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**DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH**

**DIFFERENCES IN TEMPERATURE DATA
FROM ORDINARY CLIMATOLOGICAL STATIONS
ARISING FROM ONCE DAILY READINGS
AS COMPARED TO TWICE DAILY READINGS**

W R BURROWS

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ABSTRACT

For guidance in comparing temperature data from stations reading extremes of temperature only once daily with that from stations reading twice each day, estimated differences arising from the two different procedures have been calculated for ten stations across Canada.

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DIFFERENCES IN TEMPERATURE DATA FROM ORDINARY CLIMATOLOGICAL STATIONS
ARISING FROM ONCE DAILY READINGS AS COMPARED TO TWICE DAILY READINGS

by

William R. Burrows*

1. INTRODUCTION

The Climatology Division of the Meteorological Branch of Canada maintains approximately 2000 cooperative weather stations across the nation. Because they are staffed by volunteer observers who must fit the reading of their instruments into their daily schedule many problems have resulted. Foremost of these occurs when the frequency of reading, and the time of observation of maximum and minimum temperature, varies from station to station.

The climatological day at principal stations has ended at 0600 GMT since July 1, 1961. This corresponds to local times of 2200 YST in the Yukon and 0200 AST in the Maritimes. Most cooperative observers who take twice daily readings read their maximum and minimum thermometers at approximately 0800 LST and 1700 LST with deviations of about an hour, as these times are the most convenient for them. As a result, the principal stations follow a climatological day from approximately midnight to midnight LST, while the cooperative stations where two readings a day are taken follow a day from 1700 LST the previous day to 1700 LST of the current day for their minimum temperatures, and 0800 LST the current day to 0800 LST the following day for their maximum temperatures.

Under these two procedures, differences are relatively few. Daily maximum temperatures differ only when the maximum occurs between the 0600 GMT observation and the time of the morning observation at the ordinary climatological station. Similarly the minimum temperature for the day must occur between the late afternoon and the following 0600 GMT observation to give different results from the two procedures.

In Canada the observers at approximately one third of the cooperative stations read their maximum and minimum temperatures only once a day, which results in more serious differences in temperature data. Most often they take a daily observation each morning, although a few

* This study was made during the summer of 1963 while Mr. Burrows, a physics undergraduate of the University of Alberta, was employed as a student assistant in the Climatology Division of the Meteorological Branch.

observers take observations only each afternoon or evening. When an observer reads his thermometers only in the morning he is then adhering to a climatological day beginning with the observation of the previous morning and ending with the observation taken the current morning. Under this program the maximum temperature is credited to the previous day, and the minimum temperature to the current day. When an observer reads his thermometers only in the afternoon, he is actually following a climatological day beginning at the time of observation the previous afternoon and ending at the time of the afternoon observation of the current day, with both temperatures credited to the current day.

Under these procedures, a maximum temperature based on the same climatological day as when two observations daily are taken is obtained when readings are taken once each morning. However, the ending of the climatological day for the minimum temperature is advanced from late afternoon to the time of the morning observation which does differ from the climatological day of twice daily readings. Therefore, under such a procedure an observer will often not report the same minimum for the date as would be reported with two readings daily, and there will also be considerable error in the mean minimum, and hence in the mean temperature, reported for the month. There has been some mention of these errors by Conrad in his text, "Methods of Climatology" (3), but thus far there has been nothing published in Canada to serve as a guide in determining the size and frequency of such errors imbedded in Canadian data. This circular has been prepared to give guidance in determining the probable extent of such errors.

While observers taking an observation once a day in the afternoon are not as numerous, the errors resulting from this procedure are also given. Unlike the morning observation, the afternoon only observations will give a minimum temperature based on the same climatological day as if two observations were taken. However, in this case the climatological day for the maximum temperature ends at the time of the afternoon observation instead of the following morning, and the maximum temperature can be in error.

2. DATA ANALYSIS

Using monthly maximum and minimum temperature reports obtained from form 2304 climatological station reports from 1959 to 1962 received from ten stations (fig. 1) maintained by the Canadian Department of Agriculture across Canada where twice daily readings of the extremes of temperature were recorded, simulated reports were compiled as if each station read its minimum temperatures once a day in the morning. A second set of simulated reports was compiled as if each station read its maximum temperatures once a day in the afternoon.

The effect on the mean minimum temperature of reading the extremes of temperature only once each day instead of twice daily were estimated by subtracting the mean from the original report from the simulated mean minimum, and averaging the differences over the four year period. As well, the number of days on which the simulated minima differed from those obtained by twice daily reading, were counted for each month and averaged over the same period. The results were then tabulated and illustrated graphically for each station.

The second set of reports compiled as if observations had been taken only once each day in the afternoon were analyzed in a similar manner. This analysis gave the difference in mean maximum temperature, as well as the average number of days per month on which the maximum temperature differed from the original report, with this change in observing procedures.

In the graphical and tabular presentation of the results an estimate of the differences resulting from the morning only, or afternoon only, rather than twice daily observational procedures are combined, although from the above it should be clear that only differences in either the maximum or minimum temperatures, but not both, result when an observer takes only one observation per day.

The accompanying graphs therefore show the estimated average difference in degrees for the period 1959 to 1962 caused by reading the minimum temperature once each day in the morning, or the maximum temperature once each day in the afternoon, as compared to twice daily. The estimated average number of days each month when the readings are affected by these changes in procedure, are also illustrated.

It must be noted here that for Lennoxville, Quebec, the data for January and February 1959, and November and December 1962, were not used because the maximum and minimum were read only once a day. The data for Fredericton, N. B. for January and February 1959 were not used for the same reason. Thus, the estimated differences in the mean maximum and minimum, and the days affected at these stations, are calculated over a three year period for the months mentioned.

3. GENERAL DISCUSSION

Differences in Minimum Temperatures

When a minimum temperature was estimated for a once-a-day morning observation it could differ from the value derived from the twice-a-day observation by being either lower or higher. A lower value would result during warming weather when the minimum thermometer had been reset the previous morning and the minimum temperature reading would be the actual reset value from the previous morning. A higher minimum temperature from a once-a-day morning observation would result when the weather turned colder after the morning minimum had been read. However, the carry-over of higher readings was much less frequent than that of lower values.

The effect of reading the minimum temperature once each morning as recorded in the simulated reports, almost always decreased the monthly mean minimum as recorded on the original reports. In only three cases was it increased, and these amounted to increases of only 0.1°F. each (see Table 1 and Fig. 2). Data for the transition and winter months, September to March, were without exception the most affected. In almost all

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cases the mean minimum was lower by one or more degrees from October to March. For eight of the ten stations the mean minimum was decreased 2°F. or more in at least one month during this period. At six of the ten stations the mean minimum was lowered by 2°F. or more in two months during this period, usually February and March. The interesting case is Fredericton, N. B. in which January, February and March mean minimum temperatures were lower in excess of 2°F. , with February lower by 4.3°F. It must be remembered that the January and February data were based on three years only.

At seven of the ten stations the mean minimum was decreased the most in February or March. This may be attributed to the large temperature fluctuations from day to day which often occur in these months.

Although the summer mean minimum temperatures were generally lowered, it was rarely by more than 0.5°F. , except at Kentville, N. S. In most cases, from May to August the difference produced by the simulated changes in procedure ranged from -0.3°F. to $+0.1^{\circ}\text{F.}$ As most stations took observations at approximately 0800 LST, the true minimum had usually occurred well before this time in the summer months.

The number of days upon which the simulated minimum temperatures differed from the minimum obtained from twice daily readings naturally followed the same pattern quite closely, being high in winter and low in summer (Fig. 3). All of the stations experienced at least one winter month, usually December or January, when fifteen or more minima differed on the average. The extreme was Beaverlodge, Alberta where nineteen differences in minima, on the average, were noted in the December data.

Generally, in the summer the minimum temperatures differed on five days or less. Eight of the ten stations had two days or less affected in at least one month, usually June or July. However, no station experienced a month completely unaffected over the four years.

Differences in the Maximum Temperatures

A maximum value estimated for a once-a-day observation in the late afternoon could also differ from the value derived from a twice-a-day observation by being higher or lower. A higher maximum value would result during cooling weather when the carry-over of the temperature at the time of reset the previous afternoon was warmer than the temperature of the current afternoon. A lower maximum reading would result when warming takes place during the late evening or night-time after the afternoon maximum had been read. However, the incidence of lower maximum temperatures was much less frequent than the carrying over of the high readings from the previous day. As a result, with estimated once-a-day readings, the monthly mean maxima were higher in all cases than those of twice daily readings (see Table I and Fig. 2).

The annual trend in the differences produced by reading the maximum temperature once every afternoon was not nearly so evident as that produced by reading the minimum temperatures once every morning. Only four stations: Agassiz, B. C.; Vauxhall, Alberta; Scott, Saskatchewan; and Morden, Manitoba showed a definite trend. This was one of a slow increase in the differences in the mean maximum until September, and then a fairly rapid decrease until December. The other six stations either had fairly even differences or fluctuated from month to month. However, the differences for the other six stations did tend to be somewhat lower in winter months than in summer months.

The main feature in the differences in the mean maximum temperatures that this simulated change in procedure produced was that at all stations the mean maximum was increased considerably for nearly every month. At almost every station differences in the mean greater than 1°F. occurred in ten to eleven months. The exceptions were Agassiz, B. C. and Lennoxville, Quebec, but these still had six and seven months respectively with mean maximum higher by more than 1°F.

The graphs of the resultant differences in the maximum temperatures at the prairie stations of Vauxhall, Alberta; Scott, Saskatchewan; and Morden, Manitoba showed similarities indicating that they all experience similar climates (Fig. 2). Each had a mean maxima higher by 2°F. or more in most summer months. For all three the greatest estimated deviation occurred in September, with Vauxhall and Morden having their mean maximum increased by 3.3°F. and 3.2°F. respectively.

The number of days in which the maximum obtained by reading once each afternoon would differ from the maximum obtained by twice a day readings showed a slight annual trend at all stations but Agassiz, in that there were more deviations in winter than in summer (Fig. 3). This was not nearly as marked as the trend of the same sort produced in the mean minima.

Most stations had at least two months when, on the average, fifteen or more maximum temperatures differed, most of these occurring during the winter months. At Ottawa there were six months when differences on fifteen or more days, on the average, occurred over the four year period. The extreme again occurred at Beaverlodge, Alberta, where December averaged differences on twenty days and January on twenty-one.

At all stations but Lennoxville and Harrow there was never a month with less than eight maximum temperatures differing. Most stations had the lowest number of maximum temperatures differing for a month near or greater than ten, and these occurred in the summer months at all stations but Agassiz. No station had fewer than five differences in maximum temperatures in any month.

It is interesting to note here that the three prairie stations at Vauxhall, Scott and Morden again showed similarities in that they experienced a somewhat lower number of deviations over the year, on the average, than most of the other stations across Canada.

Further Discussion

It is to be expected that the variations in the results would be determined by the climatic region in which the stations are situated. For example, in the maritime climate of the Lower Fraser Valley where Agassiz, B. C. is located, during the winter months the differences in the minimum in all months ranged between 0.0°F . and -1.0°F . This may be attributed to the absence of large temperature fluctuations from day to day due to the stabilizing influence of the Pacific Ocean and the protection of the mountain barrier against cold outbreaks from the Arctic.

The effect of the continental climate found over the rest of Canada, including the Maritimes, because of the prevailing westerly winds, was noticeable in the large differences between twice daily mean minimum and simulated once daily mean minimum which occurred in winter months, and in the even larger differences in the mean maximum during summer months. This could be accounted for by the frequency of large temperature fluctuations which can occur from day to day in a continental climate.

4. GENERAL CONCLUSIONS

Limitations

Some limitations upon the study should be kept in mind. Firstly, only four years of data were used for some months and at the two stations previously mentioned, only three years. It is difficult to base any positive conclusions unless more data are available. Secondly, the times of observation were not standard at all the stations used. Although five stations took observations at 0800 LST and 1700 LST all four years, and two more at very nearly these times, there were three stations: Ottawa, Scott and Agassiz where the times of observation fluctuated during the four year period. These three stations took their temperature observations at times differing anywhere from one half hour to one and a half hours from 0800 LST and 1700 LST. It is further expected that the stations changed to daylight saving time in the summer if this time was used in the municipality.

Conclusions

The results found in this study and reproduced graphically give an idea of the size of the correction in the monthly mean maximum and minimum temperatures which could be applied to temperature data from once-a-day observations to make them comparable to data from stations with twice daily readings.

The results from the three prairie stations of Vauxhall, Scott and Morden were relatively similar and thus might be used with some degree of confidence in a correction table for the prairies for stations taking one-a-day observations at the times of the simulated observations in this study, as most of this region experiences similar climatic conditions.

The chances of obtaining the same reading as that obtained by reading the extremes of temperature twice daily when only morning observations are available for the minima, and afternoon observations are available for the maxima varied, of course, from station to station. However, on the average it would appear that at stations taking only a morning observation the minimum temperature readings would be accurate 80% to 90% of the days in summer with a decrease to 70% to 80% in the transition months, and further decrease to only 40% to 50% in winter months. The probability of accurate observations of maximum temperature at a station taking only an afternoon observation is less well defined. On the average, the reading would be accurate on 50% to 70% of the days in the summer and during the transition months, with a decrease to 35% to 50% in winter months.

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APPROVED,


J. R. H. Noble,
Acting Director.

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TABLE 1

TABLE OF ESTIMATED DIFFERENCES IN MEAN MONTHLY MINIMUM AND MEAN MONTHLY MAXIMUM TEMPERATURES (°F) AND THE AVERAGE NUMBER OF DAYS EACH ARE IN ERROR WHEN OBSERVATIONS OF MINIMA ARE MADE IN MORNING ONLY, MAXIMA IN AFTERNOON ONLY

AGASSIZ, B. C.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max	0.4	0.8	1.0	1.4	2.0	1.8	1.7	2.4	1.5	0.7	0.2	0.1
Days	15	13	8	10	14	14	16	14	12	8	9	14
Mean Min	-1.0	-0.6	-0.4	-0.2	-0.2	-0.2	0.0	-0.3	-0.4	-0.7	-0.8	-0.8
Days	15	10	8	5	5	6	2	5	5	8	10	11

BEAVERLODGE, ALBERTA

Mean Max	1.0	1.7	1.5	2.0	1.7	1.7	1.6	1.6	1.9	1.9	1.4	0.2
Days	21	14	13	9	10	11	11	12	9	13	14	20
Mean Min	-1.8	-2.2	-2.7	-0.6	-0.1	0.0	0.0	0.0	-1.0	-1.7	1.0	-0.9
Days	18	13	13	6	4	2	2	1	7	11	14	19

VAUXHALL, ALBERTA

Mean Max	1.3	1.6	1.9	2.7	2.1	2.0	2.0	2.3	3.3	2.7	1.7	1.1
Days	16	12	12	8	10	10	9	11	12	9	11	13
Mean Min	-2.1	-1.8	-1.7	-0.2	-0.1	0.0	-0.1	-0.1	-0.2	-1.3	-2.0	-1.7
Days	17	12	9	3	2	1	1	1	4	9	12	14

SCOTT, SASKATCHEWAN

Mean Max	1.1	1.2	1.3	1.7	2.2	1.6	2.0	2.0	2.8	1.9	1.0	1.1
Days	19	11	12	8	9	8	9	12	12	9	13	17
Mean Min	-1.8	-1.3	-2.4	-0.7	-0.2	0.1	-0.1	-0.1	-0.4	-2.0	-1.6	-1.5
Days	18	16	15	10	2	3	3	4	7	15	14	16

MORDEN, MANITOBA

Mean Max	1.1	1.5	1.3	2.1	1.9	1.8	1.6	2.1	3.2	2.3	2.2	0.9
Days	14	13	15	9	10	8	9	10	11	10	12	18
Mean Min	-1.3	-1.7	-2.3	-0.7	-0.2	-0.1	0.1	-0.2	-0.1	-0.7	-1.0	-1.5
Days	14	11	11	8	3	2	3	2	4	7	12	13

HARROW, ONTARIO

Mean Max	1.7	1.7	1.3	1.6	1.8	1.8	1.1	0.8	1.5	1.5	1.6	1.3
Days	16	16	11	9	11	8	10	6	9	10	11	17
Mean Min	-1.6	-1.6	-1.3	-0.5	-0.3	0.0	-0.1	-0.1	-0.6	-1.2	-1.3	-1.1
Days	16	12	13	7	6	5	4	5	5	9	11	12

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TABLE 1 cont'd

OTTAWA, ONTARIO

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max	2.0	1.0	1.8	2.1	2.1	1.9	1.5	1.0	2.4	2.4	1.1	1.8
Days	19	16	13	12	16	14	15	9	14	16	14	18
Mean Min	-1.9	-2.4	-1.2	-0.4	-0.3	-0.4	0.0	-0.5	-0.9	-1.5	-1.2	-1.9
Days	13	10	10	6	6	5	2	6	7	9	10	15

LENNOXVILLE, QUEBEC

	*	*									*	*
Mean Max	1.6	1.3	1.2	1.2	1.6	1.0	0.7	0.4	0.8	0.8	0.9	1.2
Days	12	10	8	8	8	6	5	5	6	7	8	11
Mean Min	-2.6	-3.4	-2.0	-0.2	-0.1	0.0	-0.2	-0.6	-1.0	-0.9	-0.7	-1.5
Days	15	13	11	6	4	2	4	5	7	8	12	15

FREDERICTON, N. B.

	*	*										
Mean Max	1.7	1.3	1.5	1.5	2.3	1.7	1.5	1.5	1.8	1.8	1.7	0.6
Days	17	13	12	11	14	13	11	11	14	12	14	14
Mean Min	-2.3	-4.3	-2.1	-0.8	-0.3	-0.2	-0.1	-0.6	-0.8	-1.2	-1.4	-1.5
Days	11	15	10	6	4	3	2	5	7	8	10	14

KENTVILLE, N. S.

Mean Max	1.8	1.0	1.0	2.3	1.9	2.0	1.5	1.7	1.5	1.5	0.9	0.8
Days	19	15	12	11	13	11	12	11	10	13	13	16
Mean Min	-1.5	-2.9	-2.2	-0.6	-0.5	-0.6	-0.5	-0.7	-1.4	-1.2	-1.2	-1.3
Days	15	13	11	6	6	7	5	8	8	12	14	13

* three years of data

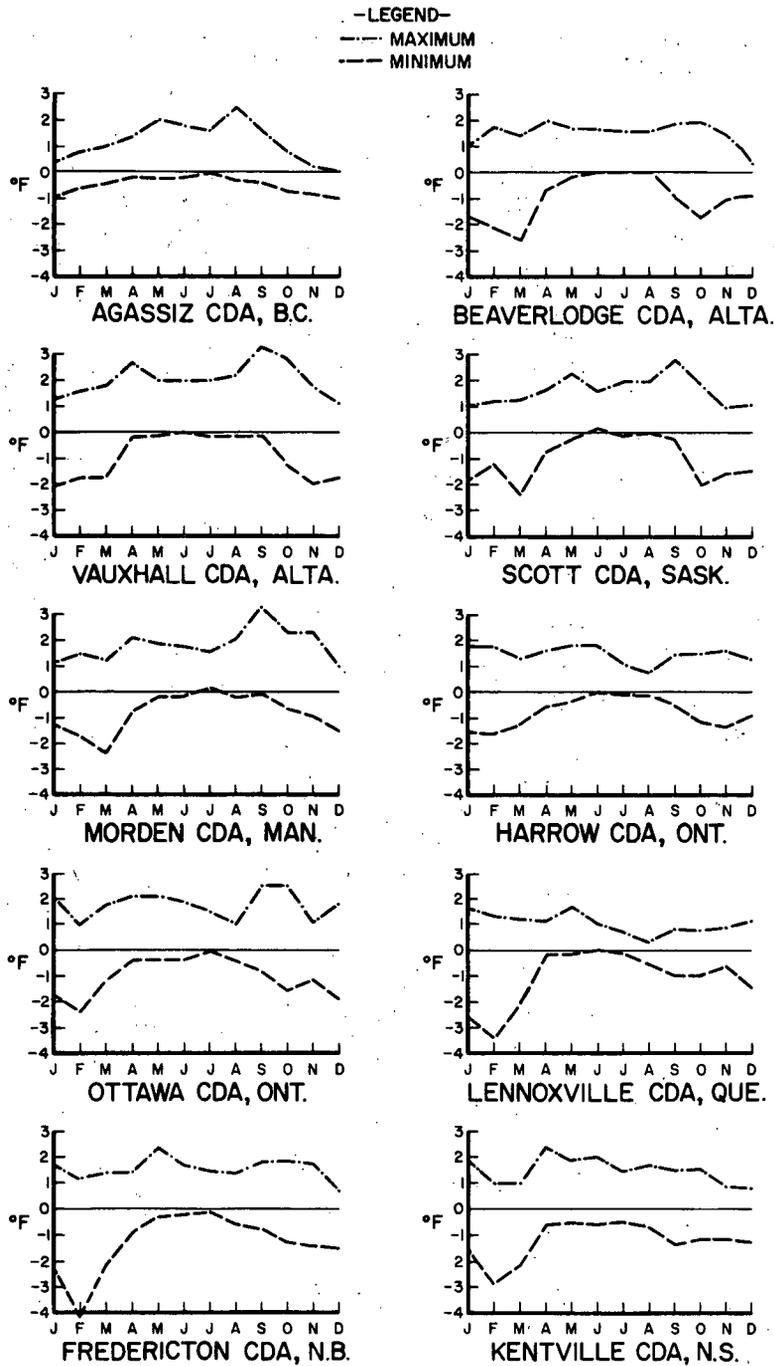


FIGURE 2 - DIFFERENCES IN MEAN MONTHLY MINIMUM (AND MAXIMUM) TEMPERATURES WHEN OBSERVATIONS ARE MADE IN THE MORNING ONLY (AFTERNOON ONLY) AS COMPARED TO THOSE DERIVED FROM TWICE DAILY OBSERVATIONS

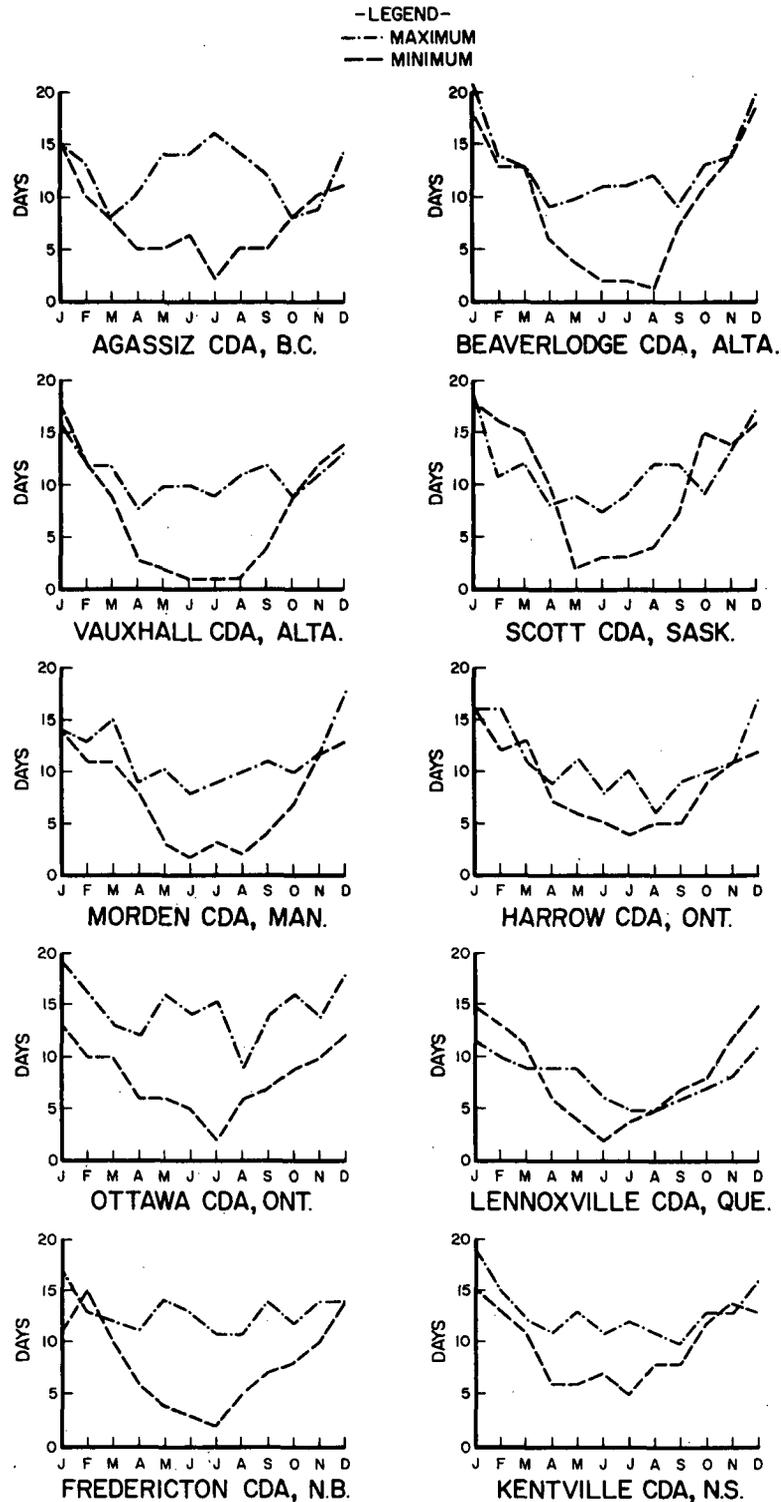


FIGURE 3 - AVERAGE NO. OF DAYS PER MONTH WHEN THE DAILY VALUES OF MINIMUM (AND MAXIMUM) TEMPERATURE OBSERVATIONS MADE IN THE MORNING ONLY (AFTERNOON ONLY) DIFFER FROM THOSE DERIVED FROM TWICE DAILY OBSERVATIONS

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