The January Thaw at New Brunswick, NJ

JOHN R. LANZANTE AND ROBERT P. HARNACK

Department of Meteorology and Physical Oceanography, Cook College—New Jersey Agricultural Experiment Station, Rutgers–The State University of New Jersey, New Brunswick 08903

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ABSTRACT

An investigation of the January thaw phenomenon, a period of unseasonable warmth, was conducted using daily maximum temperatures recorded at New Brunswick, New Jersey, from 1858–1981. Student's *t*-tests, comparing long-term means of daily maximum temperature to values from a fitted seasonal trend curve, indicate temperatures higher on 22–23 January and lower on the 29th than seasonally expected.

It was found that the January thaw does not have a fixed time of occurrence but occurs most frequently from the 19th to the 28th. During this time the interannual variability of daily maximum temperature is significantly higher than during the remainder of the month.

Evidence of a tendency for a secondary thaw maximum to occur, centered on the 26th, is evident in several different analyses. Examination of daily temperature curves for 10-, 20- and 40-year periods reveals a shift in the mean thaw date from 22–23 January to the 26th. This change has evolved over the last 30–40 years. It was concluded that the January thaw is more pronounced when the mean circulation is characterized by a contracted polar vortex over North America and abnormally strong midlatitude westerlies.

1. Introduction

The phenomenon known as the January thaw, which has its origin in New England folklore, is a period of a few days in January during which unseasonably warm temperatures have a tendency to occur. Although it is evidenced as a higher than seasonable mean of temperature, it does not occur every year or on exactly the same date. The mean time of occurrence is generally stated to be 20–23 January (Wahl, 1952). Reference to the thaw is usually limited to the northeast United States; however, Wahl (1952) has examined its effects for as far west as Missouri, while Rebman (1953, 1954) has linked the thaw to a West Coast warming phenomenon. In addition, Kangieser (1957) has suggested a possible relationship with a Phoenix temperature event. A relationship between these periods of warming has been attributed to a common tie with the planetary-scale circulation of the atmosphere (Duquet, 1963).

The January thaw is one of a broad group of phenomena known as singularities. A singularity is a recurrent anomalous departure of a weather element(s) from its normal seasonal value on or near a particular calendar date. However, even the most pronounced singularities have an occurrence rate of little more than 50%, with very different behavior in the remaining years (Wahl, 1953).

The existence of singularities, most of which originated with laymen, has long been a subject of controversy. The statistical significance of singularities was difficult to prove because of the autocorrelation of daily weather parameters. Other factors led to disbelief in singularities as well, especially the fact that even the most pronounced singularities occurred in little more than half of all years. In addition, often only short periods of record were used to substantiate them. Finally, few plausible physical explanations for their occurrence were put forth.

Not until Wahl (1952, 1953) showed the large-scale nature of the January thaw did it gain acceptance. By using maps of sea-level pressure, he indicated that the East Coast warming is coincident with a strong Bermuda high; subsequently the Bermuda high weakens while the North American polar high strengthens, causing East Coast temperatures to deviate to below seasonable values. This sequence may be an adjustment of the planetary circulation from an early to late winter stage (Wahl, 1953; Duquet, 1963).

The purpose of this study was to investigate several aspects of the January thaw phenomenon through a statistical analysis of January daily maximum temperatures at New Brunswick, New Jersey. New Brunswick temperatures, chosen for reasons of easy availability, were expected to be representative of the thaw, in accordance with the similarities found by Wahl (1952) in various time series of eastern United States stations. First, an overall view of the January thaw is presented (Section 3). Next, variations within the period of record are examined (Section 4). Finally, the thaw is related to the time-averaged, large-scale planetary circulation (Section 5).

2. Data

The data used were January daily maximum temperatures for the period 1858–1981 (excluding 1891–

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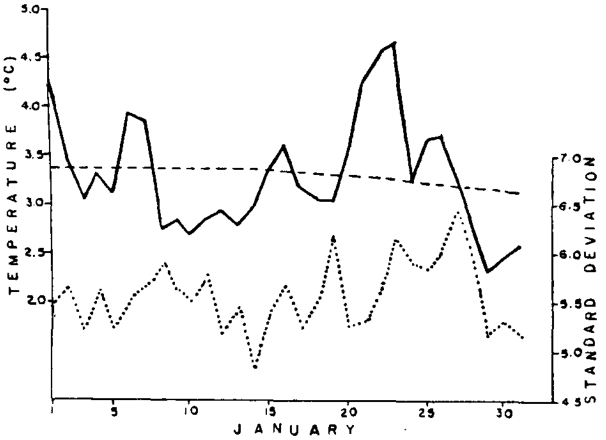

FIG. 1. Average daily maximum temperature in January (solid) and parabolic "trend curve" (dashed) with scale on the left axis. Standard deviation of daily temperature (dotted) with scale on the right axis. The trend curve represents the seasonal progression of temperature. A residual value is obtained by subtracting, from a given value, its corresponding "trend curve" value.

93, which were unavailable) for New Brunswick, New Jersey. The data, which were obtained from several sources (Spader, 1890; U.S. Department of Agriculture, 1894–97, 1901–38; U.S. Weather Bureau, 1939–62; U.S. Department of Commerce, 1963–81), came from two different stations (U.S. Department of Commerce, 1956). For the station named "New Brunswick," the period of record is 1858–90 and 1894–1909. For the station named "College Farm" (renamed New Brunswick after 1911), located on what is presently the campus of Cook College of Rutgers University, the period of record is 1898–1981. Since the time of observation was changed from 1700 to 0800 LT in 1969, the maxima attributed to a given day, during the last 13 years, are values recorded the following day.

The change in location from the original New Brunswick station to College Farm is minor (a distance of several kilometers with no significant changes in topography). Since there is a 12-year overlap (1898–1909) of data, simple linear regression was used to reconstruct the College Farm temperatures from the New Brunswick ones. A good fit was found (r^2 = 0.92). The reconstructed temperatures for 1858–97 (excluding 1891–93), along with the observed College Farm temperatures for 1898–1981, made up the time series used for the analysis.

All daily temperatures referred to in this paper are January maxima. Daily maxima were chosen for two reasons: 1) they are more representative of the layman's perception of daily temperature, since he is more cognizant of daylight hours (Reynolds, 1955); 2) maxima are more representative of the prevailing air mass temperature than are minima. In total, 121 years of January daily maximum temperatures (spanning 124 years) were used.

In relating the thaw to the atmospheric circulation, gridded monthly means (December and January) of sea-level pressure (January 1899–December 1977) and 700 mb heights (December 1946–December 1977) were used. The grid spacing used was 10° latitude × 10° longitude. Both data sets were available on magnetic tape. The former was obtained from the National Center for Atmospheric Research, while the latter came from the Scripps Institution of Oceanography.

Monthly zonal circulation indices were derived from the 700 mb height data. They were computed for five longitude sectors: Eurasia, 5°W–135°E; Pacific, 130°W–145°E; North America, 70–125°W; Atlantic, 10–65°W; and hemispheric, entire Northern Hemisphere. The indices were computed as the north–south gradient of zonally averaged height for three latitude belts: subpolar, 55–70°N; temperate, 35–55°N; and subtropical, 20–35°N. Thus, 15 different zonal indices were available for each month.

3. Ensemble temperature statistics

a. *Time series of daily temperatures*

It is reasonable to begin this investigation by examining the long-term mean magnitude and time of occurrence of the thaw as was done by Wahl (1952). To facilitate this, the time series of average daily maximum temperatures for January was constructed (Fig. 1). A parabolic trend curve was fit to the time series using the method of least squares as suggested by Panofsky and Brier (1968). The trend curve estimates a one-month portion of the normal (climatological mean) seasonal progression of temperature. Mean residuals can be computed by subtracting each day's trend curve value from its long-term mean value. A mean residual deemed significantly different from zero (in the statistical sense) would suggest the existence of a singularity. Further evidence, such as a connection with atmospheric circulation fluctuations, would bring more credibility.

The most distinctive feature of the mean residual curve (represented as the difference between the solid and dashed curves plotted in Fig. 1) is the peak at 21–23 January, with values of 1.0, 1.3 and 1.4°C, respectively. The Student's t-test was employed to test the null hypothesis that the mean of the population to which the residuals belong is zero (a two-tailed test). The null hypothesis was rejected at the 5, 2, and 3% significance levels, respectively. Also, the values for the 1st (0.9°C) and 29th (−0.8°C) were deemed significantly different from zero at the 5% level. It should be noted that the number (5) of residuals (out of 31 days) significant at the 5% level is greater than that expected by chance (31 × 0.05 = 1.55). In addition, a two-sample t-test found the residual on the 23rd significantly greater than those of the 18th and 29th at the 5 and 0.3% levels, respectively.

The relative warmth over the 21–23 January period is consistent with results presented by Wahl (1952) for several stations in the East and is a manifestation of the thaw. The negative residual on the 29th reflects a tendency for unseasonably low temperatures to follow within a few days of the thaw. It should be kept in mind that interannual variations in the exact timing of the thaw and subsequent cold spell would tend to diminish the apparent magnitude of the thaw as evidenced by the mean residuals displayed in Fig. 1.

b. Time series of daily standard deviations

Typical analyses of the January thaw in the past consisted of first examining a time series of January daily temperatures. Thus, the mean magnitude of daily temperature has been studied, but not year-to-year variability. For this purpose, the time series of the daily standard deviation of temperature was computed (dotted curve, Fig. 1). It appears that the standard deviations come from two distinct populations. Standard deviations for the 19th through the 28th as a whole have somewhat higher values than for the remainder of the month. This was verified at the 5% significance level by using the variance ratio test (Zar, 1974).

The greater interannual variability from the 19th through the 28th can be explained in terms of two properties of the phenomenon. First, the date(s) of thaw occurrence varies from year to year, with the most likely time around the 22nd or 23rd; second, significant thawing occurs in some years and not in others (Wahl, 1953).

Based on average daily maximum temperatures and standard deviations for the entire period of record, the 19th and 28th seem to be points of demarcation between the thaw and non-thaw periods. On both of these days, the residuals are near zero and the variability is high. On the two adjacent days, the 18th and 29th, the standard deviation is at near-normal values for the month. Hence, the 18th and 29th seem to be beyond the influence of the thaw's mean effect.

It is worthy of mention that unseasonably low temperatures, with relatively small tendency for variation, have occurred in the mean from the 29th through 31st, as evidenced by both relatively large negative values of the mean residuals and low standard deviations. A sharp transition from the 27th to the 29th is indicated (Fig. 1) by the precipitous drop of both the residual and standard deviations. Mean sea-level pressure maps constructed by Wahl (1952) for the pre-thaw, thaw and post-thaw periods clarify the sequence. A southwest flow during the thaw is followed by the passage of a trough and a shift to northwest winds and lower temperatures.

A final point of interest regarding the standard deviation is the pronounced maximum on the 27th, indicating high temperature variability. The fact that the mean residual is small indicates that this day has been characterized by relatively large positive and negative deviations throughout the years, which nearly balance out over the period of record. Binomial tests on frequency distributions (not shown) of extreme temperatures indicate a bimodal distribution of the occurrence of extreme positive departures (22nd and 27th). Thus, although the mean residuals indicate only the period near the 22nd as being associated with the thaw, other indicators suggest the period near the 27th as being important. In the next section, the high values near the 26th–27th will be shown to be related to a recent shift in the time of occurrence of the thaw.

4. Changes of the thaw within the period of record

a. Definition of thaw intensity and thaw date

In order to more fully investigate the characteristics of the thaw, it is necessary to study year-to-year variability, using an index of the thaw. The development of a thaw index is necessitated by the fact that the atmosphere does not conform exactly to the calendar year. Using the temperature on a fixed date, such as 23 January, as an index of the thaw, does not account for year-to-year variability in the exact date(s) of the thaw occurrence. Thus, a thaw index given by the following formulation has been derived:

$$I_t = (R_m + R_*)/2, \tag{1}$$

where $R_* = R_{m+1}$ for $R_{m+1} \geqslant R_{m-1}$, and $R_* = R_{m-1}$ for $R_{m+1} \leqslant R_{m-1}$. I_t is the index of intensity of the thaw, R_m the residual value for the largest (positive) residual of the period 18–29 January, R_{m+1} the residual value for the day after, and R_{m-1} the residual for the day before the day of the highest residual. The time period used (18–29 January) was subjectively chosen based on results and arguments presented in prior sections. This period has one day on either side of the period of most significant influence of the thaw (19–28 January). The value of the thaw index represents a two-day average deviation of temperature from normal (as determined by the trend curve). A two-day period was used since it was felt that this would be most representative of the time scale of most significant warming.

Since the most pronounced singularities occur in little more than 50% of all years (Wahl, 1953), many "thaw occurrences," characterized by low thaw index values, may represent merely a period of relative warmth in a "non-thaw" year. A "pronounced thaw" was defined as a thaw with an index value in the upper tercile in order to limit the total number of occurrences. Thus, a pronounced thaw occurs in one-third of all years.

TABLE 1. Frequency of thaws and pronounced thaws during the period 18–29 January. A "thaw" occurs on a given day if it has the highest residual in the period 18–29 in a given year. A "pronounced thaw" is a thaw whose thaw index value is in the upper tercile. "Pronounced thaw" frequencies are also given by subperiods.

	Date												
	18	19	20	21	22	23	24	25	26	27	28	29	Total
Thaws	8	8	8	13	14	16	4	11	9	12	9	9	121
Pronounced thaws	2	5	1	4	2	7	3	3	3	6	3	0	40
1858–1900	0	1	0	1	0	3	1	0	1	0	1	1	9
1901–1941	1	3	0	1	1	3	0	1	0	2	1	0	13
1942–1981	1	1	1	2	1	1	2	2	2	4	1	0	18

In addition to thaw intensity, the date of occurrence of the thaw has been determined. The thaw date is defined as the date of the largest residual during the period 18–29 January or simply day *m* from the formula for I_t. In order to insure that a thaw, as defined here, generally does not involve warming events having a longer time scale than would be associated with a singularity, moving averages of temperature centered on day *m* were computed. This procedure eliminates the effect of the varying dates of thaw occurrence. A Student's *t*-test indicated that temperature was significantly above normal (the trend curve) for only three days, from day $m - 1$ through $m + 1$. Using only pronounced thaws, one additional day (day $m - 2$) was deemed significantly above normal. Thus, thaws as defined here, generally represent short lived warming events.

b. Sub-period variations in the thaw

The January thaw phenomenon was next examined with regard to date of occurrence of the thaw. A tabulation of the total number of thaw and pronounced thaw occurrences for each day in the period 18–29 January is given in Table 1. Clustering about the 22nd–23rd is evident in both cases. There is also a peak centered on the 27th, especially with regard to pronounced thaws. The bottom part of Table 1 was constructed in order to look for long-term changes in the preferred time of thaw occurrence by portioning the period of record (1858–1981) into three subperiods of roughly equal length. The statistics on the bottom of Table 1 reveal that pronounced thawing activity has increased twofold from the early to the late subperiod. Most of the increase has occurred from the 26th through the 28th.

Next, long-term changes in the thaw were analyzed through the use of the time series of average daily maximum temperature for subperiods of various lengths. Curves for subperiods of length 10, 20 and 40–41 years were examined; selected curves are shown in Figs. 2a–2f. As a means of reference, the trend curve, based on the 121 years of data (Fig. 1), has been included on each graph.

The period before 1900 was characterized by generally below "normal" temperatures indicated by the 10-, 20- and 40-year curves (not shown). Thaws were weak as both the thaw index values and the frequency of pronounced thaws were low. A weak thaw maximum was found for the 21st–23rd.

Starting in the period 1900–09 (Fig. 2a), the first strong thawing was experienced. The maximum on the 22nd has a value of 9.3°C. The next three decades also show signs of thaw activity. The 41-year curve for 1901–41 (Fig. 2e), which has a single maximum on the 21st–23rd, is most characteristic of the findings of previous investigators. Also, Wahl's secondary thaw of 6–7 January is prominent.

The final subperiod of data, 1942–81, proves to be the most interesting since the majority of prior studies were completed before or during the early part of this subperiod. Throughout this subperiod the importance of the secondary maximum centered on the 26th, which developed in the 1940's or 1950's, increases. The shift from the 22nd to the 26th can be seen by comparing Figs. 2e, 2c and 2d. By the time of the last decade (Fig. 2b), the 26th has become the primary maximum. Because of the magnitude of this feature since 1942, a new relative maximum on the 26th is present in the curve for 1942–81 (Fig. 2f); for the two prior 40-year curves, the primary maximum was on the 21st–23rd. This explains why the analyses presented in Section 3 showed evidence of a secondary maximum which appears weak when using ensemble statistics.

5. Thaw intensity and the atmospheric circulation

The final portion of this paper deals with investigating the relationship between the thaw intensity and several meteorological variables which relate to the planetary circulation. Initially, the thaw index was correlated with the 15 zonal circulation indices (described fully in the data section) for January and December (Table 2). The January correlations indicate the large-scale connections involved. The strength of the relationship between the intensity of the thaw and the zonal circulation generally increases from high to low latitudes. Also, the relationship is strongest for the North American and Atlantic sectors. One exception, however, is in the Pacific polar region.

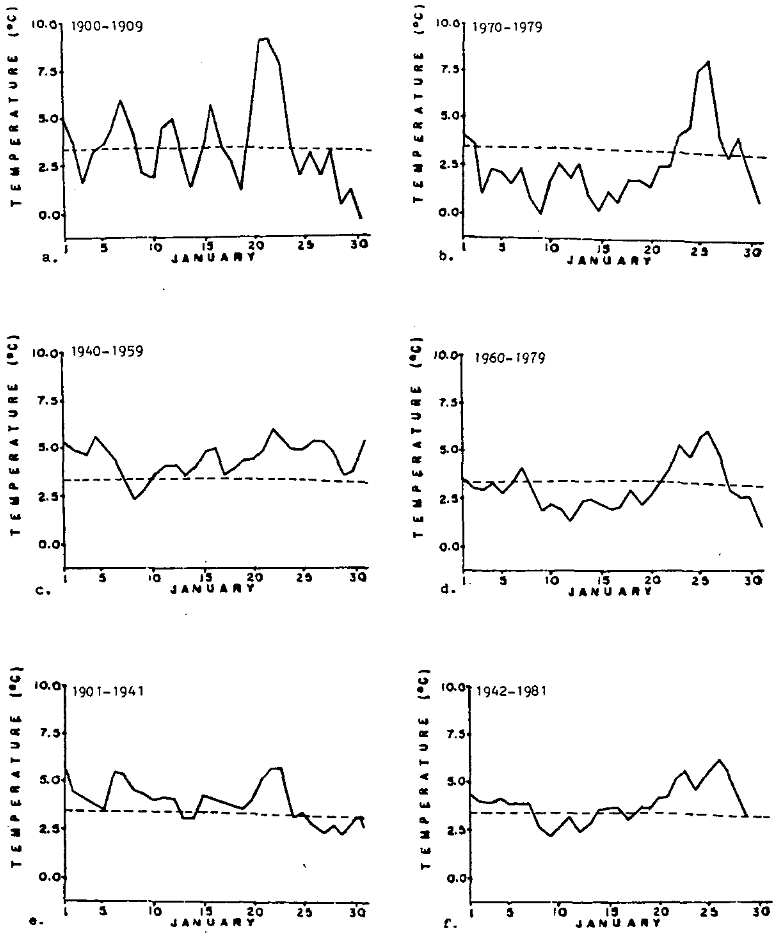

FIG. 2. Average daily maximum temperature in January for selected subperiods of length 10, 20 or 40–41 years. The trend curve (dashed) from Fig. 1, based on the entire sample, is included as a means of reference.

The correlations shown in Table 2 indicate that the January circulation pattern which favors thaw occurrence is characterized by contracted circumpolar westerlies, particularly in the North American and Atlantic sectors. Northward displacement of the westerlies (relative to normal) results in a weaker westerly component of flow in the subtropics (negative correlations), while the polar, and especially the temperate, latitudes experience enhanced westerly flow (positive correlations). Stronger than normal westerlies in the mid and high latitudes tend to confine polar air masses, thereby favoring warm air intrusions from the subtropics to the eastern United States.

Similar correlations (Table 2), using December parameters, indicate the antecedent circulation pat-

TABLE 2. Correlation between the thaw index and zonal circulation indices for the months of December and January. Correlations (based on 31 years) significant at the 5% (*) and 1% (**) levels are noted.

	Eurasian	Pacific	North American	Atlantic	Hemispheric
December					
Polar	0.00	−0.03	−0.03	0.26	0.06
Temperate	−0.07	0.03	0.36*	0.06	0.14
Subtropical	−0.25	−0.03	−0.43*	−0.45**	−0.25
January					
Polar	−0.03	0.41*	0.26	0.17	0.23
Temperate	0.13	−0.04	0.68**	0.35*	0.41*
Subtropical	−0.21	−0.27	−0.58**	−0.55**	−0.45**

tern (on a time scale of a month) which favors the occurrence of the January thaw. With the exception of the North American sector, correlations for the polar and temperate latitudes are generally small and insignificant. Significant correlations involving the subtropical circulation indices are found just as for January.

In order to get a more detailed and continuous picture of the concurrent and antecedent mean circulation pattern favoring the thaw, the gridded sea-level pressure and 700 mb height data were used to construct difference maps. The first step was to compute the average sea-level pressure (or 700 mb height) fields separately for cases in which the thaw index was in the upper and lower tercile. The Student's *t*-statistic was computed for the difference (upper minus lower tercile of the thaw index) at each grid point. The resulting *t* fields using January and December sea-level pressure are shown in Figs. 3 and 4, respectively. The corresponding fields using 700 mb heights (not shown) are quite similar, with most features displaced slightly to the west, as one would expect. The *t* fields which use sea-level pressure are presented here, rather than those derived from 700 mb heights, since the former have a larger sample size (79 as opposed to 31). The most prominent aspect of the two *t* fields is the anomalous strength of the subtropical anticyclones, particularly in the Atlantic, associated with pronounced thaws. This pattern is similar to that found by Klein (1965) to favor above normal five-day mean temperatures at Albany, New York during winter.

The statistics and maps presented in this section seem to present a clear and unambiguous picture of the circulation pattern associated with the January thaw. However, the findings here directly contradict Wahl (1953). He computed two temperature curves (similar to those in Figs. 1 and 2) stratified according to "high" or "low" January mean zonal index cases. While Wahl never explicitly stated the domain of the zonal index he used, it was inferred, from his paper and a reference (Rossby, 1939), that the one he used corresponds to the hemispheric temperate zonal index used here. Wahl (1953) concluded that the January thaw was accentuated for cases of low (hemispheric temperate) zonal index. He based his conclusion on the fact that the peak near the 22nd was sharper in those cases. This seems to be due to the fact that adjacent values to the 22nd were lower. However, the peak values for the two curves are nearly identical (see Fig. 1, Wahl, 1953). Wahl also based his conclusion on the accentuation of a peak on the 7th. The subperiod temperature curves presented in the last section indicate that this feature was a transient one and probably bears no relationship with the long-term features described here. Wahl's high-index curve actually shows higher values in the latter half of the month. Although this

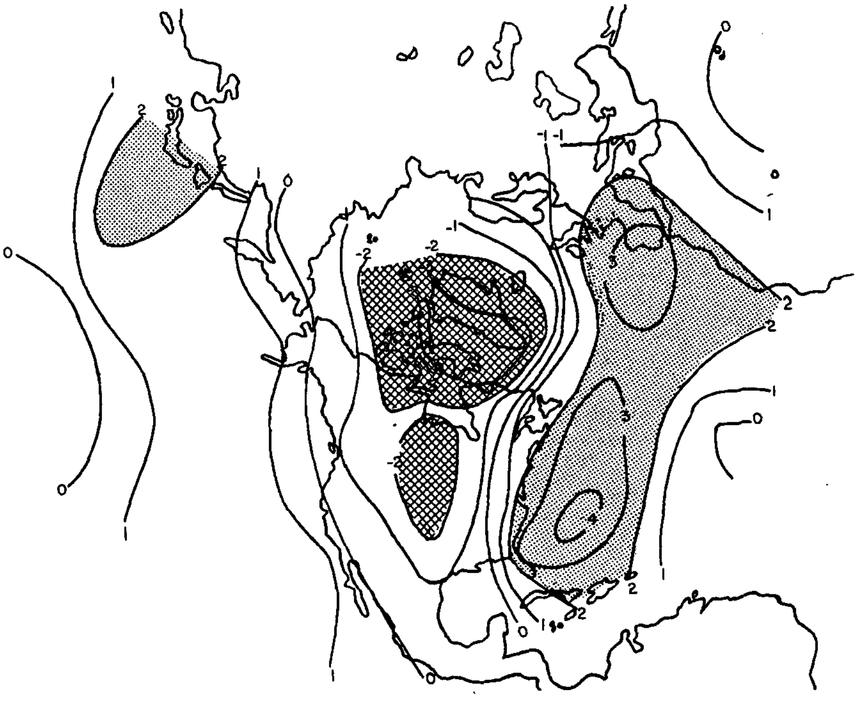

FIG. 3. Student's *t*-statistic testing the null hypothesis H_0: $\bar{X}_H - \bar{X}_L = 0$, where $\bar{X}_H$ and $\bar{X}_L$ are the means of January sea level pressure for years in which the thaw index was in the upper and lower terciles. Stippled and crosshatched areas denote regions of significant (5% level) sea level pressure difference between "weak" and "strong" thaw Januaries.

FIG. 4. As in Fig. 3 except for December sea-level pressure.

diminishes the sharpness of the peak, it is probably indicative of more significant thawing for the high-index cases. These conclusions are supported by the two curves in Fig. 5 which are the same as Wahl's (Fig. 1, 1953) except that more recent data were used.

Perhaps the most significant finding of this study has not yet been stressed. The relationships found here between the planetary circulation and the strength of the thaw are somewhat surprising. It should be kept in mind that the index used to quantify the strength of the thaw is based on the single station (two-day average) extreme temperature occurring some time during a period of less than two weeks. Global connections between monthly mean circulation and monthly mean temperature at a given station would not be at all surprising. However, the relationships which were found here are between monthly mean circulation and two-day extreme temperature occurring some time during a period of much less than a month.

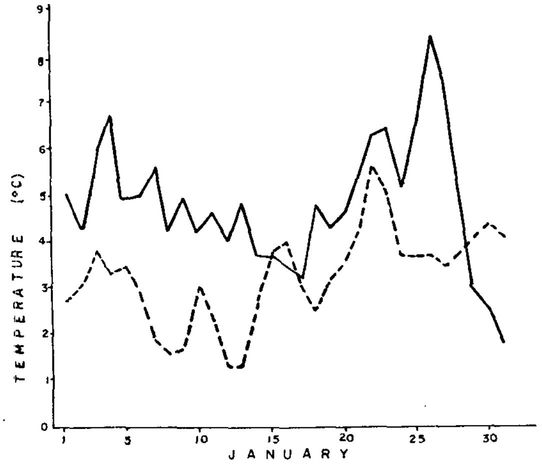

FIG. 5. Average daily maximum temperature in January stratified according to hemispheric temperate zonal index. Solid (dashed) curve is based on years with the zonal index above (below) the median value.

6. Conclusions

This paper reports the results of an investigation of the January thaw phenomenon. While prior investigators were primarily concerned with proving the validity of the thaw, this study de-emphasized that aspect and instead concentrated on examining some characteristics of the thaw at New Brunswick, New Jersey. The results can be summarized as follows:

1) The peak in the mean January temperature curve at the 22nd–23rd is the result of the long-term effect of the thaw. These two days have experienced the most significant thawing with regard to both frequency and magnitude. Similarly, on the 29th (or approximately a week after the thaw) "unseasonably low" temperatures were found in the mean.

2) The January daily standard deviations, which measure interannual variability, come from two populations—those from the period most influenced by the thaw (19th–28th) and those outside this period. The latter are significantly less than the former.

3) The thaw has some year-to-year variability in time of occurrence. The most likely time of occurrence has been subjectively determined as the 19th–28th.

4) A shift of the mean date of occurrence of the thaw, from the 22nd–23rd to the 26th, has taken place over the last 30–40 years.

5) An index of the intensity of the thaw was derived. It measures the two-day average deviation of temperature from "normal" and quantifies the interannual variation in the strength of the thaw.

6) The strength of the thaw (as measured by the thaw index) is tied to the January (and to a lesser extent the December) monthly mean hemispheric circulation. Thus, a short-term extreme temperature event is linked to the planetary circulation. In addition, the claim by Wahl (1953) that weaker westerlies in midlatitudes favors the thaw is disputed.

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