A Note on Fluctuations in the Normal Temperature Trend at Selected Canadian Stations

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ABSTRACT

Spurious fluctuations in the normal mean daily temperatures for ten Canadian stations are filtered out, using weighted running means. The filtered curves reveal cycles of temperature peaks at intervals of about 17 days. An attempt is made to relate these cycles to the index cycles of the atmospheric general circulation.

1 Introduction

The term "January thaw" is often heard during early winter in various parts of Canada. The term refers to a short "warm weather" period that generally occurs during or around middle January in many parts of Canada. According to our recollections, two such "warm spells" were experienced during January 1968 and 1969 in Montreal and Toronto, and recent ones in Edmonton during January 1973 and 1974. In each of these four cases, the warming trend occurred just prior to the annual minimum temperature which generally occurs in late January.

In this note, long-term averages of mean daily temperatures at selected Canadian stations are closely examined. It is found that this temperature fluctuation is not only confined to a mid-January thaw, but appears over the winter months (December to March) in a quasi-periodic manner with a period of about half a month. These quasi-periodic fluctuations are especially well-marked when the raw data is smoothed out, using a scheme of running means as discussed in the next section. An attempt is made to relate these cyclic fluctuations in the mean daily temperatures to the index cycles of the general circulation.

2 Treatment of Data

Since the main objective was to study January temperatures, only the winter months of December to March are investigated here, as temperature changes are most pronounced during these winter months at mid-latitudes. Fig. 1 shows long term (more than 90 years) averages of daily temperatures for Edmonton,

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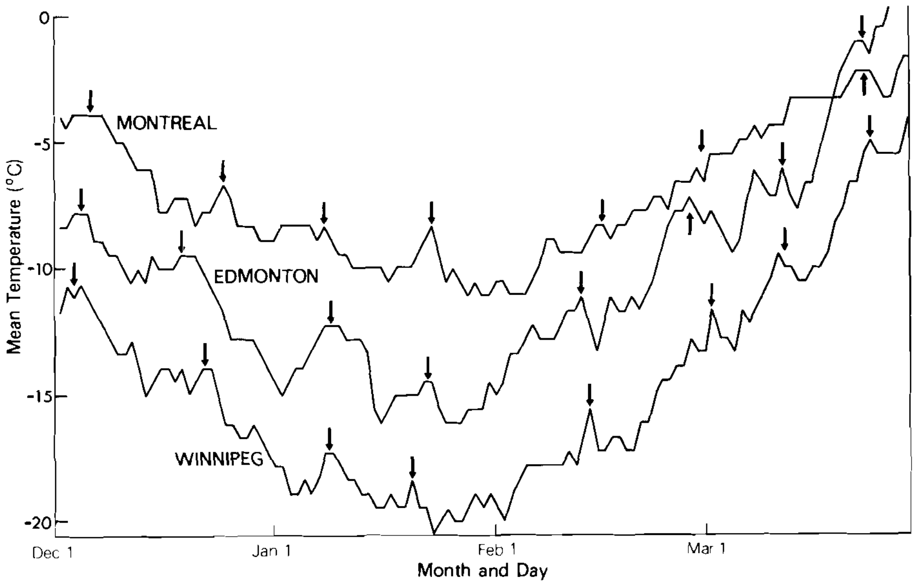

Fig. 1 90-, 98-, and 99-year averages of mean daily temperatures for Edmonton, Winnipeg, and Montreal respectively, for December 1 to March 31st. Arrows indicate the main peaks.

Winnipeg and Montreal, respectively. It can be seen that spurious fluctuations are not all filtered out by simple averaging over 90 years or more. In addition, one notes almost coincidental peaks (indicated by arrows in Fig. 1) spaced approximately half a month apart, but with some longitudinal lag in time from west to east.

In order to smooth the spurious fluctuations in the data a suitable scheme of weighted running means was used. Typically a weighted running means can be expressed as

$$\overline{T}_t = \sum_{k=-n}^{n} w_k T_{t+k}$$

$$= w_{-n}T_{t-n} + w_{-n+1}\,T_{t-n+1} + \dots w_0 T_t + \dots + w_n T_{t+n} \qquad (1)$$

Here T_t is the raw value of the temperature at time t. $\overline{T}_t$ is the corresponding smoothed value and w_n are a set of approximately chosen weights. The value of n will depend upon the length of the time over which the running mean is desired. For example, a seven-day running mean will be accomplished by choosing $n = 3$. The spurious fluctuations in our temperature records correspond to high frequency waves which can be suppressed by using a suitable scheme of running means corresponding to a low-pass filter (see Holloway, 1959). In this study, we have used a nine-day running mean having weights w, decreasing in magnitude outward from the principal weight. As pointed out by Holloway (1959), such a scheme of weighting function reduces the negative response and does not generate any unwanted ripples on the smoothed output.

The values of the weighting functions and the corresponding filter responses have been discussed by Danielson and Bleck (1970).

3 Results and discussion

Fig. 2 shows the smoothed temperature curves for Edmonton, Winnipeg, and Montreal, using 90 years or more of data. The main peaks at 15–20 day intervals stand out very clearly. Fig. 3 depicts the curve for Regina[1] which shows similar quasi-periodic fluctuations. The smoothed temperature curves for Halifax[1] and St. John's[1] (Newfoundland) are shown in Fig. 4. Since the normal temperature range for these maritime stations is relatively smaller, Fig. 4 is drawn with a stretched temperature scale; nevertheless it is interesting to note that these curves also exhibit small but definite temperature fluctuations. The smoothed curves for the remaining stations,[1] not shown here, all show essentially similar fluctuations, including Calgary[1] with its notorious chinooks throughout the winter months.

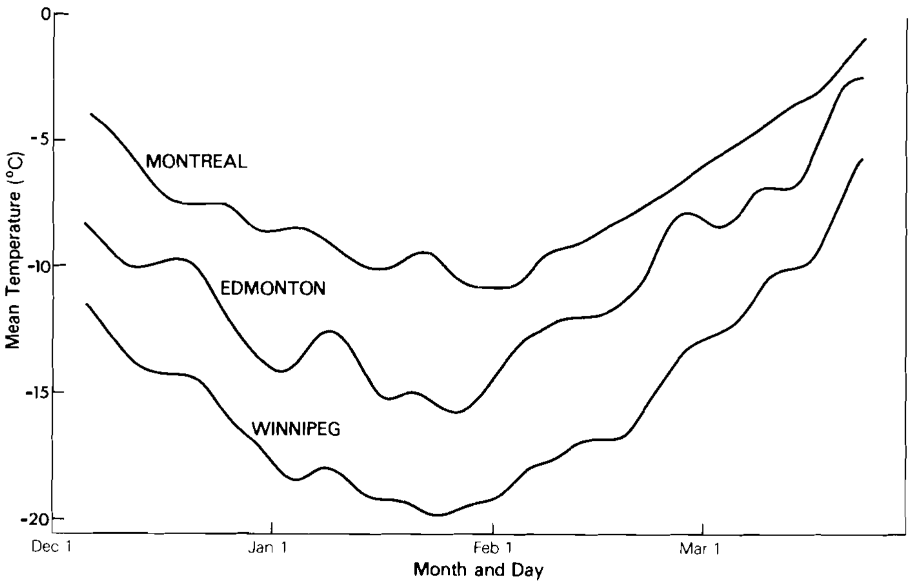

Fig. 2 Seven-day weighted running means of the 90-year(+) mean daily temperatures for Edmonton, Winnipeg, and Montreal, for December 4 to March 28.

Table 1 lists and summarizes the average period of the temperature cycle for all stations using a nine-day running mean. Here the period is defined as the average number of days between successive maxima on the filtered curves. Thus, when spurious fluctuations are filtered out, the average periods range from 15 to 20 days, giving a mean over all the stations of 17.2 days. The peaks for the smoothed curves as well as for the raw data do not coincide for all the stations; rather, there appears to be a west to east propagation of the cycle with time as can be seen from an inspection of Figs. 1 to 3.

[1]Thirty years of raw data were used for these curves.

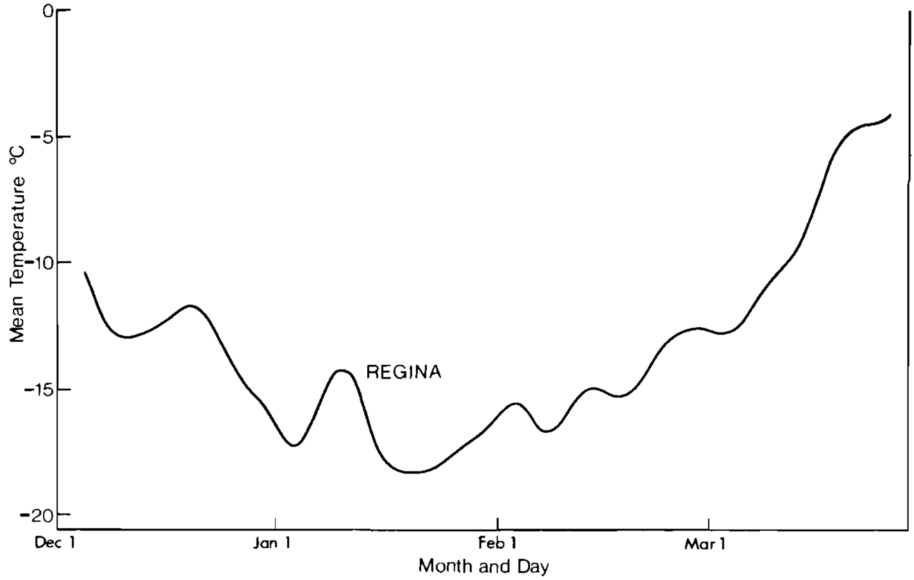

Fig. 3 Nine-day weighted running means of the 30-year mean daily temperatures for Regina, for December 4 to March 28.

The results presented above suggest a general quasi-periodic pattern of fluctuations in the normal temperatures over various parts of Canada. Similar fluctuations in the normal temperature records at selected locations in the north-eastern United States have been documented by Wahl (1952) in his studies on the January thaw in New England. According to Wahl the January thaw at Boston is only a part of a much larger phenomenon, namely a change-over from a westerly circulation pattern to a northwesterly flow pattern. Such large-scale circulation patterns have been extensively studied by Namias (1950, 1953) who has attempted to relate these changes to index cycles of the general circulation. The fundamental role of the index cycles is to transport the excess of heat energy from tropical latitudes to mid-latitudes. This heat transport is accomplished through large-scale eddies, which impose quasi-periodic fluctuations on the zonal index, resulting in index cycles having periodicity from 3 to 8 weeks (see Namias, 1953). As pointed out by Namias, one also finds fluctuations of shorter periods in the index cycles, similar to the temperature fluctuations under discussion. Fig. 5, after Namias (1953), shows zonal indices at 700 mb for 5-day means for November through March for nine years. If one observes all the peaks of zonal indices for December through March, the nine-year average number of index maxima then yields a period of slightly more than 15 days, as opposed to 16–17 days for the temperature fluctuations. A comparison of Fig. 5 with Figs. 1 and 2 shows that high zonal index is in general associated with temperature peaks in raw as well as smooth data (Figs. 1 and 2). Similar results have been reported by others (see Chang, 1972).

To what latitudes do the temperature fluctuations extend? A partial answer to this can be given: Longley (1958), in his studies on temperature fluctuations

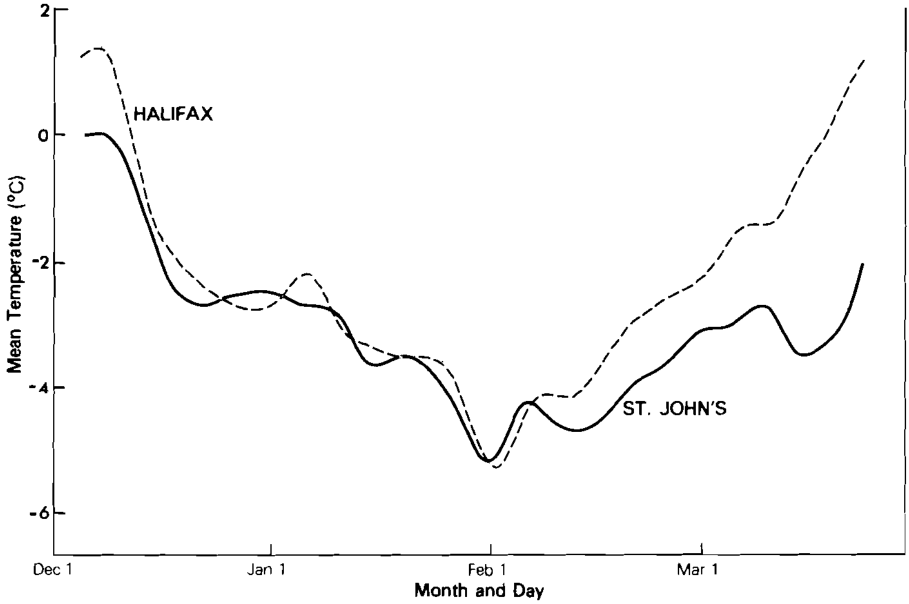

Fig. 4 Nine-day weighted running means of the 30-year mean daily temperatures for Halifax, and the 25-year mean daily temperatures for St. John's, for December 4 to March 28 (temperature scale stretched).

TABLE 1. Average Period of Temperature Fluctuations, December to March, for selected Canadian Stations.

Station	Period of Averaged Temperatures (yrs)	Period of Weighted Running Mean (days)	Average Period of Fluctuation (days)
Edmonton	90 (1880–1969)	7	15.0
Winnipeg	98 (1872–1969)	7	16.8
Montreal	99 (1871–1970)	7	17.4
	Mean of 90-year(+) data	....	16.4 days
	Median of 90-year(+) data	....	16.8 days
Edmonton	30 (1941–1970)	9	16.6
Calgary	30 (1931–1960)	9	17.8
Grande Prairie	25 (1942–1967)	9	17.2
Whitehorse	30 (1942–1971)	9	16.0
Saskatoon	29 (1942–1970)	9	19.7
Regina	30 (1931–1960)	9	17.0
Winnipeg	30 (1931–1960)	9	16.6
Montreal	30 (1941–1970)	9	15.4
Halifax	30 (1931–1960)	9	18.3
St. John's	25 (1942–1966)	9	17.0
	Mean of 25–30-year data	....	17.2 days
	Median of 25–30-year data	....	16.9 days

at Resolute, Northwest Territories, computed seven-day running means for eight years of data. Fluctuations similar to those under discussion can be observed in his smoothed data with an average period of 16 days; this is again in good agreement with the average value of the period in Table 1. No attempt

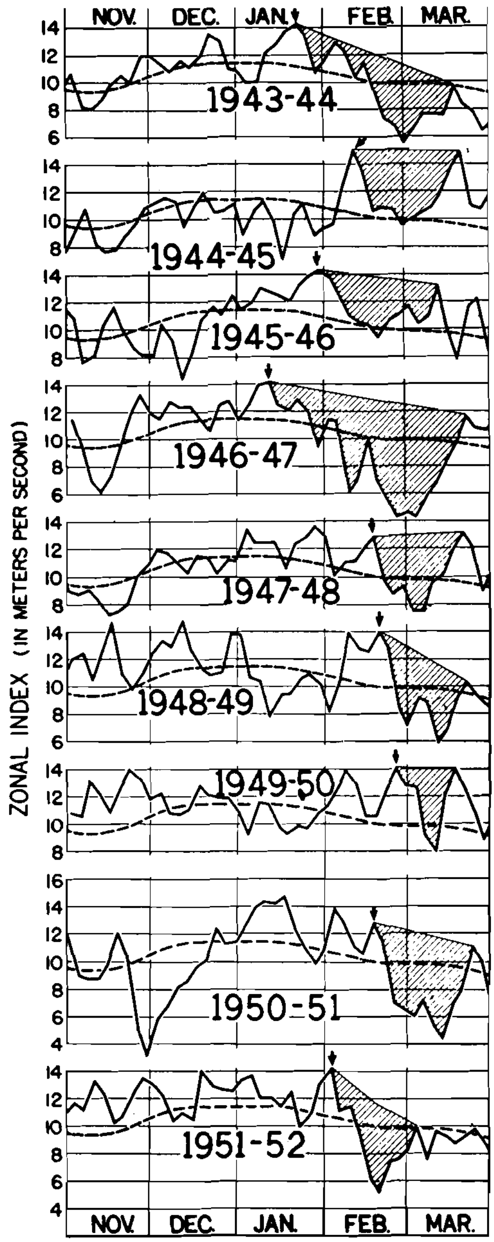

Fig. 5 Zonal indices at 700 mb for 5-day means for November through March of nine years; broken lines connect normal values for calendar months; hatched areas denote primary index cycles beginning with the high index periods indicated by arrows. After Namias (1953).

is made in this study to determine the southern extent of these temperature fluctuations.

4 Concluding remarks

The existence of a "January thaw" in the long-term records of selected Canadian stations appears to be a real feature, which is associated with the quasi-periodic temperature fluctuations having an average period of about two weeks. The general interest in a January thaw, but not in the other peaks and lulls in the annual temperature trend, is possibly due to a psychological reaction to warmer temperatures just preceding the annual minimum temperature. For example, the pronounced "cooling" in mid-February is not noted as well, perhaps because temperatures are then on the upswing anyway.

Our analysis brings out a possible relationship between the temperature fluctuations and the index cycles of the general circulation; this is in general agreement with earlier studies. As the meridional transport of heat energy is accomplished through variations of the zonal index, it appears to impose temperature fluctuations characteristic of the quasi-periodic nature of the index cycles.

It is interesting to note that these fluctuations stand out even after averaging and smoothing the temperature data for over 90 years. This seems to suggest that there may be some preferred positions (in time) for these cycles. To the best of our knowledge, none of the theoretical and observational studies on index cycles suggests any coupling between the index cycles and the time of the year. We are therefore inclined to surmise that the fixed topographic features of the earth, together with the fixed ocean-land distribution tend to induce fluctuations in the general circulation at certain preferred times of the year, excepting for minor variations. These minor but significant variations tend to make the index-cycles quasi-periodic, and hence, unpredictable.

Acknowledgements

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