*EASTERN REGION TECHNICAL ATTACHMENT*
*NO. 93-7C*
*JULY, 1993*

# TRENDS IN ANNUAL AND SEASONAL AVERAGE TEMPERATURE AT CARIBOU MAINE

*Charles L. McGill*
*National Weather Service Office*
*Caribou, Maine*

## 1. INTRODUCTION

The debate within the scientific community as to whether the Earth's climate is undergoing a long term significant warming due to an increase in "greenhouse" gases has been ongoing for a number of years (Schneider 1990; Kellogg 1991; Michaels and Stooksbury 1992). The average temperature at Caribou, Maine during the decade 1980-1989, increased by 0.5°F over that of the previous decade. This was also the warmest of the five complete decades for which temperature records have been recorded at Caribou. While this is consistent with the trend noted at many other locations around the world (Duchon 1986; Iovino 1991; Conover 1992), the cause of this increase in temperature cannot conclusively be linked to an increase in "greenhouse" gases. This study does not seek to prove or disprove the theory that global warming is occurring due to an increase in greenhouse gases. Rather, the goal of this study is to present the trends in annual and seasonal average temperature that have occurred at Caribou, Maine over the past 51 years of observation.

## 2. PROCEDURE

Average temperatures on an annual (Table 1) and seasonal (spring, summer, fall, and winter) basis (Table 2) for the years 1940 through 1990 were examined. The intent was to ascertain the temperature trends of the data over the period of analysis. It was determined that the location of the temperature sensor in Caribou, has only undergone minor changes throughout the period of record. Therefore any changes in the temperature record cannot be attributed to a change in temperature sensor location. Weather observations began to be taken in Caribou, Maine on January 16, 1939. However, since data were not available for the entire year of 1939, this year was not used for this study.

Due to the highly variable nature of annual and seasonal average temperatures, 15-year running averages (Tables 3 and 4) were calculated. This time period compensates well for interannual and intraannual variability. Ten-year running averages contained too much variability, while 20 year running averages produced too few data points. By using 15-year periods, 37 data

points were generated. The first 15-year period ran from January 1, 1940 to December 31, 1954, while the last 15-year period was from January 1, 1976 to December 31, 1990.

Linear regression analysis was applied to each of the 15-year running average data sets. The corresponding equation was then used to produce a regression line from the data points. This line depicts the trend of the data over the period of study and is illustrated as a thin solid line on the graphs of the 15-year running averages.

The arithmetic mean of the seasonal and annual average temperatures were also computed. This value is illustrated as a horizontal thin solid line on the average temperature graphs.

It should be noted that while the winter season (Dec.-Feb.) covers two separate years, each season has been represented by a single year, corresponding to the year in which the majority of the season (Jan. and Feb.) occurs. For example, the winter season of 1939-40 is presented as 1940.

## 3. RESULTS

### *a. Spring*

The regression line for the 15-year running average of the average spring (Mar.-May) temperature (Figure 1), shows a distinct warming trend with much of the warming occurring during recent 15-year periods. The temperature variation for the 15-year running averages is 2.7°F. The coldest temperature was 36.1°F (1943-57), while the warmest temperature was 38.8°F during the final 15-year period. The equation generated by the regression analysis is:

$$y = -75.83 + 0.0577x. \quad (1)$$

The correlation coefficient from the analysis is 0.75, indicative of a substantial trend (Mendenhall and Sincich 1984).

The increase in the 15-year running average over the last 15 periods is illustrated in Figure 2. Of the last 15 years, 11 are above the sample mean, with one being equal to the average. Included in this period is the warmest spring on record in Caribou. The effect of these seasons on the sample mean is certainly not trivial. Of the first 36 seasons, 20 were below the sample mean, while 15 were above.

### *b. Summer*

A similar trend is apparent in the 15-year running average for the average summer (Jun.-Aug.) temperature (Figure 3). The regression line again shows a distinctive warming trend. Most of the warming occurred between the 15-year periods 1954-68 and 1967-81. After the end of the 28 year warm period, the 15-year running average leveled off and started to decrease. There was a 2.0°F temperature variation for the period of study. Values ranged from a minimum of 61.7°F for the period 1950-64, to a maximum of 63.7°F during the periods 1967-81 and 1970-84. The regression equation for the summer data is:

$$y = -40.10 + 0.0525x. \quad (2)$$

The correlation coefficient was 0.71.

From 1967 to 1984, there was a period of summer seasons that ran well above the sample mean (Figure 4), leading to the peak

in the 15-year running average. As with the spring season, many of the seasons over the first two-thirds of the study period fell below the sample mean. In fact, only 5 of the first 19 seasons were warm enough to rise above the sample mean. The other 14 "cool" summer seasons resulted in the lowest 15-year running averages.

*c. Fall*

In contrast to the spring and summer seasons, the 15-year running average of the average fall (Sept.-Nov.) temperature exhibited a cooling trend over the period of study (Figure 5). Much of the cooling during the fall season has occurred since the 1957-71 period. The warmest 15-year period average temperature was 43.4°F during the period 1947-61, while the coldest 15-year period average temperature was 41.9°F during the period 1972-86. This sample showed a variation of 1.5°F. The regression equation for the fall data is:

$$y = 111.66 - 0.035x. \quad (3)$$

Similar to the spring and summer seasons, the correlation coefficient was 0.75.

An examination of the average fall season temperatures (Figure 6) revealed that since 1972, only 6 of the 18 seasons were above the sample mean. Prior to 1972 there were 6 straight seasons with temperatures above the sample mean. Furthermore, the decline in seasonal average temperature at the end of the study period is clearly illustrated.

*d. Winter*

The 15-year running average of the average winter temperature (Figure 7), also showed a cooling trend over the period of study. The greatest period of cooling occurred between 1949-63 and 1963-77. Since the 1963-77 period, the 15-year running average has increased. The temperature variation in the 15-year running average was 2.0°F. The warmest temperature occurred during the period 1949-63, with a maximum temperature of 14.2°F. The coolest temperature occurred during the period 1963-77, with a value of 12.2°F. The resulting regression equation from the winter data is:

$$y = 75.52 - 0.032x. \quad (4)$$

The regression analysis yielded a correlation coefficient of 0.33.

The sizable intraannual temperature swings that occurred during the winter season are illustrated (Figure 8). The decade of the 1950s was noted for some very mild winters in Caribou, with only two seasons falling below the sample mean. However, it is interesting to note that the winter of 1959 was the coldest winter on record in Caribou.

The decade of the 1970s produced several of the coolest winter seasons on record. Only three of the seasons were warmer than the sample mean, with one being equal to the sample mean. In contrast to the 1950s, the winters of the 1970s were responsible for the coldest temperatures in the 15-year running average (Figure 7).

*e. Annual*

Analysis of the 15-year running average for annual average temperatures (Figure 9), revealed a warming trend over the period of study. The temperature variation for this period was 0.7°F, with a minimum of 38.6°F for the period 1940-54 (also 1962-

76), and a maximum of 39.3°F for the period 1973-87 (and also 1976-90). For the annual data, the regression equation is:

$$y = 18.12 + 0.011x. \quad (5)$$

Despite the relatively high correlation between the change in temperature and the change in time for the spring, summer, and fall seasons, the resulting correlation coefficient for the annual data was only 0.35.

The annual average temperature (Figure 10) shows that the final 15 years have led to an increase in the 15-year running averages (Figure 9).

## 4. CONCLUSION

Regression analysis has shown that the average annual temperature at Caribou, Maine has warmed over the last 51 years. However, the cause of this warming is unknown. Any relationship between the total annual increase in temperature and the "greenhouse" effect, or other natural changes in the Earth's climate, is yet to be determined. Overall, the magnitude of the spring and summer average temperature increases have been larger than the fall and winter average temperature decreases. Consequently, this has resulted in an increase in the annual average temperature.

This study has illustrated many interesting features about the temperature characteristics at Caribou, Maine over the past 51 years. The results suggest that a more detailed study, which makes use of more sophisticated statistical analysis techniques is warranted.


## ACKNOWLEDGEMENTS

The author would like to thank Dr. Bruce Berryman, Professor, Lyndon State College, for his many helpful comments and critiques. Thanks also to Fred Ronco, DMIC, WSFO PWM, and the staff for their suggestions on improvements, and to the personnel at Eastern Region Scientific Services Division.


## REFERENCES


Conover, John, 1992: Are New England Winters Getting Milder?. *Weatherwise*, 45, 24-25.

Duchon, Claude E., 1986: Temperature Trends at San Juan, Puerto Rico. *Bull. Amer. Meteor. Soc.*, 67, 1370-1377.

Iovino, Dean L., 1991: Changes in Observed Temperature at Scranton, Pennsylvania. *Eastern Region Staff Reports*, Tech. Attach. 91-2C, 1-8.

Kellogg, William W., 1991: Response to Skeptics of Global Warming. *Bull. Amer. Meteor. Soc.*, 72, 499-511.

Mendenhall, William, and Terry Sincich, 1984: *Statistics for the Engineering and Computer Sciences*, Dellen Publishing Corporation, San Francisco, CA, 355-360 and 379-382.

Michaels, Patrick J., and David E. Stooksbury, 1992: Global Warming: A Reduced Threat?. *Bull. Amer. Meteor. Soc.*, 73, 1563-1577.

Schneider, Stephen H., 1990: The Global Warming Debate Heats Up: An Analysis and Perspective. *Bull. Amer. Meteor. Soc.*, 71, 1292-1304.

| Year | Average Temperature | Year | Average Temperature |
|---|---|---|---|
| 1940 | 37.2°F | 1966 | 40.3°F |
| 1941 | 38.0°F | 1967 | 38.2°F |
| 1942 | 38.9°F | 1968 | 39.2°F |
| 1943 | 36.3°F | 1969 | 40.1°F |
| 1944 | 38.7°F | 1970 | 39.6°F |
| 1945 | 38.9°F | 1971 | 38.3°F |
| 1946 | 38.1°F | 1972 | 36.2°F |
| 1947 | 38.8°F | 1973 | 40.4°F |
| 1948 | 38.1°F | 1974 | 37.9°F |
| 1949 | 39.5°F | 1975 | 39.0°F |
| 1950 | 38.7°F | 1976 | 37.1°F |
| 1951 | 39.2°F | 1977 | 39.5°F |
| 1952 | 39.7°F | 1978 | 38.4°F |
| 1953 | 41.1°F | 1979 | 41.8°F |
| 1954 | 38.5°F | 1980 | 38.7°F |
| 1955 | 38.6°F | 1981 | 41.3°F |
| 1956 | 37.8°F | 1982 | 39.0°F |
| 1957 | 38.9°F | 1983 | 40.4°F |
| 1958 | 38.4°F | 1984 | 39.7°F |
| 1959 | 39.0°F | 1985 | 38.1°F |
| 1960 | 40.4°F | 1986 | 38.1°F |
| 1961 | 39.2°F | 1987 | 39.9°F |
| 1962 | 38.0°F | 1988 | 39.4°F |
| 1963 | 37.9°F | 1989 | 38.0°F |
| 1964 | 38.6°F | 1990 | 40.7°F |
| 1965 | 37.6°F | | |

**Table 1.** Average Annual Temperatures for Caribou, Maine 1940-1990.

| Year | Spring Average Temperature | Summer Average Temperature | Fall Average Temperature | Winter Average Temperature |
|---|---|---|---|---|
| 1940 | 36.2°F | 61.0°F | 40.1°F | 13.3°F |
| 1941 | 36.5°F | 61.1°F | 40.9°F | 11.6°F |
| 1942 | 39.8°F | 62.7°F | 43.1°F | 12.5°F |
| 1943 | 32.1°F | 61.1°F | 42.5°F | 9.4°F |
| 1944 | 35.2°F | 63.7°F | 43.7°F | 11.0°F |
| 1945 | 39.1°F | 62.8°F | 41.8°F | 11.5°F |
| 1946 | 37.1°F | 61.1°F | 44.6°F | 10.0°F |
| 1947 | 33.9°F | 63.9°F | 44.4°F | 12.8°F |
| 1948 | 34.4°F | 62.1°F | 45.1°F | 8.4°F |
| 1949 | 37.4°F | 64.3°F | 41.8°F | 14.5°F |
| 1950 | 36.2°F | 60.8°F | 43.0°F | 13.9°F |
| 1951 | 38.9°F | 61.1°F | 42.4°F | 17.0°F |
| 1952 | 37.7°F | 64.6°F | 41.3°F | 13.9°F |
| 1953 | 38.7°F | 61.8°F | 45.1°F | 17.4°F |
| 1954 | 35.5°F | 60.1°F | 43.0°F | 16.7°F |
| 1955 | 35.9°F | 63.8°F | 42.2°F | 15.1°F |
| 1956 | 32.8°F | 59.6°F | 42.2°F | 15.3°F |
| 1957 | 37.3°F | 60.5°F | 45.4°F | 10.5°F |
| 1958 | 40.1°F | 59.9°F | 41.5°F | 17.4°F |
| 1959 | 37.3°F | 63.4°F | 42.9°F | 8.0°F |
| 1960 | 37.8°F | 62.8°F | 43.7°F | 17.8°F |
| 1961 | 34.7°F | 62.7°F | 46.7°F | 11.0°F |
| 1962 | 38.7°F | 61.0°F | 41.1°F | 12.8°F |
| 1963 | 35.0°F | 62.8°F | 44.3°F | 12.0°F |
| 1964 | 37.7°F | 61.1°F | 40.4°F | 12.7°F |
| 1965 | 37.2°F | 61.2°F | 40.0°F | 12.4°F |
| 1966 | 38.3°F | 62.2°F | 43.1°F | 16.0°F |
| 1967 | 31.5°F | 64.9°F | 43.8°F | 14.0°F |
| 1968 | 38.8°F | 61.5°F | 45.0°F | 11.1°F |
| 1969 | 36.4°F | 62.5°F | 43.2°F | 17.0°F |
| 1970 | 38.0°F | 65.8°F | 45.3°F | 13.3°F |
| 1971 | 37.7°F | 61.5°F | 43.5°F | 10.1°F |
| 1972 | 35.1°F | 62.2°F | 39.9°F | 8.8°F |
| 1973 | 38.8°F | 66.0°F | 41.4°F | 10.0°F |
| 1974 | 34.3°F | 63.9°F | 41.1°F | 13.8°F |
| 1975 | 37.3°F | 64.8°F | 43.2°F | 13.2°F |
| 1976 | 37.4°F | 63.4°F | 38.8°F | 9.9°F |
| 1977 | 40.7°F | 62.7°F | 42.7°F | 8.9°F |
| 1978 | 37.0°F | 64.0°F | 39.9°F | 13.1°F |
| 1979 | 42.5°F | 64.5°F | 45.1°F | 14.1°F |
| 1980 | 39.3°F | 63.4°F | 40.6°F | 14.8°F |
| 1981 | 40.6°F | 64.0°F | 41.8°F | 14.1°F |
| 1982 | 37.7°F | 61.8°F | 44.0°F | 12.8°F |
| 1983 | 39.0°F | 63.6°F | 44.3°F | 17.4°F |
| 1984 | 36.1°F | 63.5°F | 43.2°F | 14.5°F |
| 1985 | 36.1°F | 62.1°F | 42.7°F | 13.5°F |
| 1986 | 39.8°F | 60.1°F | 39.2°F | 12.0°F |
| 1987 | 40.8°F | 62.4°F | 42.6°F | 12.9°F |
| 1988 | 39.0°F | 63.4°F | 42.1°F | 14.8°F |
| 1989 | 37.6°F | 62.8°F | 42.1°F | 12.2°F |
| 1990 | 37.8°F | 65.3°F | 43.1°F | 10.8°F |

**Table 2.** Seasonal Average Temperatures for Caribou, Maine 1940-1990.

| 15 Year Period | Average Temperature | 15 Year Period | Average Temperature |
|---|---|---|---|
| 1940-54 | 38.6°F | 1959-73 | 38.9°F |
| 1941-55 | 38.7°F | 1960-74 | 38.8°F |
| 1942-56 | 38.7°F | 1961-75 | 38.7°F |
| 1943-57 | 38.7°F | 1962-76 | 38.6°F |
| 1944-58 | 38.9°F | 1963-77 | 38.7°F |
| 1945-59 | 38.9°F | 1964-78 | 38.7°F |
| 1946-60 | 39.0°F | 1965-79 | 38.9°F |
| 1947-61 | 39.1°F | 1966-80 | 39.0°F |
| 1948-62 | 39.0°F | 1967-81 | 39.0°F |
| 1949-63 | 39.0°F | 1968-82 | 39.1°F |
| 1950-64 | 38.9°F | 1969-83 | 39.2°F |
| 1951-65 | 38.9°F | 1970-84 | 39.2°F |
| 1952-66 | 38.9°F | 1971-85 | 39.1°F |
| 1953-67 | 38.8°F | 1972-86 | 39.0°F |
| 1954-68 | 38.7°F | 1973-87 | 39.3°F |
| 1955-69 | 38.8°F | 1974-88 | 39.2°F |
| 1956-70 | 38.9°F | 1975-89 | 39.2°F |
| 1957-71 | 38.9°F | 1976-90 | 39.3°F |
| 1958-72 | 38.7°F | | |

**Table 3.** 15 Year Running Average - Average Annual Temperature for Caribou, Maine.

| 15 Year Period | Spring Average Temperature | Summer Average Temperature | Fall Average Temperature | Winter Average Temperature |
|---|---|---|---|---|
| 1940-54 | 36.6°F | 62.1°F | 42.9°F | 12.9°F |
| 1941-55 | 36.6°F | 62.3°F | 43.0°F | 13.0°F |
| 1942-56 | 36.3°F | 62.2°F | 43.1°F | 13.3°F |
| 1943-57 | 36.1°F | 62.1°F | 43.2°F | 13.2°F |
| 1944-58 | 36.7°F | 62.0°F | 43.2°F | 13.7°F |
| 1945-59 | 36.8°F | 62.0°F | 43.1°F | 13.5°F |
| 1946-60 | 36.7°F | 62.0°F | 43.2°F | 13.9°F |
| 1947-61 | 36.6°F | 62.1°F | 43.4°F | 14.0°F |
| 1948-62 | 36.9°F | 61.9°F | 43.2°F | 14.0°F |
| 1949-63 | 36.9°F | 61.9°F | 43.1°F | 14.2°F |
| 1950-64 | 37.0°F | 61.7°F | 43.0°F | 14.1°F |
| 1951-65 | 37.0°F | 61.8°F | 42.8°F | 14.0°F |
| 1952-66 | 37.0°F | 61.8°F | 42.9°F | 13.9°F |
| 1953-67 | 36.6°F | 61.9°F | 43.0°F | 13.9°F |
| 1954-68 | 36.6°F | 61.8°F | 43.0°F | 13.5°F |
| 1955-69 | 36.6°F | 62.0°F | 43.0°F | 13.5°F |
| 1956-70 | 36.8°F | 62.1°F | 43.2°F | 13.4°F |
| 1957-71 | 37.1°F | 62.3°F | 43.3°F | 13.1°F |
| 1958-72 | 37.0°F | 62.4°F | 43.0°F | 13.0°F |
| 1959-73 | 36.9°F | 62.8°F | 43.0°F | 12.5°F |
| 1960-74 | 36.7°F | 62.8°F | 42.8°F | 12.9°F |
| 1961-75 | 36.6°F | 62.9°F | 42.8°F | 12.5°F |
| 1962-76 | 36.8°F | 63.0°F | 42.3°F | 12.5°F |
| 1963-77 | 36.9°F | 63.1°F | 42.4°F | 12.2°F |
| 1964-78 | 37.1°F | 63.2°F | 42.1°F | 12.3°F |
| 1965-79 | 37.4°F | 63.4°F | 42.4°F | 12.4°F |
| 1966-80 | 37.5°F | 63.6°F | 42.4°F | 12.5°F |
| 1967-81 | 37.7°F | 63.7°F | 42.4°F | 12.4°F |
| 1968-82 | 38.1°F | 63.5°F | 42.4°F | 12.3°F |
| 1969-83 | 38.1°F | 63.6°F | 42.3°F | 12.8°F |
| 1970-84 | 38.1°F | 63.7°F | 42.3°F | 12.6°F |
| 1971-85 | 38.0°F | 63.4°F | 42.1°F | 12.6°F |
| 1972-86 | 38.1°F | 63.3°F | 41.9°F | 12.7°F |
| 1973-87 | 38.5°F | 63.3°F | 42.0°F | 13.0°F |
| 1974-88 | 38.5°F | 63.2°F | 42.1°F | 13.3°F |
| 1975-89 | 38.7°F | 63.1°F | 42.2°F | 13.2°F |
| 1976-90 | 38.8°F | 63.1°F | 42.2°F | 13.1°F |

**Table 4.** 15 Year Running Averages - Seasonal Average Temperatures for Caribou, Maine.

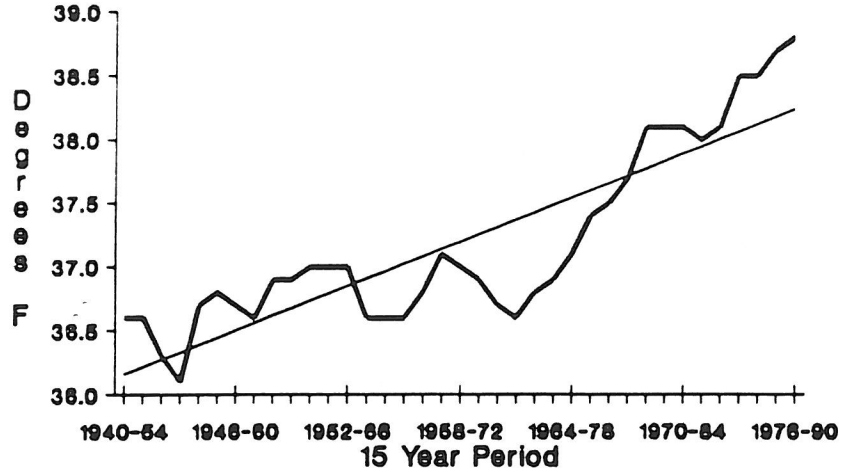


Figure 1. Regression analysis for the 15 year running average spring average temperatures at Caribou, ME (1940-1990).

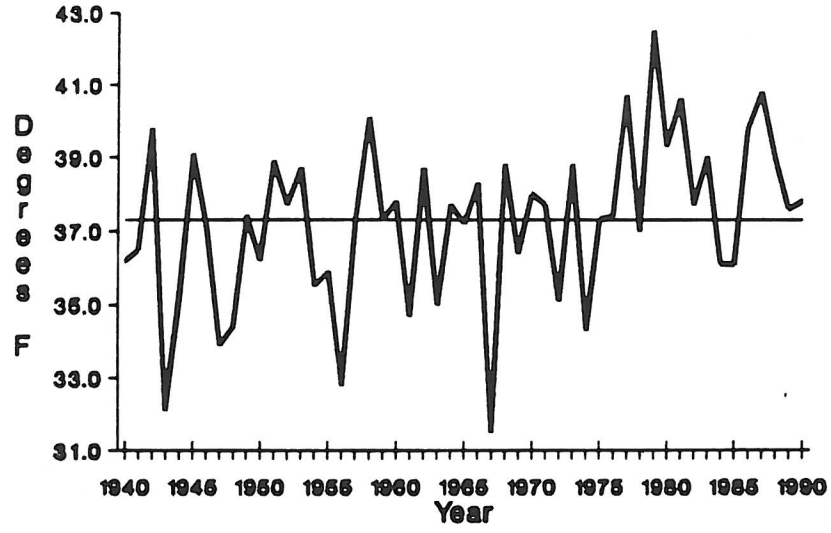


Figure 2. Average spring temperatures for Caribou, ME from 1940 to 1990. (thin line is sample mean).

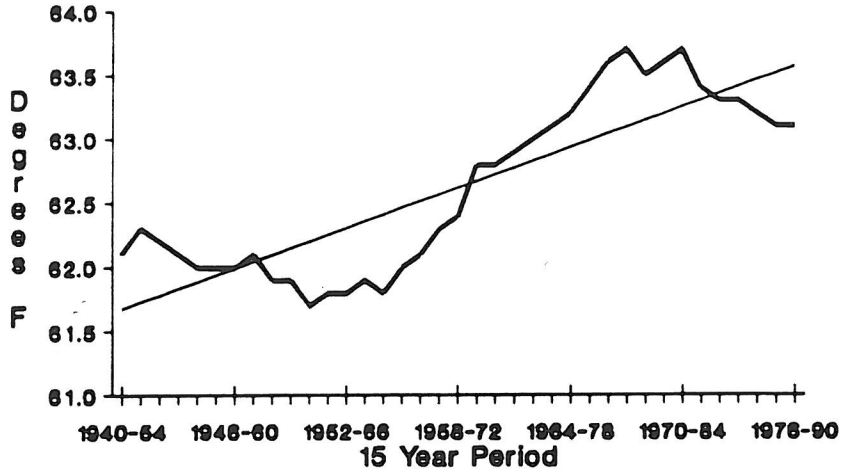


Figure 3. As in Fig. 1 except for the summer season.

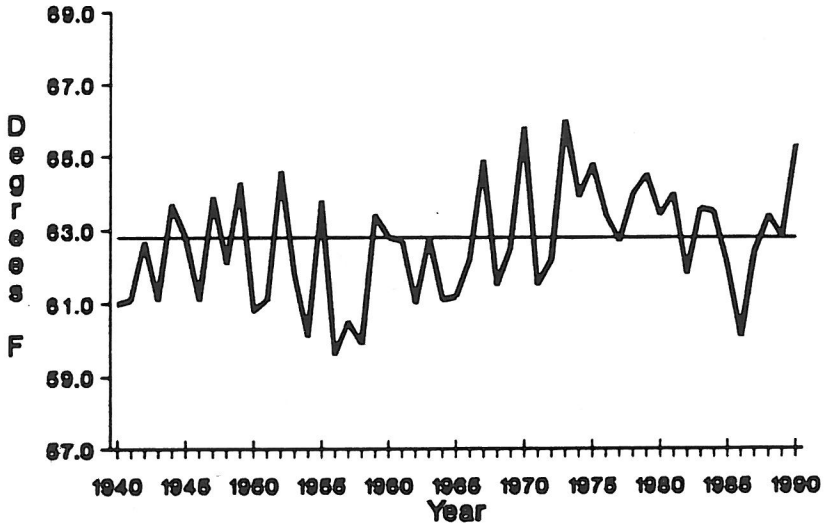


Figure 4. As in Fig. 2 except for the summer season.

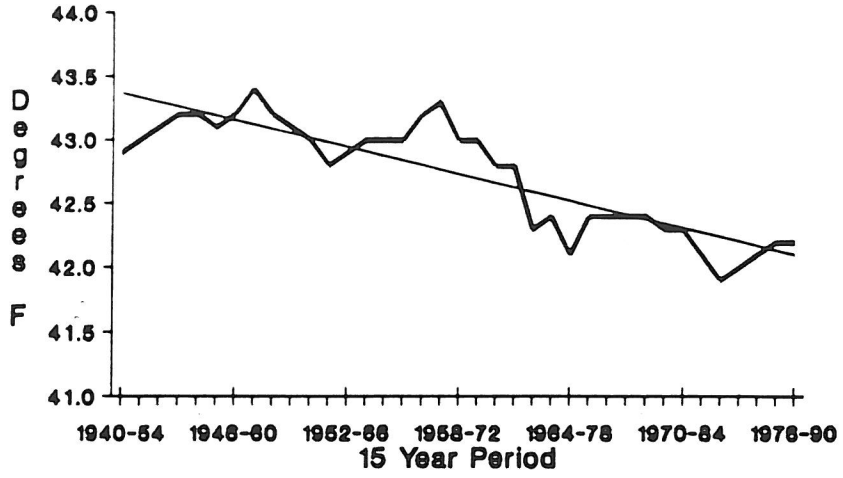


Figure 5. As in Fig 1. except for the fall season.

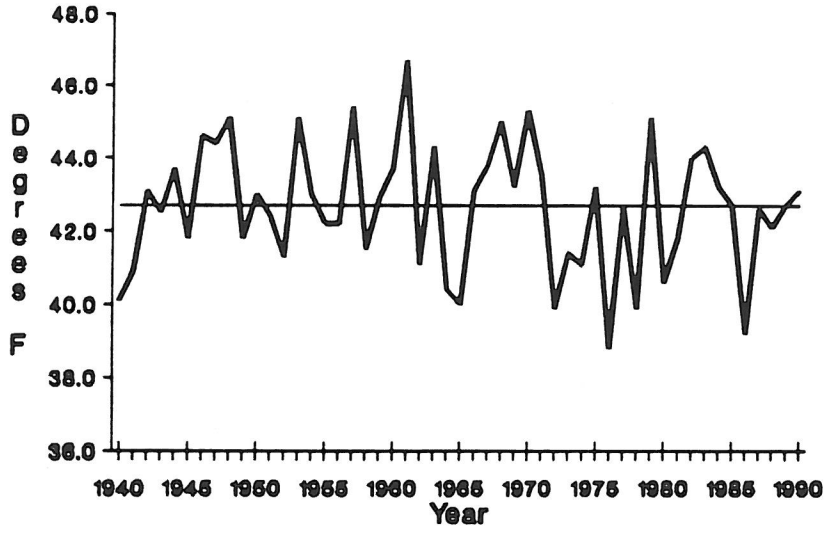


Figure 6. As in Fig. 2 except for the fall season.

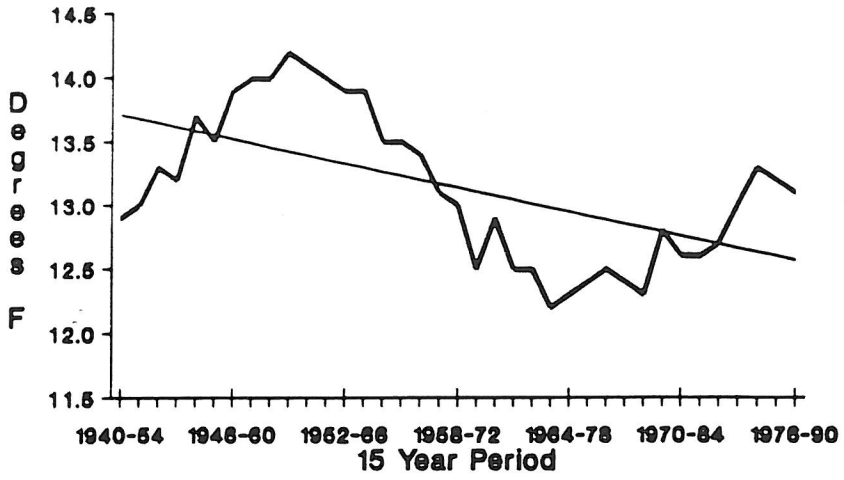


Figure 7. As in Fig 1. except for the winter season.

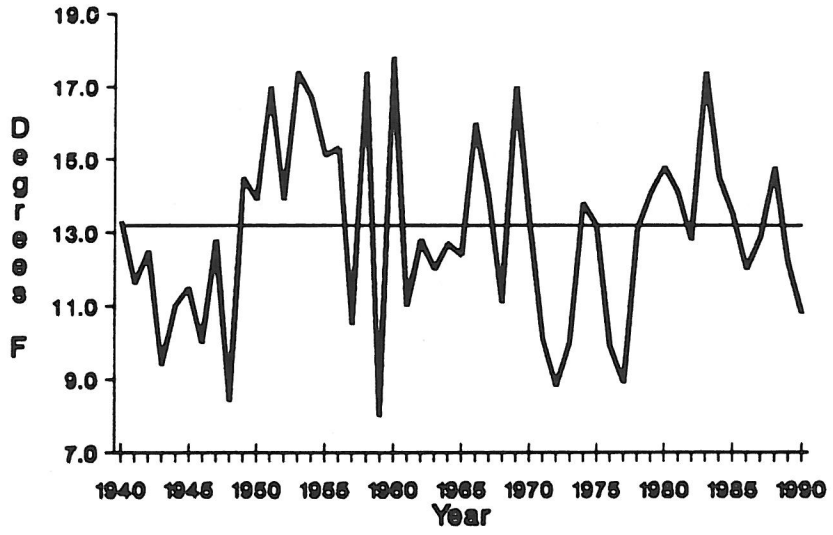


Figure 8. As in Fig. 2 except for the winter season.

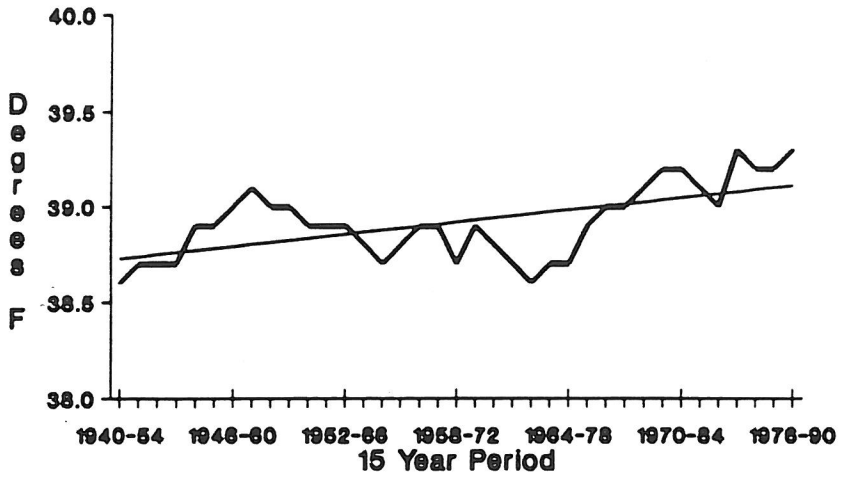


Figure 9. As in Fig. 1 except for the average annual temperature.

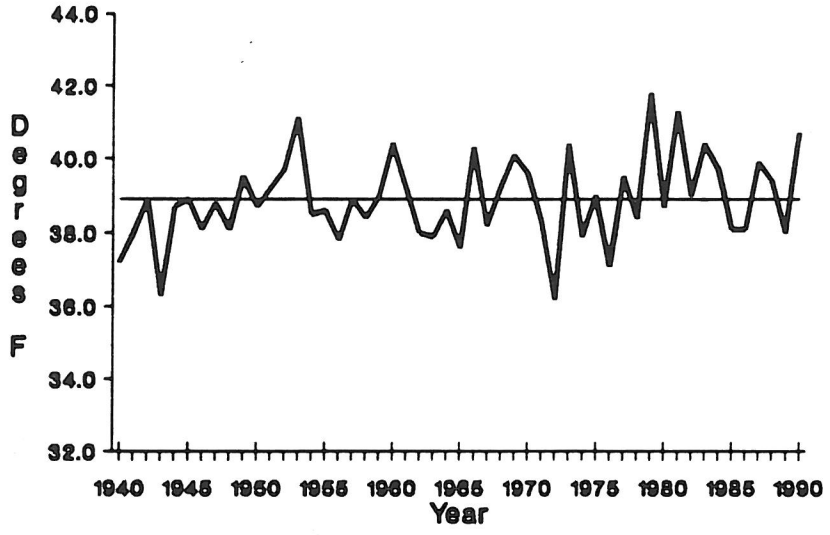


Figure 10. As in Fig 2. except for the average annual temperature.