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ANNUAL AND SEASONAL TEMPERATURE TRENDS FOR MEMPHIS, TENNESSEE, 1872-1985

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ABSTRACT

Monthly climatic data are available for Memphis,Tennessee since 1871. The climate record for Memphis spans more than a century and provides an opportunity to evaluate climatic trends. Temperature patterns for Memphis are analyzed on an annual and seasonal basis to identify temperature trends over the last century. Analysis indicates a general cooling of winter temperatures, but a general warming of spring, summer, fall and mean annual temperatures.

INTRODUCTION

There have been several analyses of long term temperature trends for locations in the United States and other locations of the world (Budyko, 1971, Lamb, 1971, Diaz and Quayle, 1980, Hansen, et al., 1981, Agee, 1982, Jones et al., 1982, Barnett, 1983, Baker et al., 1985, Skeeter, 1985, Suckling, 1986, McCabe, 1988). The consensus is that in the Northern Hemisphere during the last century there have been several distinct periods of temperature change; a cooling during the middle to late 1800s, a warming around the turn of the century to a maximum near the late 1930s and then a subsequent cooling to the mid 1970s (Agee, 1982). Recently, since the mid 1970s, mean Northern Hemisphere temperatures have risen slightly (Jones et al.,1982, Jones, 1985).

For Memphis, Tennessee monthly temperature data are available since 1871. This data set is interesting in that it covers more than 114 years. The data offer an opportunity to look at temperature trends since the late 1800s to the present. The objective of this paper is to identify long term annual and seasonal temperature trends for Memphis, Tennessee.

THE MEMPHIS, TENNESSEE TEMPERATURE RECORD

Official weather observations in Memphis, Tennessee began in 1871 as part of the weather network established by the United States Army Signal Corp. The original weather station was located in downtown Memphis and operated from 1871 to 1965. In 1931 a second weather station was established at the site of the Memphis municipal airport, which is approximately 13.3 kilometers south-southeast of the downtown station. The airport station became the official weather station for Memphis in 1941, and has been the official station to the present. Thus, the data period represented by the two weather stations in Memphis spans over 114 years. The movement of the official reporting station from the downtown location to the airport possibly resulted in some slight heterogeneity in the data due to the change of weather station location and exposure (Mitchell, 1953, Jones et al., 1986). To account for potential heterogeneity in the data, the record is analyzed both as a single long term record, as well as two separate segments,

1872-1940 and 1941-1985.

The data for Memphis were obtained from several government publications: 1) Annual Meteorological Summaries with Comparative Data for Memphis, Tennessee, U.S. Department of Agriculture, 1871-1940; 2) Local Climatological Data with Comparative Data for Memphis, Tennessee, U.S. Department of Commerce, 1941-1960; and 3) Climatological Data for Memphis, Tennessee, U.S. Department of Commerce, 1961-1985. Data from 1871 are not included in this study as they are incomplete.

The raw data are highly variable and trends are difficult to find. To facilitate analysis of the data, five-year moving averages were used. Therefore, graphs illustrating five-year moving averages begin in 1874 (representing 1872-1876) and end at 1983 (representing 1981-1985).

ANNUAL TEMPERATURE TRENDS

In Figure 1 five-year moving average mean annual temperatures for Memphis are plotted. The average for the 114-year period is 16.6°C with a standard deviation of .6°C. In Figure 1 several periods of warming and cooling are evident. For example, mean annual temperatures were below normal for most of the late 1800s up until near 1920. Subsequently, mean annual temperatures remained above normal for almost 20 years. A cool period then occurred from 1940 to near 1950. The early 1950s were warmer than normal, but during the late 1950s mean annual temperatures dropped below normal and remained there until the mid 1970s. Since the mid 1970s mean annual temperatures have been above normal.

SEASONAL TEMPERATURE TRENDS

To analyze these patterns further, seasonal analyses were performed to examine temperature patterns within each season over the 114-year period. The winter period was represented by the average of data for the months of December, January and February. Spring values were derived from data for March, April and May. Data from June, July and August were averaged to give summer average temperatures. The fall period was represented by data from the months of September, October and November (Trenberth, 1983). The five-year moving averages for all of these periods are illustrated in Figure 1.

The winter data produced a long term mean of 6.0° C and indicate a high degree of variability producing the highest standard deviation of any of the seasons (1.8° C). The patterns for the winter data are not as clear as those found for mean annual temperatures. During the late 1800s, the cooler than normal period found in the mean annual data is not evident in the winter data. However, a warmer than normal period during the 1920s, 1930s and 1950s is evident. A cool period during the late 1950s, 1960s and early 1970s is also

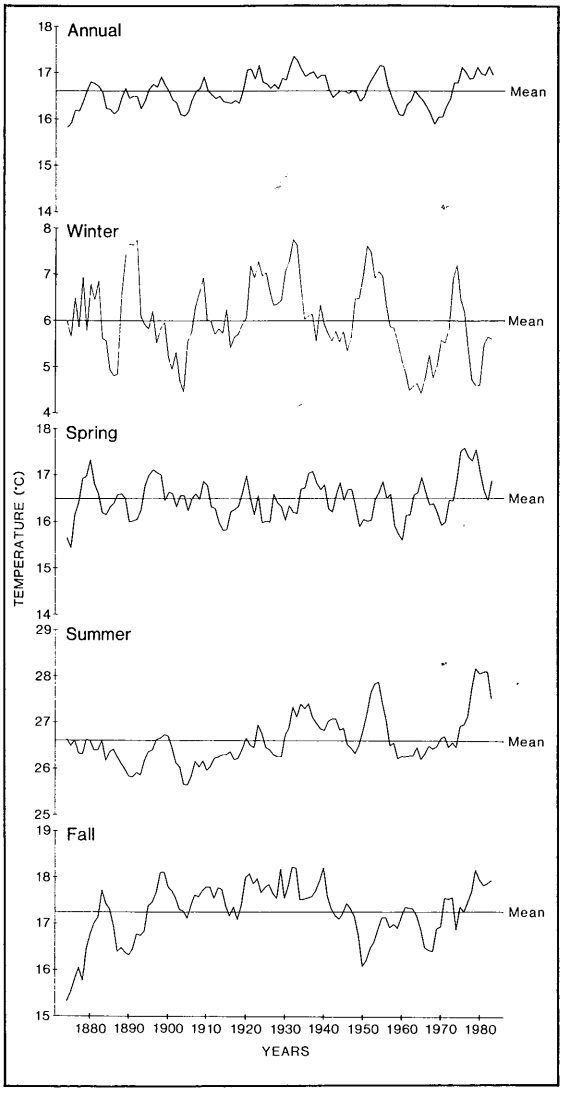

Figure 1. Five-year moving average temperatures for Memphis, Tennessee, 1872-1985.

apparent. Except for a short term warming during the mid 1970s, winter temperatures have remained cooler than normal since the late 1950s. In a more detailed study of winter temperatures for Tennessee, McCabe (1988) found a significant trend of decreasing January temperatures for several locations in Tennessee since the 1950s. Studies in other parts of the southern United States have also suggested a cooling of winter temperatures since the 1950s (van Loon and Williams, 1976, Diaz and Quayle, 1980, Barnett, 1983, Skeeter, 1985, Suckling, 1986).

The five-year moving average spring temperatures do not show any clear temperature patterns. It is interesting, however, that there does appear to be a warmer than normal period from the early 1970s through the 1980s, which agrees with the pattern for mean annual temperatures. The long term mean spring temperature is 16.5° C with a standard deviation of 1° C.

The long term mean summer temperature is 26.6° C. The

summer data produced the lowest standard deviation of all of the seasons, with a value of .9° C. The five-year moving average summer temperatures contain several interesting patterns. A generally cooler than normal period is apparent during the late 1870s to near 1930, which was also apparent in the mean annual temperature data. Except for a few slightly cooler than normal years in the late 1940s, 1950s and early 1960s, summer temperatures have been higher than normal from the late 1920s to the present.

Fall temperatures produced a long term mean of 17.3° C and a standard deviation of 1.1° C. The five-year moving average fall temperatures also indicate an interesting pattern. For example, the 1870s, 1880s and early 1890s were primarily associated with cooler than normal fall temperatures. From the mid 1890s to the 1930s fall temperatures were above normal except for a few cases. During the 1940s fall temperatures dropped below normal and generally remained below normal until the mid 1970s. Since the mid 1970s, fall temperatures have been above normal. The patterns of fall temperatures seem to support the patterns found for mean annual temperatures, but are much more extreme.

Long Term Trends

To further outline temperature trends, linear regressions were performed on the five-year moving averages of both the mean annual and seasonal data to determine if any long term trends exist. A student's t-test was used to determine if the trends were significant.

Linear trend analysis of five-year moving average mean annual temperatures indicates a general increase of temperatures over the data period (slope = .003) that is significant at the .01 level. In contrast, the trend of winter temperatures indicates a decline (slope = -.005), but is only significant at the .10 level. The spring data suggest a trend of increasing temperatures, however the trend is weak (slope = .002) and barely significant at the .10 level. The summer data indicate a strong trend of increasing temperatures over the data period (slope = .009) and is highly significant at the .001 level. Similarly, the trend for fall temperatures also indicates warming temperatures (slope = .005), and is significant at the .05 level.

To account for potential heterogeneities in the data record around 1941, when the official reporting station was relocated, the data record was divided into two segments, 1872-1940 and 1941-1985. In this way the two segments represent two relatively homogeneous records, with reference to station location. Linear trend analysis of the separate periods on a mean annual and seasonal basis supports the findings of the analysis of the entire record. Spring, summer, fall and mean annual temperatures indicate warming trends for both segments of the record. Winter temperatures suggest a warming trend prior to 1941 and a significant cooling trend after 1941.

Discussion and Conclusion

The temperature trends in Memphis, Tennessee since 1872 indicate a cooler than normal period during the late 1800s, changing to a warmer than normal period through the 1920s and 1930s. A cooling began during the 1940s with a subsequent warming since the mid 1970s. These trends seem to be in accordance with trends found for the Northern Hemisphere (Diaz and Quayle, 1980, Agee, 1982).

The data for Memphis also indicate a general long term trend of increasing temperatures over the study period. The only exception being the weak declining trend of winter temperatures.

The declining trend found for winter temperatures is the result of a recent decline of winter temperatures since the 1950s, that is primarily a function of increased meridional flow over the United States since the 1950s. The increased meridional flow has generally been associated with a trough over the southeastern United States which has permitted cold polar air to push further to the south during the winter months (Kalnicky, 1974, Dickson and Namias, 1976, Angell and Korshover, 1977). In contrast, during 1974 a warmer than normal winter was experienced, this was the result of a shift of the trough and ridge pattern over the United States to the west. The result being a decrease of polar air intrusions into the southeastern United States and increased influxes of maritime tropical air (Wagner, 1975). The long term trend of winter temperatures thus results in a decline due to several cooler than normal winters since the 1950s.

The general temperature trend for Memphis, however, is a warming since the 1800s. Warming trends are found for spring, summer, fall and mean annual temperatures, as well as for winter temperatures before the late 1930s. These trends are interesting with respect to theories concerning global warming as a result of increasing amounts of "greenhouse" gases in the atmosphere, such as carbon dioxide (Hansen et al., 1981, Dickinson and Cicerone, 1986). The temperature trends found for the Memphis data appear to support a warming trend.

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