to form the total precipitation. At first order observing locations (generally major airports with professional observers operational on a 24/7 basis) and at some volunteer observing sites snowfall is collected in a Nipher snow gauge and the snowfall water equivalent measured directly by melting and measuring the snow collected. At most sites in the volunteer network snowfall water equivalent is estimated by dividing the snow fall by 10. So the snowfall in cm has the same value as the snow water equivalent in mm.

For principal stations, additional daily elements such as peak wind gusts, days with a variety of weather phenomena such as thunderstorms or freezing precipitation, and elements based on hourly elements such as wind, sunshine, and solar radiation are also available. Generally the network of volunteer stations is limited to basic daily temperature and precipitation observations.

The climate day at first order observing sites defined by the 24-hour period ending at 06UTC. The climate at volunteer observing sites ends at around 8 am local time and can vary somewhat from location to location.

As in many other countries, observing practices have evolved through the current normals period, and continue to evolve. Observations at one time almost exclusively taken and recorded by human observers are increasingly being automated. Some principal stations in the MSC network were automated during the 1990's. As this occurred, the only precipitation observations available were daily total precipitation (mm) from an automatic weighing precipitation gauge. The observations from these stations in these years (mostly the late 1990's) were not used for the normals calculations since daily rainfall and snowfall observations were not available.

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Table 1. List of Normals Elements currently available online

ELEMENT GROUP	NORMAL ELEMENT NAME
Temperature	Mean daily temperature deg C
	StdDev mean monthly temperature deg C
	Mean daily max temperature deg C
	Mean daily min temperature deg C
	Extreme maximum daily max temperature deg C
	Extreme minimum daily min temperature deg C
Precipitation	Total rainfall mm
	Total snowfall cm
	Total precipitation mm
	Mean Daily Snow Depth cm
	Median Daily Snow Depth cm
	Mean month end snow depth cm
	Extreme daily rainfall mm
	Extreme daily snowfall cm
	Extreme daily precipitation mm
	Extreme Daily Snow Depth cm
Days with Maximum Temperature	Days with daily max temperature LE 0 deg C
	Days with daily max temperature GT 0 deg C
	Days with daily max temperature GT 10 deg C
	Days with daily max temperature GT 20 deg C
	Days with daily max temperature GT 30 deg C
	Days with daily max temperature GT 35 deg C
Days with Minimum Temperature	Days with daily min temperature GT 0 deg C
	Days with daily min temperature LE 2 deg C
	Days with daily min temperature LE 0 deg C
	Days with daily min temperature LT -2 deg C
	Days with daily min temperature LT -10 deg C
	Days with daily min temperature LT -20 deg C
	Days with daily min temperature LT -30 deg C
Days with Rainfall	Days with rainfall GE 0.2 mm
	Days with rainfall GE 5 mm
	Days with rainfall GE 10 mm
	Days with rainfall GE 25 mm
Days With Snowfall	Days with snowfall GE 0.2 cm
	Days with snowfall GE 5 cm
	Days with snowfall GE 10 cm
	Days with snowfall GE 25 cm
Days with Precipitation	Days with precipitation GE 0.2 mm
	Days with precipitation GE 5 mm
	Days with precipitation GE 10 mm
	Days with precipitation GE 25 mm

Days with Snow Depth	Days with snow depth GE 1 cm
	Days with snow depth GE 5 cm
	Days with snow depth GE 10 cm
	Days with snow depth GE 20 cm
Wind	Days With Wind >= 52 km/hr
	Days With Wind >= 63 km/hr
	Extreme of daily max gust km/hr
	Direction of extreme of daily max gust
Degree Days	Total degree-days Above 24 deg C
	Total degree-days Above 18 deg C
	Total degree-days Above 15 deg C
	Total degree-days Above 10 deg C
	Total degree-days Above 5 deg C
	Total degree-days Above 0 deg C
	Total degree-days below 0 deg C
	Total degree-days below 5 deg C
	Total degree-days below 10 deg C
	Total degree-days below 15 deg C
	Total degree-days below 18 deg C
Soil Temperature	Mean of daily soil temperature at 5 cm depth (AM obs) deg C
	Mean of daily soil temperature at 5 cm depth (PM obs) deg C
	Mean of daily soil temperature at 10 cm depth (AM obs) deg C
	Mean of daily soil temperature at 10 cm depth (PM obs) deg C
	Mean of daily soil temperature at 20 cm depth (AM obs) deg C
	Mean of daily soil temperature at 20 cm depth (PM obs) deg C
	Mean of daily soil temperature at 50 cm depth deg C
	Mean of daily soil temperature at 100 cm depth deg C
	Mean of daily soil temperature at 150 cm depth deg C
	Mean of daily soil temperature at 300 cm depth deg C
Evaporation	Mean of daily lake evaporation mm

3. CALCULATION METHODS

First, the average or total, as appropriate for the element, for individual months was calculated and maintained in a database table as long term monthly means. Among other things, the number of days missing and the maximum consecutive number of days missing and total number of observations were recorded for each month and for each element.

The normals values were then calculated as the average for each month of all the individual months in the period that were sufficiently complete. For normals values representing averages (temperature), the WMO "3 and 5 rule" was used (the month was not used if more than 5 days total or more than 3 consecutive days were missing). For normals values representing totals of daily elements (such as precipitation, degree-days, or days with…) an individual month was required to be 100% complete in order for it to be included. The normals values were then calculated as the mean of each month. The annual normal value was calculated as the mean or total of the monthly normals values.

A normal code was assigned for each month according to the completeness criteria presented in *Table 2*. The monthly code that represented the least degree of completeness was assigned to the annual normal code for that element and location.

Table 2. Normal Code

Normal Code	Number of complete months required in the 1971-2000 period
A	WMO "3 and 5 rule" i.e. no more than 5 in total and no more than 3 consecutive years missing for both temperature and precipitation
B	25
C	20
D	15
E	10
F	5
G	1

Note that stations with a normal code of "A" in both temperature and precipitation are designated as meeting the WMO standard for normals calculation. Locations with normals having code A,B,C or D (i.e. at least 15 years record in the normals period) are published on the MSC Internet site. See below for the site's description and a discussion of the uncertainty reflected in periods shorter than the full 30-years. The numbers of stations with each normal code for daily temperature are listed in *Table 3.*

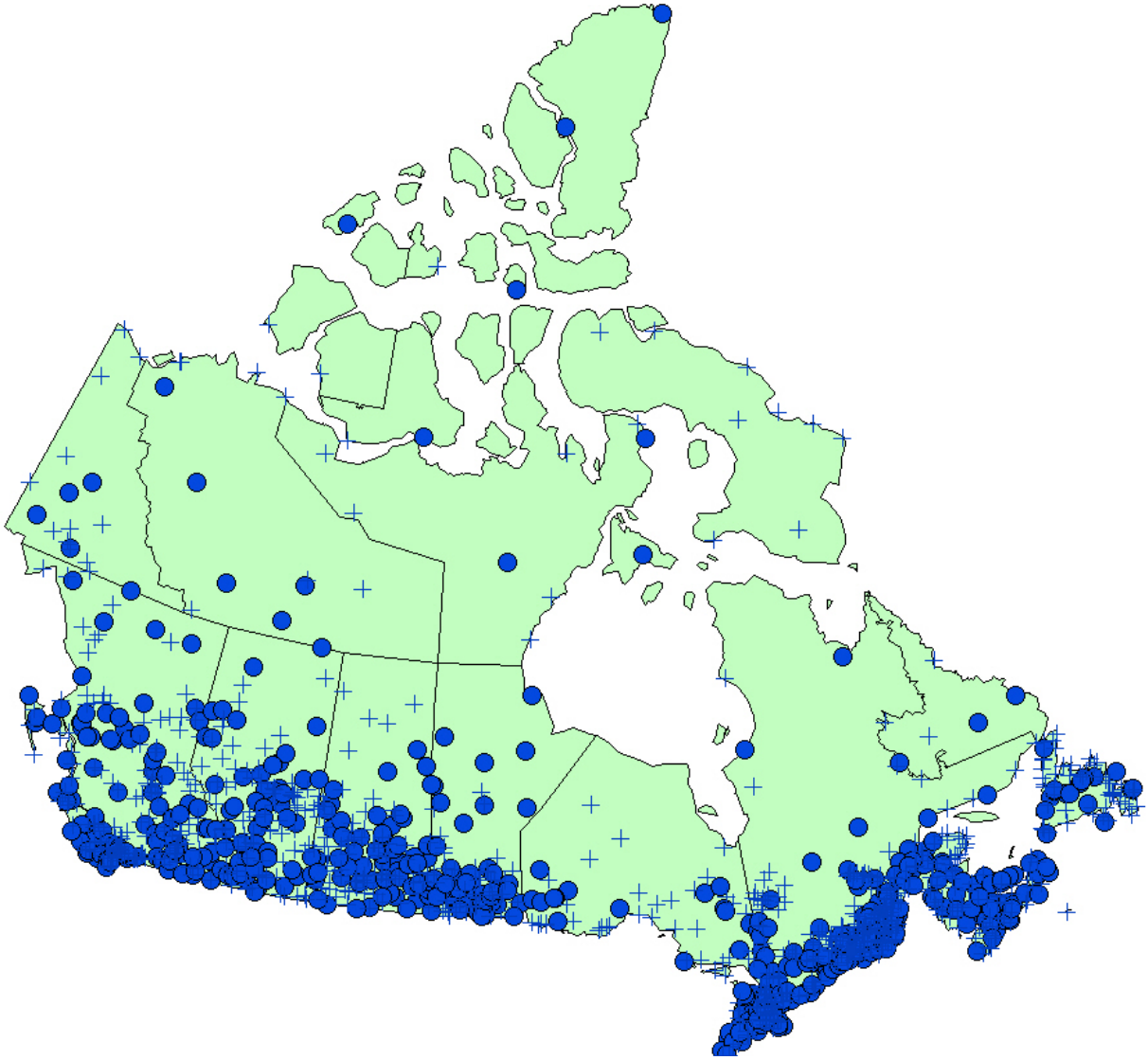
Table 3. Number of stations by Normal Code for Temperature

Normal Code	Number of Stations	
A	545	
B	9	
C	406	
D	412	
	1372	Total
Other (E,F,G)	2231	
	3603	Grand Total

Figure 1 shows the distribution in Canada of the locations with normal codes A, B, C, or D. The density of locations, similar to Canada's population, is greatest in a ribbon along the southern border with the U.S.

Note that no explicit corrections were made to normals values to account for any variations in siting, instruments, or observing procedures. To the degree that these confounding influences can affect trends in temperature and precipitation, these normals values should not be used to draw precise conclusions about changes in climate. In the MSC, researchers who investigate climate change in Canada using long-term observational data sets, have investigated these effects and made adjustments accordingly before analyzing the record for trends. Mekis, et al. (1999), Vincent, et. al. (2002), Zhang, et al. (2000)

Figure 1. Map of Canadian Climate Normals 1971-2000 Locations Normals Code A (dots) and B,C,D (crosses)



4. CLIMATE EXTREMES

Besides the monthly averages and totals, the extremes of selected elements by month including the daily maximum and minimum temperature, and the daily rainfall, snowfall, and total precipitation, and the dates of occurrence, were compiled and provided along with the normals elements. Extremes were compiled from the entire period of record of each location and not restricted to just the 1971-2000 normals period.

Table 4 shows some of the extremes of the extreme observations.

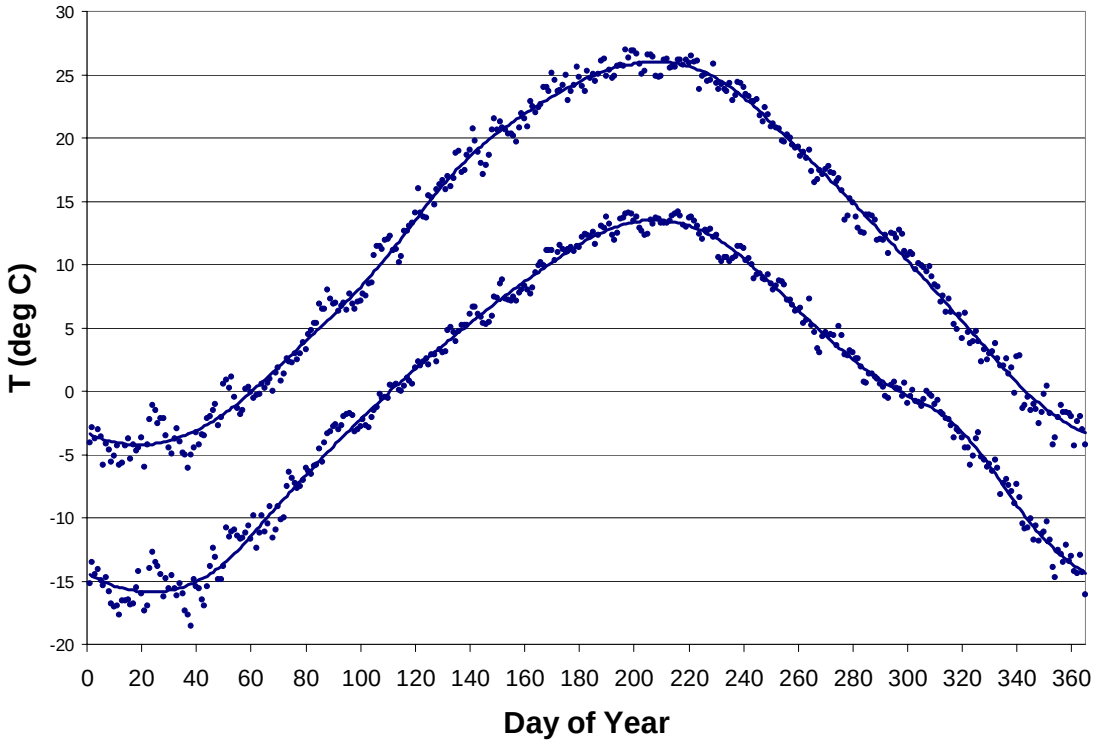
Table 4. Extremes

ELEMENT	VALUE		PLACE NAME	PROV.	DATE
Temperature					
Hottest Monthly Mean	22.67	deg C	Windsor	Ontario	July
Coldest Monthly Mean	-38.43	deg C	Eureka	Nunavut	February
Hottest Mean Maximum	29.5	deg C	Oliver	B.C.	July
Coldest Mean Minimum	-41.94	deg C	Eureka	Nunavut	February
Hottest Month on record	27.18	deg C	Pelee Island	Ontario	August, 1916
Coldest Month on record	-47.87	deg C	Eureka, Nunavut	Nunavut	February, 1979
Hottest Temperature on record	45	deg C	Midale and Yellowgrass	SASK.	July 5, 1937
Coldest Temperature on record	-62.8	deg C	Snag	Yukon Territory	February 2, 1947
Precipitation					
Greatest Monthly Mean Total Rainfall	642.72	mm	Seymour Falls	B.C.	November
Greatest Annual Mean Total Rainfall	3844.27	mm	Seymour Falls	B.C.	
Greatest Monthly Mean Snowfall	273.2	cm	Glacier National Park, Mount Fidelity	B.C.	December
Greatest Mean Snowfall	1471.19	cm	Glacier National Park, Mount Fidelity	B.C.	
Greatest Mean Monthly Precipitation	642.72	mm	Seymour Falls	B.C.	November
Greatest Mean Precipitation	4021.51	mm	Seymour Falls	B.C.	
Extreme Daily Rainfall	489.2	mm	Ucluelet Brynnor Mines	B.C.	October 6, 1967
Extreme Daily Snowfall	146	cm	Premier	B.C.	November 27, 1989
Extreme Daily Precipitation	489.2	mm	Ucluelet Brynnor Mines	B.C.	October 6, 1967
Extreme Snow Depth	976	cm	Cypress Bowl Upper	B.C.	April 9, 1999
Days With					
Maximum Temperature <= 0 deg C	287.7	days	Alert	Nunavut	
Maximum Temperature > 35 deg C	258.95	days	Amphitrite Point	B.C.	
Minimum Temperature > 0 deg C	353.04	days	Victoria (Phyllis Street)	B.C.	
Minimum Temperature < -30 deg C	164.13	days	Eureka	Nunavut	
Days with Rainfall >= 25 mm	70.68	days	Boat Bluff	B.C.	
Days with Snowfall >= 25 cm	12.87	days	Glacier National Park, Mount Fidelity	B.C.	
Days with Precipitation >= 25 mm	72.24	days	Boat Bluff	B.C.	
Days with Snow Depth > = 100 cm	128.09	days	Glacier National Park Rogers Pass	B.C.	
Degree Days					
Above 24 deg C	45.27		Hamilton	Ontario	
Above 18 deg C	423.97		Chatham	Ontario	
Above 5 deg C	2609.99		Spences Bridge Nicola	B.C.	
Above 0 Deg C	4031.57		Vancouver Harbour	B.C.	
Below 0 deg C	7516.21		Eureka	Nunavut	
Below 5 deg C	9044.58		Eureka	Nunavut	
Below 18 deg C	13731.77		Eureka	Nunavut	
Wind					
Days with wind speed >= 52 km/hr	187.1	days	Cape St. James	B.C.	
Days with wind speed >= 63 km/hr	122.14	days	Cape St. James	B.C.	
Maximum Wind Gust	193	km/hr	St. John's	NFLD.	March 15, 1956
	193	km/hr	Cape St. James	B.C.	February 9, 1978

5. DAILY TEMPERATURE NORMALS

Climate temperature normals comprise monthly mean values. Temperature, especially in spring and fall shows considerable season trends throughout the month. The monthly mean temperature value may not adequately represent for some purposes temperatures that can occur at the beginning or end of a month. To address this issue, daily temperature normals were calculated by fitting a cubic spline (Fortran code provided by the National Climatic Data Center in Asheville NC) to the monthly normals of daily maximum and minimum temperatures. The results for Fredericton NB are presented *in Figure 2*.

Figure 2



Daily average maximum and minimum temperature for Fredericton NB as calculated by a cubic spline fit to the monthly mean maximum and minimum temperatures for 1971-2000 (solid line) compared to the daily average maximum and minimum temperatures calculated for each day individually.

From *Figure 2* it is seen that the cubic spline fit provides a good, if significantly smoothed approximation to the individual daily averages. Other functions that might be fit to the data or other calculation methods such as multiple-day running averages might also be used. The spline method generally results in only one maximum or minimum value in a year with the function continuously increasing or decreasing between the two. The smooth seasonal transition has advantages presenting daily normals with temperature forecasts and was selected for general use. Daily normals based on some other methods will provide more day-to-day variation and can result, for example, in a situation where a daily normal maximum temperature in spring is lower than an earlier day in the season. Although computationally correct, the apparent contradiction with the overall seasonal trend can result in questions, and be counter-intuitive. On the other hand, some of the less smoothed day-to-day variations are statistically significant. From Figure 3, the individual daily temperatures in early January and early February (days 10 and 40) are colder than the "January thaw" in late January. This feature is smoothed by the spline fit and the coldest day of the year on average will be reported as late January rather than early February as the individual daily data would suggest.

6. UNCERTAINTY DUE TO A SHORTER PERIOD

Climate normals represent a base 30-year period. Most observing locations in Canada do not have complete records for the 30-year period. For instance, of the Canadian 545 locations with normals code A, there are only 44 locations with every month complete in both temperature and precipitation. Apart from any uncertainty due to site, instrument, or observing program changes, or general representativeness of the observing site with the surrounding region, then the normals values for most locations will have some uncertainty due to the fact that the observations are not complete for the 30-year period.

To estimate this uncertainty we conducted some trial calculations for the 44 locations with a complete record in the 1971-2000 period. For mean temperature and total precipitation, means were calculated for each sub-period representing consecutive years of length from 1 through 30 years for each month and annually. Then the standard deviation of the differences between the mean of each sub-period and the full 30-year mean was calculated. For example, for the sub-periods having length 10 years, 21 monthly and annual mean values were calculated for the overlapping sub-periods 1971-1980, 1972-1981,….,1991-2000. The standard deviation of the differences between these means and the mean for the 1971-2000 period represents a measure of uncertainty due to an incomplete record.

A map showing the 44 locations is provided in *Figure 3* and results are provided in *Figures 4* and *5*.

Figure 3. Canadian locations for which the 1971-2000 Canadian Climate Normals are based on a complete 30-year record.

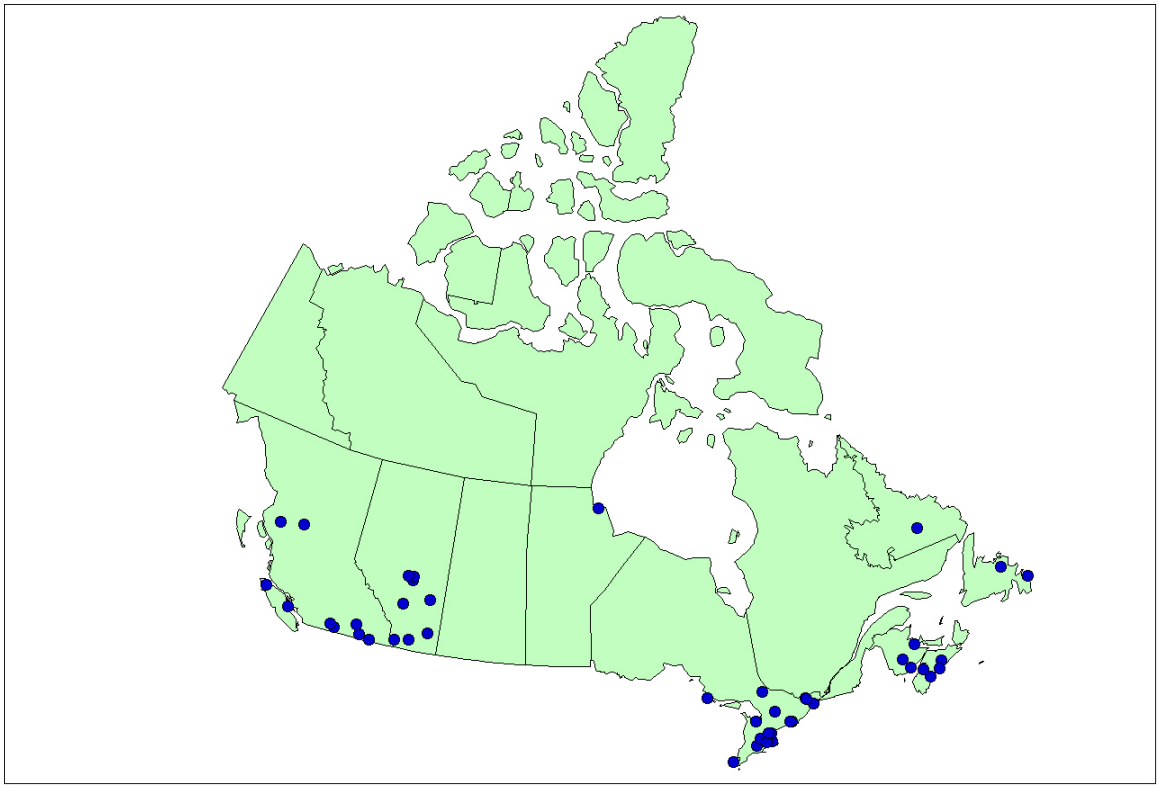
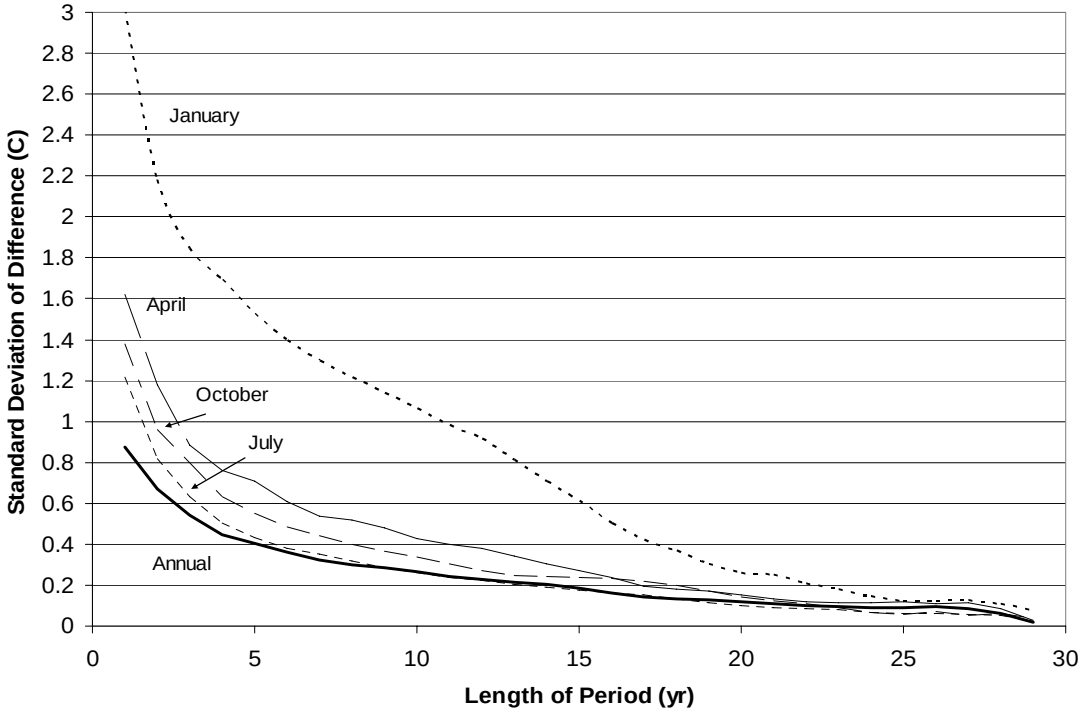
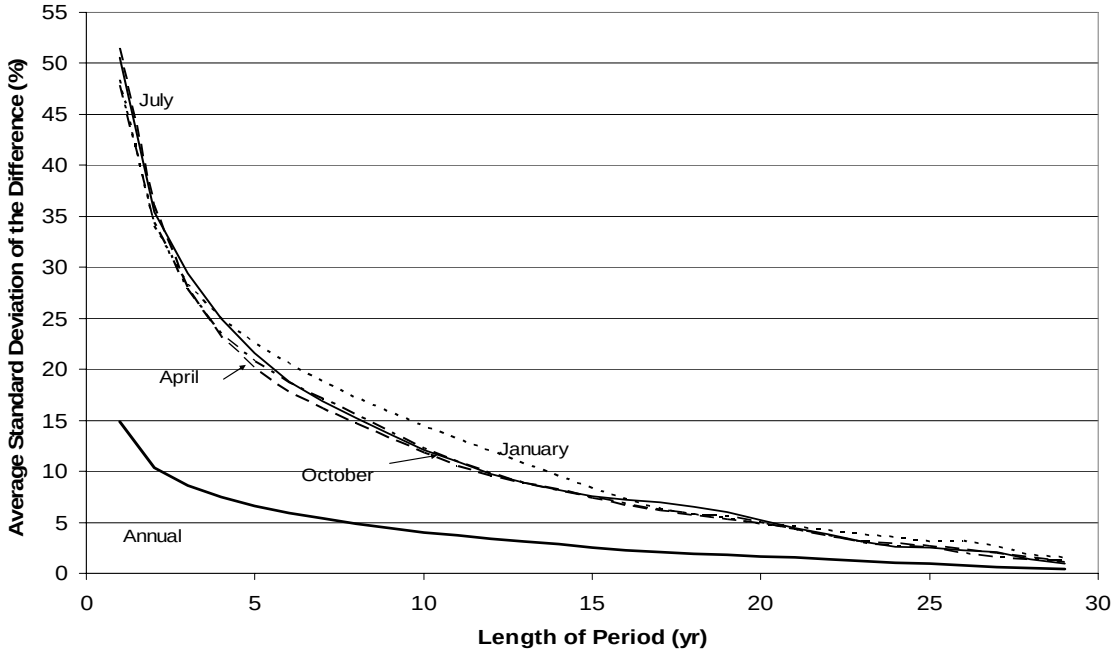


Figure 4



TEMPERATURE. Variation with Length of Period of the Average Standard Deviation of the Difference Between the Average of Sub-Periods and the 30-year Mean Temperature for Selected Months and the Annual Period. Average over 44 Locations.

Figure 5



PRECIPITATION. Variation with Length of Period of the Average Standard Deviation of the Difference Between the Average of Sub-Periods and the 30-year Mean Precipitation for Selected Months and the Annual Period. Average over 44 Locations.

The sub-periods used for these calculations overlap so the mean values calculated for each sub-period are not independent. Nonetheless, the standard deviations of the differences and their means can be viewed as an estimate of a standard error related to the uncertainty due to incomplete records.

In *Figure 4*, the standard deviation is significantly higher for January for all periods than the other selected months or the annual period. For the 15 year period (the shortest period for which normals are provided on our web site), the January standard deviation is about 0.7 C whereas the other selected month range from 0.2 to 0.3 C, and the standard deviation for the annual period is 0.2 C. Clearly, on average, the winter months are more variable and the uncertainty for the January temperature normals is higher due to a short record than the other months.

The standard deviation for precipitation, calculated as the average percentage difference, in Figure 5 shows a somewhat different pattern. The standard deviations for selected months are larger than the annual period, for all lengths of sub-period, but the differences amongst months are small. There is less seasonal variation in the uncertainty of precipitation than is the case with temperature. The standard deviation for precipitation for a 15-year sub-period is about 8% for monthly values and about 3% for the annual value, with decreasing uncertainty with increasing length of period. These results can be a guide to selecting normals values based on the normals code (A,B,C, or D).

Note that the average temperature standard deviation for the one-year sub-period is exactly the same as the temperature standard deviation published with the normals.

7. NORMALS AVAILABILITY

The 1971-2000 Canadian Climate Normals are provided on the MSC weatheroffice web site at climate.weatheroffice.ec.gc.ca, for basic elements calculated from daily climate observations. The normals are selectable by location name, and presented in tabular format. Planned additions in the coming months include:

- new elements based on hourly observations (such as wind and solar radiation)
- an enhanced interactive user interface to select locations based on element availability and normals code (period length)
- a downloadable bulk file of normals values for importing into a spreadsheet or database
- normals of the frost-free period
- an almanac with daily records and daily temperature normals

In contrast to previous Canadian Climate Normals (reference), we plan only electronic publication of the current normals.

8. CONCLUSION

The Meteorological Service of Canada has updated the Canadian Climate Normals for the 1971-2000 period. Basic temperature and precipitation normals for 1372 locations having at least a 15-year record in the normals period are published and available on the MSC public web site. Additional normals products will be added in the coming months.

Estimates of uncertainty suggest a typical error of 0.2 C for the annual mean temperature and 3% for the annual precipitation for locations having a 15-year record, relative to the full normals period. Errors for individual months range as high as 0.7 C for temperature and 8% for precipitation.

9. ACKNOWLEDGEMENTS

The authors would like to thank Randy Brown, Art Leganchuk and Frank Lauritzen for developing and running the software used for the calculations. Thanks are also due to various MSC staff who contributed to the development and review of the project. Finally, we appreciate the assistance of Marc Plantico and Tim Owen at the National Climatic Data Centre who provided their cubic spline Fortran code for calculating daily normals.

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