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# MINIMUM TEMPERATURES IN THE CANADIAN ARCTIC

by

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ABSTRACT

A study of daily temperatures in the winter in the Canadian Arctic shows that the coldest period of the year, on the average, advances from about 25 January in the 62-68°N latitude band to the first week of March for the area north of 80°N. The trend of the 95-kPa temperatures differs, at some stations, significantly from that of surface temperatures. This fact casts some doubt on the methods of observing temperatures with a deep snow cover.

## 1. Introduction

In 1924, Pollog (see Wexler, 1959) noted the "kernlose" (coreless) pattern of winter temperatures in the Arctic Basin. In this pattern, the temperature drops slowly if at all during the winter season. There is no clear minimum nor any clear indication when the temperature begins its spring rise. A similar temperature variation was discovered by Wexler (1959) for Antarctica. Because of the small mean variation from month to month, the variability from year to year resulted frequently in monthly variations which were the reverse of the normal trend. Wexler had, for many stations, only short periods of observations, and for some stations these monthly variations were not lost in the averaging process.

About the same time Longly (1958) presented an examination of the temperature trends through the year at Resolute, Northwest Territories (75N 95W). A major interest of Longley was to discover the coldest time of the year based on average temperatures. This, for Resolute, he concluded, was in early March, about three weeks after the sun first appears above the horizon. This conclusion was based on less than 10 years of data. It seemed useful to examine this same problem again using the longer period of observations now existing, and also to extend the study to other arctic stations.

## 2. Data Used

Longley's analysis showed that the trends of temperature in the arctic regions, particularly those related to the point of minimum temperature could not be obtained from mean monthly values, but it was necessary to examine daily values. For this current study, available values of daily maximum and minimum temperatures were abstracted from the Monthly Record of Meteorological Observations (Atmospheric Environment Service a) for the months of January, February and March from 1941 to 1977. Twenty long-term stations from the Arctic and sub-Arctic were selected. Table 1 gives a list of the stations, their locations, and the numbers of years of observation. Figure 1 gives a map of the area with the locations of the stations. The record from Aklavik was combined with the later-established station, Inuvik.

For each station and for each day from 1 January until 31 March, the mean maximum and mean minimum temperatures were obtained. An exception was made for three stations of the western sub-arctic, Norman Wells, Yellowknife, and Churchill. For these, the mean temperature begins to rise well before the end of February and an examination of March temperatures seemed unnecessary for the purpose at hand.

Data were at times missing, and means had to be computed using fewer observations than implied by the data of Table 1. For some missing data, fictitious data were inserted. Maximum temperatures were missing from some records on days when the minimum temperature was below -40°C, although the values were given for both earlier and later dates when the minimum was higher. It seemed obvious that the maximum temperature was missing because the mercury in the maximum thermometer froze at -39°C. For stations in the far north, synoptic observations (Atmospheric Environment Service b) gave values of temperature every three hours. From these, an estimate could be made of the maximum for the day. For other missing data of this nature, the value of -40° was used. This, it was hoped, would result in a more nearly exact picture of the trends of normal temperature than would be obtained by averaging only the other data. Fortunately, the frequency of such situations was low.

Table 1. Stations used in the study with locations and lengths of record.

| Station | Location N | W | Period (Years) | Station | Location N | W | Period (Years) |
|---|---|---|---|---|---|---|---|
| Alert | 83 | 62 | 27 | Inuvik | 68 | 134 | 37 |
| Arctic Bay | 73 | 85 | 27 | Aklavik | 68 | 135 | |
| Baker Lake | 64 | 96 | 31 | Isachsen | 79 | 104 | 29 |
| Cambridge Bay | 69 | 103 | 37 | Mould Bay | 76 | 119 | 29 |
| Churchill | 59 | 94 | 37 | Norman Wells | 65 | 127 | 34 |
| Clyde | 70 | 69 | 32 | Resolute | 75 | 95 | 30 |
| Coppermine | 68 | 115 | 37 | Resolution Is. | 61 | 65 | 29 |
| Eureka | 80 | 86 | 30 | Sachs Harbour | 72 | 125 | 22 |
| Frobisher Bay | 64 | 69 | 30 | Tuktoyaktuk | 69 | 133 | 26 |
| Hall Beach | 69 | 81 | 21 | Yellowknife | 62 | 114 | 35 |
| Holman Island | 71 | 118 | 26 | | | | |

## 3. Analysis of Temperature Trends

The values of the mean daily temperatures were smoothed somewhat by taking 5-day moving averages. The curves showing these averages are given in the various parts of Figure 2.

A glance at the different curves found in Figure 2 shows that the temperatures do not form a smooth curve but fluctuate above and below a smooth long-term trend. In the last century, Buchan presented data to claim that the periods of warmth and cold tend to come at specific times each year. As a result, these abnormal periods became known in Great Britain as Buchan periods. Wahl (1952) showed that the January thaws were more probable in Boston in the period 21-23 January than at any other time in the month. Strong and Khandekar (1975) discovered cycles of about 17 days in the temperature fluctuations about the mean in a number of locations of southern Canada. Cycles at the northern stations are apparent in Figure 2. These may be of interest to some but they make it more difficult to determine the date at which the temperature is normally at the lowest point.

Although the date at which the temperature begins to climb because of the returning sun is not clearly defined, one may use the curves of Figure 2 to make an estimate. Table 2 gives the author's range of dates for the time of change. The stations are listed by latitude going from south to north. For comparison the date is given when the sun first reaches 5° above the horizon. The curve for Norman Wells presents an anomaly. The time of minimum is clearly 14 January, but this is at variance with that at Yellowknife, 3° farther south and with Inuvik, 3° farther north. Even at Edmonton, 12° farther south, the lowest mean minimum temperature based on the period 1941-1970 is -22 on 25 January. It is hard to accept the conclusion that, on the average, the temperature at Norman Wells starts to climb on 15 January.

According to the results shown in Table 2, there is a progression of the time of lowest temperature as one moves northward. Yet there is little distinction in the times for the stations between 67°N and 75°N, Coppermine to Resolute. The change from this latitude band to Mould Bay and Isachsen is also small.

The curves of mean temperature show that during the period of observations the week centering on 16 February was unusually cold. Almost every curve showed a dip at that time and 24 out of the 40 extreme values occurred during that week. The warm spell before the end of February was not so well marked. The temperatures at Eureka and Alert fell in early March to lower values than in mid-February, so that, for northern Ellesmere Island, the date of the minimum was taken in early March.

Table 2. Periods during which the temperature reaches its minimum value.

| Station | Date of middle day of 5-day period with lowest temperature MAXIMUM | MINIMUM | Period of minimum mean daily temperature | Date sun first 5° above horizon |
|---|---|---|---|---|
| Churchill | 28 Jan | 15 Jan | 25-31 Jan | |
| Resolution Island | 29 Jan | 27 Jan | 26 Jan - 2 Feb | |
| Yellowknife | 13 Jan | 27 Jan | 25-30 Jan | 21 Dec |
| Frobisher Bay | 1 Feb | 1 Feb | 28 Jan - 3 Feb | 13 Jan |
| Baker Lake | 28 Jan | 28 Jan | 26-30 Jan | 13 Jan |
| Norman Wells | 14 Jan | 14 Jan | no clear answer | 17 Jan |
| Coppermine | 17 Feb | 18 Feb | 14-18 Feb | 2 Feb |
| Inuvik | 11 Feb | 11 Jan | 7-12 Feb | 2 Feb |
| Tuktoyaktuk | 16 Feb | 16 Feb | 14-18 Feb | 6 Feb |
| Hall Beach | 16 Feb | 17 Feb | 13-18 Feb | 6 Feb |
| Cambridge Bay | 16 Feb | 18 Feb | 13-18 Feb | 6 Feb |
| Clyde | 17 Feb | 17 Feb | 15-20 Feb | 9 Feb |
| Holman Island | 16 Feb | 16 Feb | 15-18 Feb | 11 Feb |
| Sachs Harbour | 17 Feb | 14 Feb | 14-20 Feb | 14 Feb |
| Arctic Bay | 17 Feb | 18 Feb | 16-20 Feb | 18 Feb |
| Resolute | 18 Feb | 19 Feb | 18-24 Feb | 22 Feb |
| Mould Bay | 18 Feb | 17 Feb | 18-22 Feb | 26 Feb |
| Isachsen | 18 Feb | 19 Feb | 19-23 Feb | 6 Mar |
| Eureka | 2 Mar | 2 Mar | 26 Feb - 2 Mar | 9 Mar |
| Alert | 7 Mar | 10 Mar | 6-10 Mar | 16 Mar |

In the study by Longley (1958) the mid-February cold spell was matched at Resolute by another at the beginning of March, leading him to the conclusion that the reversal of temperature did not occur until 6 March. The results from the longer period suggest a date 10 days to 2 weeks earlier, but the warm temperatures at the end of February make it difficult to conclude that the low point of the temperature curve occurs during that period.

Making allowance for the short-period cycles of temperature, the curves of Figure 2 show that the time of minimum temperature advances as one goes northward from the last week of January at 60-65°N latitude to the first week of March for the regions north of 80° latitude. Even such an early date is surprising for the northern areas. At Alert the sun remains below the horizon until 1 March, and is only 3° above the horizon at noon on 10 March. There would be little solar heating to warm the air during the first week of March.

## 4. Spatial Variability of Temperature

From the calculations outlined above, the variability of daily temperatures was obtained by computing the standard deviations. The averages of these varied somewhat from month to month, but the changes across the area are significant. Figures 3 and 4 give, respectively, the mean standard deviations for February for maximum and minimum temperatures.

The two maps show that the variability decreases to the north. It is highest along the Mackenzie River where warm air from the Pacific, modified in its path, occasionally penetrates. Atlantic storms entering Baffin Bay and Davis Strait can bring warm air northward. In both areas, the extreme situations can bring above-freezing temperatures in January and February. In the central part of the area such flows have little effect, and temperature variations are smaller.

## 5. The Arctic Inversion

The foregoing analysis has been based on recorded surface temperatures only. Another set of data brings further confusion into the problem. During the arctic winter, an inversion in the atmosphere with its base at the snow surface exists almost continuously.

An analysis of the strength of this inversion was undertaken in some detail for Resolute and Inuvik, and for other stations in less detail. Data were available for the years 1961 to 1976 for the 95-kPa level, the lowest standard level reported. In a manner similar to that described above, the 5-day running mean temperatures for the period 1 November to 31 March were computed for the 12-GMT observations. These observations were used because the values would be closest to the minimum values when the diurnal rhythm was established. Also computed were the 5-day running mean temperature differences. Curves showing the changes in the variables are given in Figures 5 and 6.

The temperature curves for Inuvik show a gradual cooling through November and December to the cold period about 15 January, a warm period near the end of January, followed by the lowest temperatures near the middle of February. The temperature rise is rapid after 15 February but there is a secondary minimum in early March. The curves, then, match closely the curves for Inuvik found in Figure 2. The curve for Inuvik in Figure 6 shows that the inversion increases from November to January. This would cause a greater drop in the surface temperature than at 95 kPa. This difference, occurring before the time of minimum temperatures, would not be reflected in the attempt to determine the low points of the curves in Figure 5.

The corresponding curves for Resolute do not match so closely, although they are similar. The curves of Figure 5 show the coldest temperatures about 15 January, with slightly higher surface temperatures about 15 February. Thereafter the variations are minor.

The curves showing the strengths of the inversion are significant here. The curve for Inuvik in Figure 6 shows a difference of 3-4°C in November and December, rising to 5°C in January and February and 6°C in March. For Resolute, the mean strength is 3-4°C in November and December, rising to 5°C in January, and to over 6°C in February and March. Because of this variation, the minimum in mid-February at the surface has almost disappeared at 95 kPa. Although the two minima at the surface are only 1°C different, it is 3°C warmer at 95 kPa in mid-February than in mid-January.

The results noted above have significance in the problem of establishing the time of minimum temperature. In the kernlose winter of the Arctic, a change of 3°C will change, in some instances, the point of minimum. For example, the 95-kPa curve for Resolute would suggest a minimum in mid-January, while the mid-February date could easily be accepted if one were using the surface data. With the Inuvik curves, this difference would not arise.

The change in the strength of the inversion varies from one radiosonde station to another. For example, at Baker Lake, the mean temperature difference between the two levels is 3.2°C in November, 6.6°C in February; at Coppermine, 2.9°C in November, 6.8°C in February; at Eureka, 8.8°C in November, 9.6°C in February; and at Mould Bay, 4.5°C in November, 7.9°C in February.

It is not easy to understand why the inversion becomes stronger at Resolute. One explanation might be the change in the mean pressure distribution. A high pressure builds over the Queen Elizabeth Islands in March and April. The mean wind drops from 22.7 km hr$^{-1}$ in January to 19.6 in March. If this were the explanation then the inversions should increase at most of the stations studied. But this result is not observed.

Another possible explanation for the observed increase in the inversion comes from the snow cover near the observing point. As observed by the author, the thermometer screen at Resolute lies a short distance from a group of buildings. As the winter advances, the drifting near the buildings reaches out and results in a deep snow cover near the screen, rising in late winter to near the bottom of the screen. The recorded surface temperature then is no longer 1.3 m above the radiating surface but is very close to that level. In the strong inversions of the Arctic, this can be 2 or more degrees below the temperature at 1.3 m. This change in the "surface" temperature is then added to the inversion between the surface and 95 kPa as noted in the Resolute curve in Figure 4. If the thermometer screen remains in an area relatively free of snow this effect would not be noted.

The author has no other evidence to support the hypothesis. Such evidence might be obtained if information about the depth of snow near the screen at the different observing points was available. But this depth can differ greatly from the published depths of snow cover.

If one attributes the differences found in the curves at Resolute to the increase in the depth of snow around the thermometer screen, one will find differences in the inversion from station to station depending upon the trends of snow cover around the screen. For example, at Inuvik the snow cover may rise during November and December, thus explaining the increase in the inversion noted in Figure 6. Unfortunately, for the purpose of resolving this problem, data are not available. The snow cover near the screen is affected by the local environment and cannot easily be estimated from the depth of snow in the climatological reports.

Other meteorologists familiar with the Arctic may propose other hypotheses to explain the difference in trends of the temperature at 95 kPa and the surface. Both trends are related to the net heat supply to the area. The direct solar heat begins to affect temperatures 2 weeks or more after the sun first rises. Net advection is influenced by the mean pressure distribution. With high pressure developing over the Queen Elizabeth Islands in March, the net advection along the Mackenzie will bring warming temperatures to augment the sun's effect. To the east, the net advection will counteract the solar heating and so delay the time of minimum temperatures.

## 6. Summary

Curves are presented giving the running mean temperatures at a number of observing stations in the Canadian Arctic for January, February, and March. These, as expected, show short period cycles imposed upon the trend of cooling to a minimum and warming thereafter. These cycles are such that it is impossible to date clearly the time of minimum temperatures. Yet, the total results show that, on the average, the lowest temperature advances from late January south of the Arctic Circle to the first week of March at the northern part of Ellesmere Island.

A study of the trend of 95-kPa temperatures shows that it differs for some stations from that of the surface temperatures. No clear explanation is advanced, but the suggestion is made that the increasing depth of the snow near thermometer screens may result in a bias toward colder observed surface temperatures.

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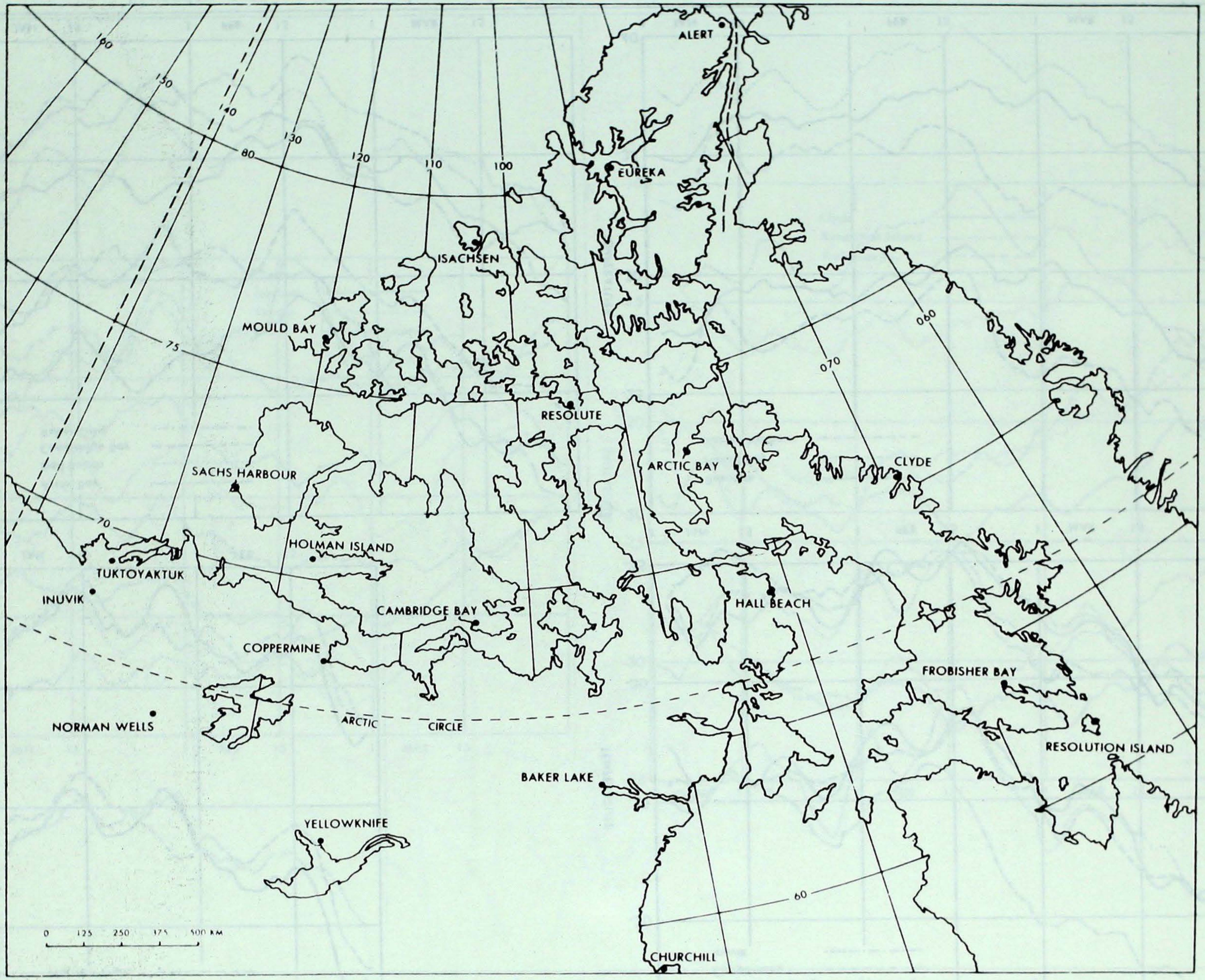


Figure 1. Northern Canada showing the locations of stations used in this report.

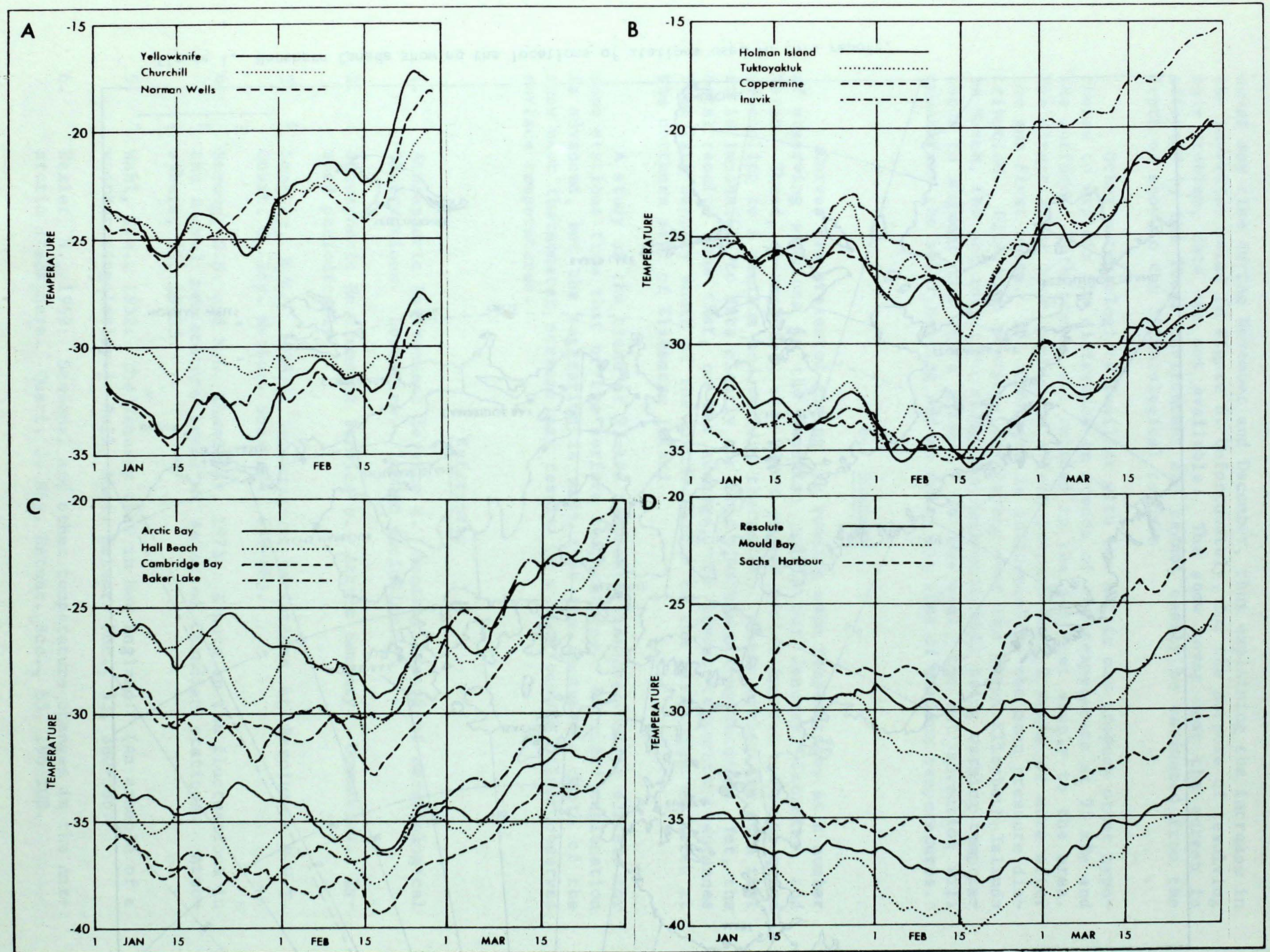


Figure 2 Five-day running mean maximum and minimum temperatures at Canadian Arctic stations.

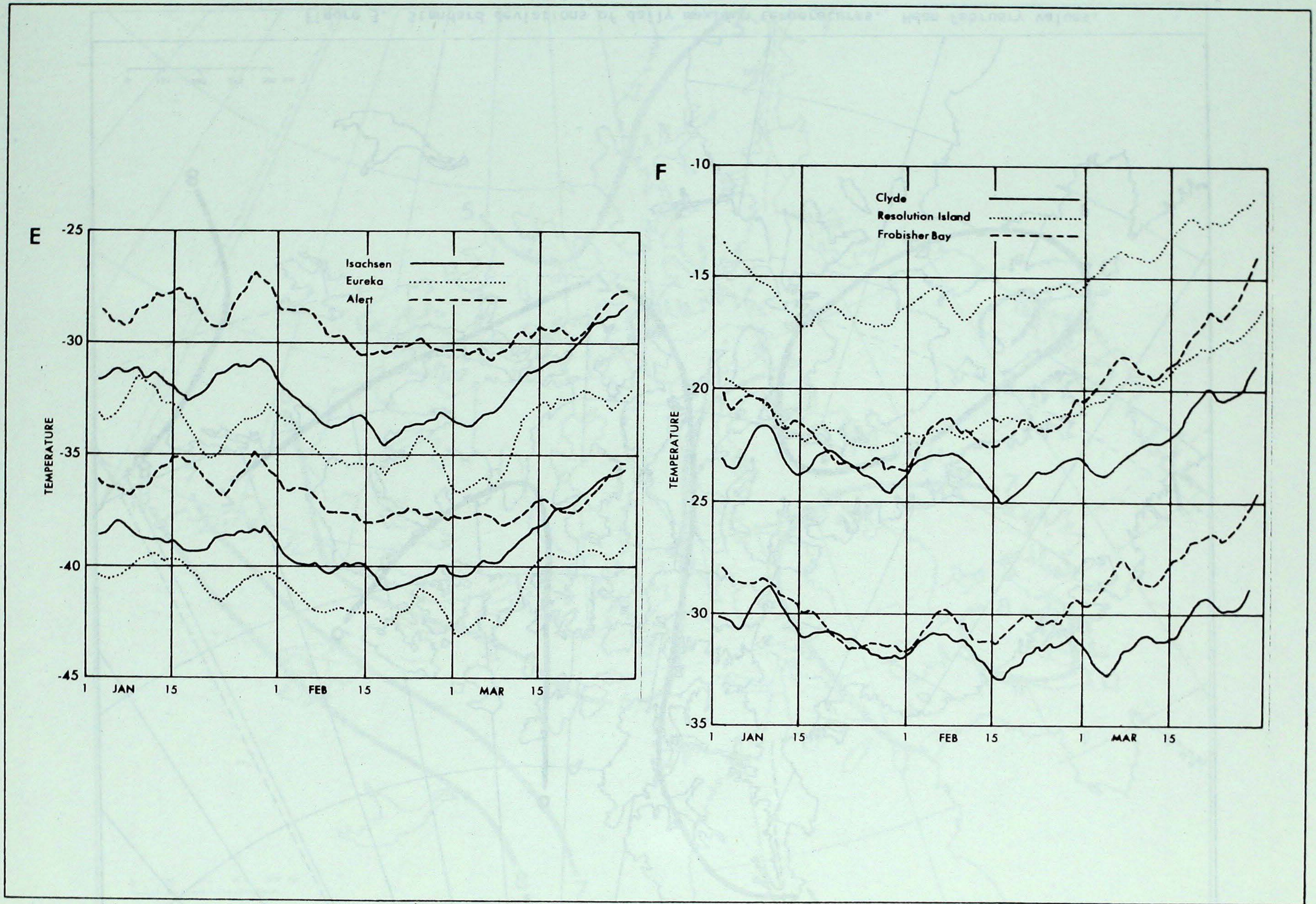


Figure 2 (continued) Five-day running mean maximum and minimum temperatures at Canadian Arctic stations.

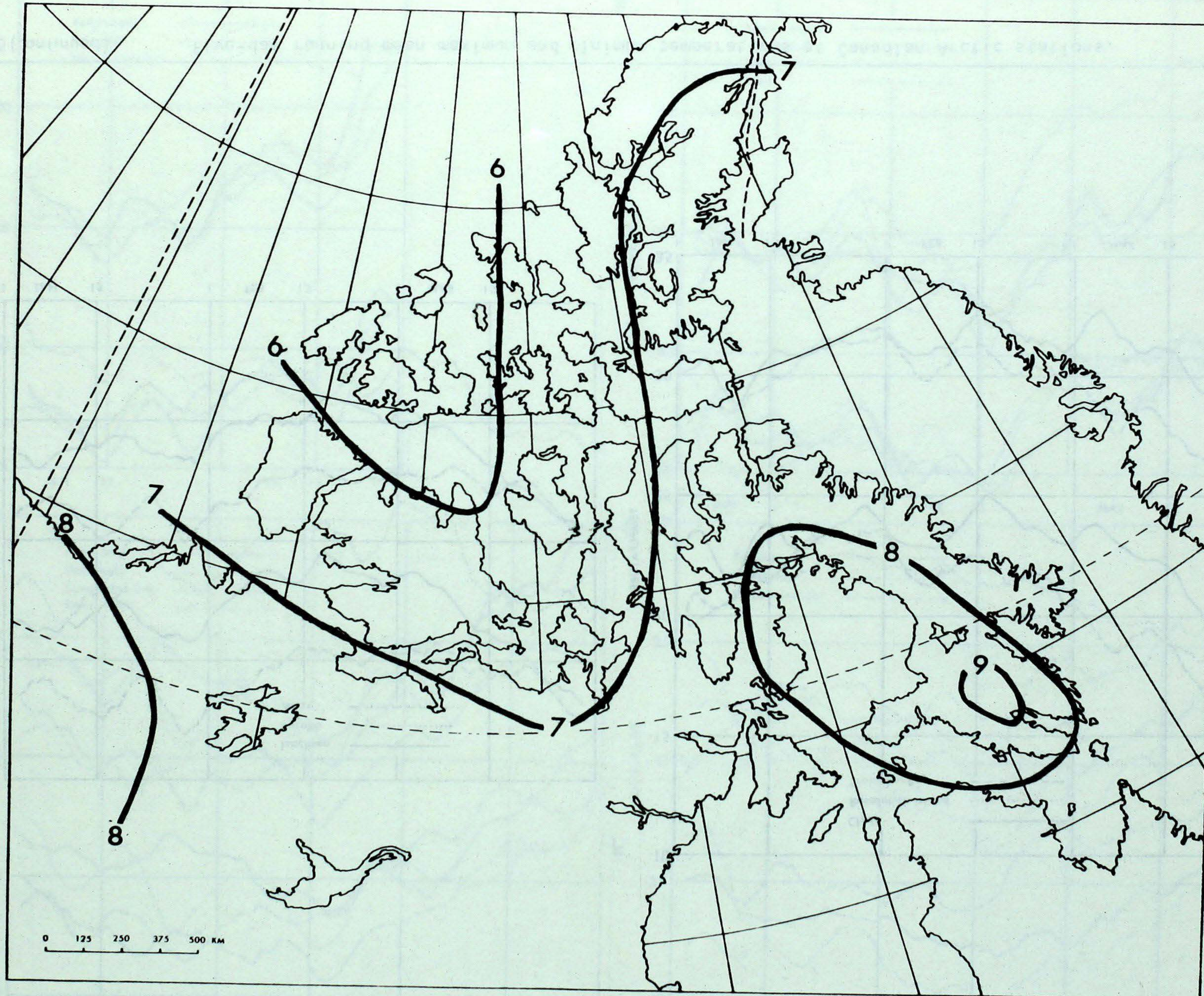


Figure 3. Standard deviations of daily maximum temperatures. Mean February values.

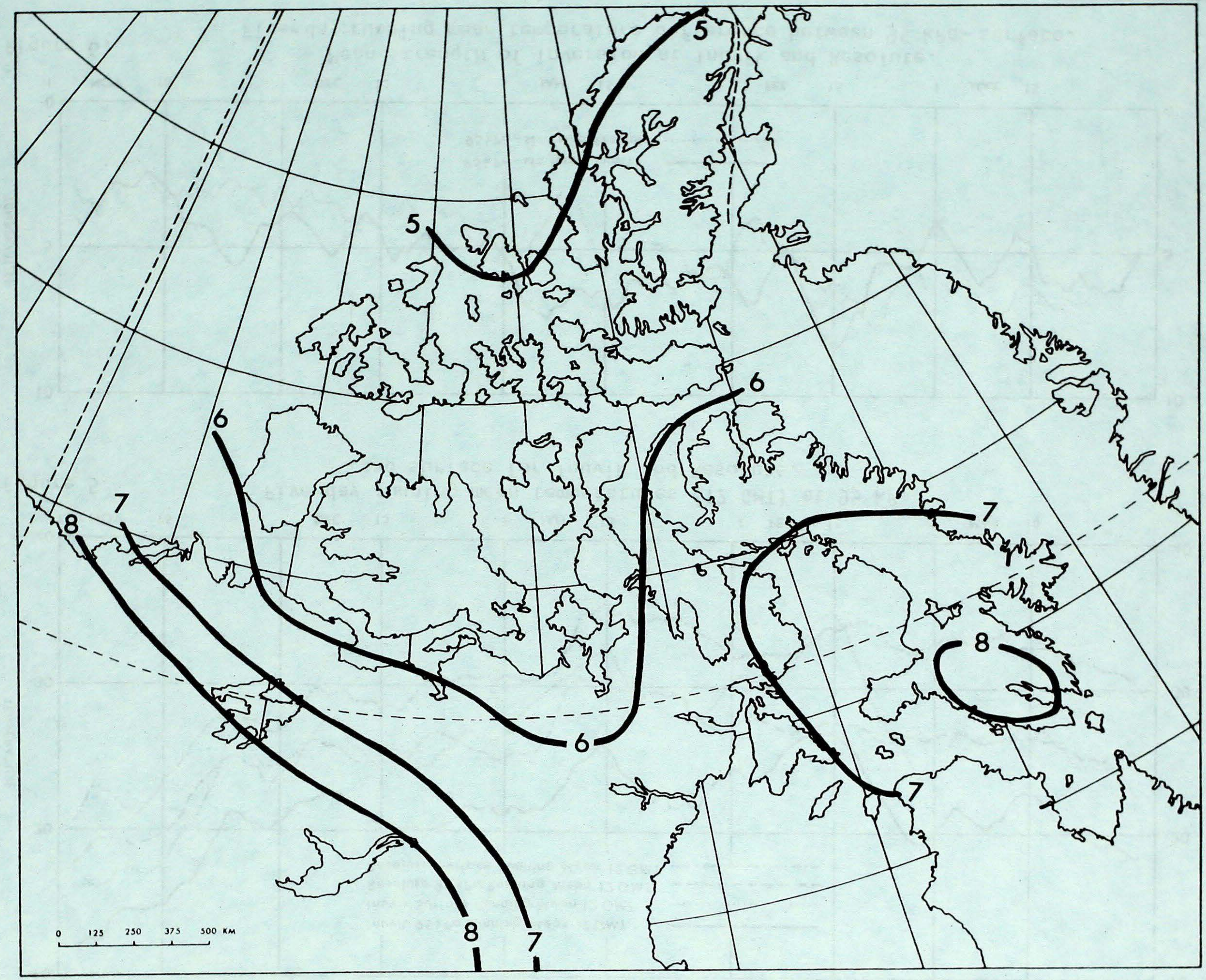


Figure 4. Standard deviations of daily minimum temperatures. Mean February values.

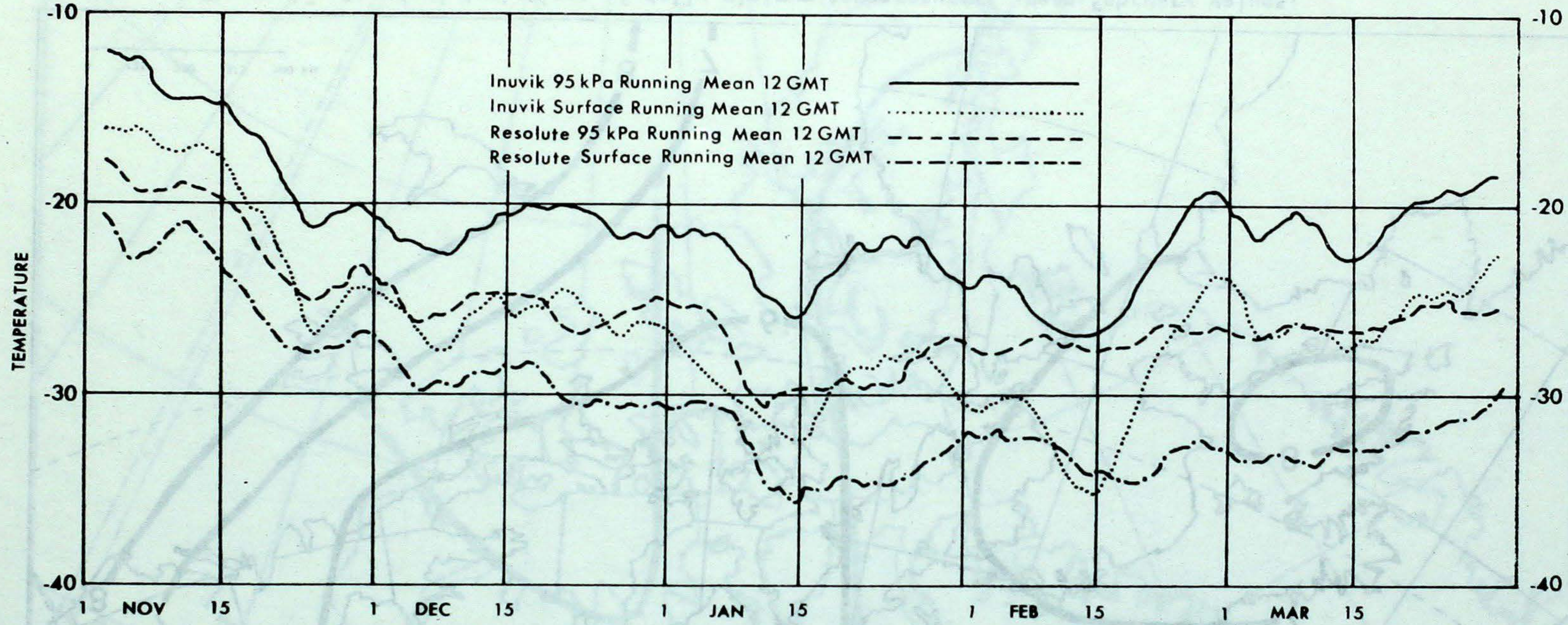


Figure 5. Five-day running mean temperatures (12 GMT) at 95 kPa and surface for Inuvik and Resolute.

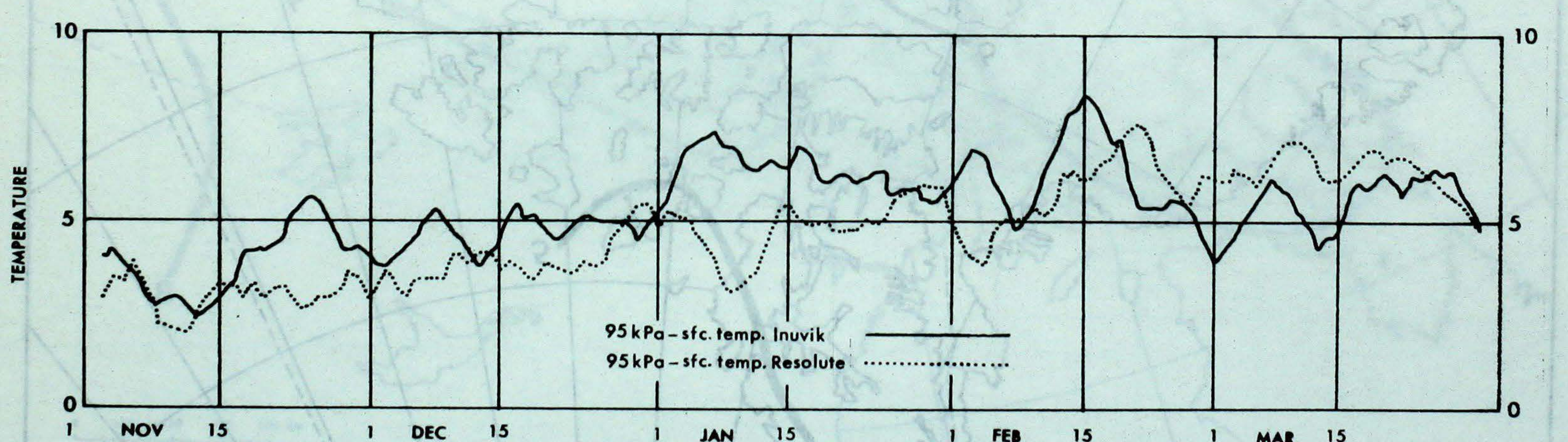


Figure 6. Mean strength of inversion at Inuvik and Resolute. Five-day running mean temperature difference between 95 kPa - surface.