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An Investigation of Historical Temperature and Precipitation Data at Climate Benchmark Stations in Illinois [redacted]

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Stanley A. Changnon, Derek Winstanley, and Kenneth E. Kunkel

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Abstract: Twelve weather stations in Illinois with long records (1901-1995) of temperature and precipitation were assessed as possible benchmark stations with quality data for use in studies of past fluctuations of climate and for monitoring future changes in climate. Various tests indicate that 11 stations had quality records. Temperatures in Illinois increased 2.5° F from 1900 to the 1930s, remained high until the late 1950s, and decreased by 2.5° F since. Precipitation since 1900 has varied regionally, increasing in the north and west, and remaining unchanged in the south. The number of droughts has not changed over time, but the number of days with 2-inch and 3-inch rainfall has increased over the past 30 years while the number of days with 4-inch rainfall has not changed. Climate changes in Illinois are discussed in the context of global climate change.

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Indexing Terms: Temperature, Illinois, climatology, weather, weather data, precipitation, climatic data, global climate change.

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ABSTRACT

A central question surrounding the issue of potential global climate change due to natural and/or anthropogenic influences is the detection of a change in the climate. To this end, an in-depth study was made of historical climatological data at Illinois weather stations with long-term quality records that can be used in the future to monitor the climate and to assess the behavior of Illinois; climatological conditions over the past 95 years, 1901-1995. Based on data from quality long-term stations located in relatively small unchanging communities and no missing historical data, 12 candidate benchmark weather stations were selected to represent the north-south and west-east variations in climate across Illinois.

Historical temperature and precipitation data for these 12 candidate benchmark stations were subjected to a series of tests to ascertain whether the records were of sufficiently high quality to be used in sensitive analyses of past or future shifts in climatological conditions. Three tests applied to the temperature data revealed that six stations had high quality records since 1901: Aledo, Carlinville, Hoopeston, Rushville, Sparta, and Windsor. Adjustments could be made for five of the other stations with discrete, often short periods of questionable data, but the data for Marengo (northern Illinois) were so questionable that it was eliminated as a benchmark station for temperatures. Three tests were also applied to the historical precipitation data to investigate the quality of these records, and these tests revealed that the data for Mt. Carroll (northwestern Illinois) were of poor quality, and the data for two other stations, Sparta and Carlinville, were suspect.

Temperature and precipitation data of quality were then analyzed to assess fluctuations over the past 95 years. Annual maximum and annual minimum temperatures revealed that highest values occurred in the 1930s and the 1950s and the lowest values during 1960-1985. The linear 95-year trends of temperature at all stations showed slight decreases with time, from 0.001 ° F to 0.0009° F per year. The difference between the average maximum and average minimum temperatures at the benchmark stations has changed with time, becoming less during the last 25 years by 1.5 ° F. This could be due to increased cloudiness during the last 30 years. Analysis of the seasonal temperature data revealed that the trends in spring were essentially unchanging from 1901-1995, but those for summer, fall, and winter indicated slight downward trends over the 95-year period.

Annual precipitation values at the quality benchmark stations showed the highest values in the 1940s and 1970s. Long-term 95-year linear trends of annual precipitation were unchanging at Illinois stations in the southern half of the state. Stations in east-central Illinois showed slight upward trends in annual values. These same trends were found in the summer precipitation, but Illinois stations had unchanging long-term trends during winter. The incidence of heavy rain events, measured as 2 inches and 3 inches per day, showed an increase of 10-15 percent during the past 30 years, reaching a peak in 1981-1985. However, the number of 4-inch or heavier rains peaked in the 1901-1920 period. Droughts in Illinois showed no trend with time.

Annual temperatures in Illinois were compared with global mean values and those that result from modeling the effects of additional greenhouse gases and sulfates in the atmosphere. This revealed that Illinois values increased by about 4.0° F from the mid-nineteenth century to the 1930s, and global values increased by about 1.0 ° F. Since the 1930s, temperatures in Illinois have decreased, whereas global values, and those estimated from anthropogenic influences, have continually increased over the past few decades. The increase in Illinois temperatures during the 1860-1940 period coincides with human land use changes, such as drainage of the prairies for farming and extensive urban-industrial development, and these could have had some effects on regional climate. However, natural factors influencing the climate were likely fluctuating too, making it difficult to ascertain the causes of past fluctuations. Uncertainty over causes of climate fluctuations-the mix of natural and anthropogenic factors-makes it difficult to predict future conditions.

INTRODUCTION

For 20 years there has been growing scientific speculation about the potential for a major shift in the global climate due to anthropogenic effects. These include possible changes due to ever increasing releases of trace gases into the atmosphere, which would alter the earth's greenhouse effect, and the effect of particulates (aerosols). Most scientific studies of the potential influence of an altered greenhouse have suggested a warming in the global mean temperature, ranging from 3 ° F to 8° F. Studies of aerosol effects suggest a strong surface cooling influence in regions such as Illinois where fossil fuel burning is relatively large.

Worldwide concern over such possible global environmental impacts has led to extensive studies attempting to ascertain the potential dimensions of a future climate change at global, continental, and regional scales. Global climate change models (GCMs) employed to simulate the effects of an enhanced greenhouse effect have produced different regional results for the central United States. These modeling experiments all concluded that there would be considerable warming, particularly in the colder half-year, and a shift in precipitation, with some models indicating more annual precipitation and others less than today's average (Changnon and Wendland, 1994).

Such potential changes in the climate of Illinois were recognized many years ago as having serious effects on Illinois' water resources (Water Plan Task Force, 1982). Further studies of potential impacts of climate change addressed other weather-sensitive arenas such as agriculture, water management, and energy (Changnon and Wendland, 1994).

The predictions for a major change in the global climate over the next 100 years have not been without serious scientific debate. The GCM experiments involved major assumptions, and scientists have challenged the models and the degree of warming predicted as a result of an enhanced greenhouse effect (OTA, 1993). The scientific uncertainties involved in this issue include these two key questions: 1) Has the climate begun to change? and 2) How will we know when the predicted climate change actually begins? These are among the central questions surrounding the global change issue, and some scientists have offered indices that they believe to be useful indicators of a shift in climate due to an enhanced greenhouse effect (Karl et al., 1995).

In 1991, the Illinois General Assembly identified the Illinois State Water Survey as the state's center for scientific research and information related to global climate change. Consequently, a program of research was launched, which included the issue of "monitoring and detection" of climate change (Changnon, 1991). This helped lead to a study of the 1901-1994 records of hail in Illinois to assess historical fluctuations as a basis for detecting past and potential future shifts in climate (Changnon, 1995). The results of the hail analysis indicated that the frequency of hail in Illinois had been in a general decline since the mid-1960s.

The Illinois General Assembly also established the Illinois Task Force on Global Climate Change in 1991. Its assignment was to monitor national policy, and to study and make recommendations for state policies and programs regarding climate change (Illinois House of

Representatives, 1991). The Task Force identified the need to detect the onset of climate change in Illinois as one of the key state issues (Global Climate Change Task Force, 1994) and called for the identification of four or more existing weather stations in Illinois, each maintained by the National Weather Service, as "climate change benchmark stations." These stations, to be distributed around the state, would each have long, quality historical records of at least 95 years in length as of 1995. Their selection would provide the basis for biannual scientific assessments of changes in temperature or precipitation that could signify a departure from past conditions of this century.

The ensuing text first describes the selection and testing of the records of 12 candidate stations. Potential adjustments were identified in portions of the historical record for selected stations. Results of analyses of the historical fluctuations of the temperature and precipitation data from the stations selected as benchmarks are presented. Finally, the relationship of Illinois conditions to those projected from global atmospheric changes due to human effects is explored. Natural and anthropogenic factors influencing climate are also assessed.

Acknowledgments

Paul Dailey of the National Weather Service assisted in the selection of the 12 benchmark stations. Robert Scott provided considerable assistance in performing various data analyses and Floyd Huff provided useful commentary on the manuscript. Wayne Wendland assisted in the statewide data analysis. Audrey Bryan assembled the station histories. Wayne Wendland provided statewide data. Jean Dennison and Joyce Fringer helped assemble and type the text. Eva Kingston edited the manuscript. Linda Hascall prepared the graphics.

SELECTION OF BENCHMARK STATIONS

Scientists at the Illinois State Water Survey assigned to the Task Force worked in conjunction with National Weather Service scientists to identify Illinois weather stations suitable for use as benchmark stations. Using several criteria, 12 stations were selected as potential benchmark stations. First, each station had to have at least 95 years or more of complete temperature and precipitation records as of 1995. Second, each station had to be located throughout this period in a small community where the size of the community would not have created a substantial "heat island" that would create local influences on temperatures over time. Third, the selected stations had to be representative of the various climatic regions of the state. Fourth, the historical records of these stations had to be tested and examined for homogeneity in their 1901-1995 records to determine if they were suitable candidates for climate monitoring.

Table 1 indicates the length of record and other relevant information for each of 12 candidate benchmark stations, and figure 1 shows their locations. Climatologists at the Illinois State Water Survey have performed an extensive assessment of the historical data of these 12 candidate stations, and this report describes their findings. Appendix A presents the histories of these 12 stations.

Table 1. Candidate Benchmark Stations

Location	*Years of record*	1990 *population*	*Current weather observer*
Aledo	95	3,600	Donald Korns
Anna	101	4,800	J. Bon Hartline
Carlinville	103	5,400	Jack Campbell
Hoopeston	95	5,800	John Mushrush
Marengo	140	4,700	Jerome Hoch
Minonk	101	1,980	Robert Weakly
ML Carroll	105	1,725	Terry Bailsman
McLeansboro	110	2,600	Jennilyn Posteltheweight
Rushville	101	3,230	James Farrar
Sparta	108	4,850	Radio Station WHCO
Walnut	102	1,500	Jim Larkin
Windsor	95	770	Orris A. Seng

Figure 1. The 12 candidate benchmark weather stations in Illinois.

changes, but 30- 40 years to detect changes in the precipitation. This finding reflects the greater temporal variability in precipitation values.

A significant question that must be addressed in assessing the quality of historical records is the various artificial effects on temperature and precipitation values. In considering temperature data measured by maximum and minimum thermometers read and reset once each day, there are three principal ways these values can be changed: changing the instrument, relocating the weather station, or shifting the time of day at which measurements are taken.

The same standard glass thermometers have been in use since records began in the 1890s. However, in the last few years, the National Weather Service has been shifting to the use of new MMT (Max-Min Temperature) measuring units that allow the observer to measure the values from inside rather than actually going outdoors to the weather shelter. Installation of MMT devices has been found to cause systematic changes in the values of maximum and minimum temperatures. It is also possible that a liquid-in-glass thermometer could incorrectly measure conditions if a bubble in the internal liquid went undetected or was not changed over a period of years.

A weather station is usually relocated when a new observer takes over the station observations. The historical records of these 12 benchmark stations show that most of the station moves were over short distances within these small communities, representing moves of only tenths of miles. However, two of the 12 stations underwent moves of several miles once during their historical records. Shifting the site from a rural location into even a small community could have an influence on the temperature values.

Most cooperative substations since 1890 have made their daily measurements of temperature in the late afternoon, generally between 5 and 7 p.m. A shift in observation time to the a.m. hours (for example, 7 a.m. or 8 a.m.) can affect the temperature values because these times are close to the normal time of occurrence of the daily high and low temperatures. High daily values usually occur in the late afternoon and the minimum daily values usually occur in the morning, the time when a.m. observations are taken. As Karl et al. (1986) have shown, the net effect is that the annual mean temperature at a station with morning observations is typically 1.8° F lower than the mean temperature based on data collected in the afternoon.

Station relocations can also affect precipitation records. Surrounding structures and the environment have a significant influence on the amount of precipitation caught in a standard raingage of the National Weather Service. High structures, trees, and dense bushes near the raingage reduce the wind flow over the raingage, and this leads to a greater catch of rain and snow. Such exposure differences can account for 5-15 percent differences in the amount of precipitation during a year (Kurtyka, 1953). Instrument problems also can occur, such as a raingage that develops a small leak that goes undetected for a period of years. Changes in time of observations do not influence precipitation records, but as noted, moves of stations that bring on either more or less sheltering of the raingage can influence the amount of catch.

TESTING OF TEMPERATURE DATA

The historical 1901-1995 temperature records of the 12 benchmark stations were subjected to three types of tests to help determine their quality and homogeneity over time. The first test was comparative and based on differences in average values. This involved the compilation of nine-year moving averages of the mean, maximum, and minimum temperatures for the 12 stations, and this was done for annual and seasonal data. The values of a candidate station under test were compared with two or three nearby benchmark stations to determine odd values, which were recorded along with the general magnitude of the differences.

A second form of test was adopted from hydrology and consisted of the use of the "double mass curve analysis" in which the annual temperature values of each station are summed (1901 values added to 1902 values, and 1903 values added to sum of 1901-1902 values, etc.). These summed values over the 95 years of a candidate station are plotted on a graph along with the summed values of an adjacent benchmark station. If the values of both stations correlate perfectly over time, the curve of their combined accumulative temperature values will form a straight line from 1901-1995, as shown in figure 2a for Rushville and Carlinville. If a change in temperature occurred at either station in a given year, leading to cooler or warmer values relative to those of the past, the angle of the line will change, allowing detection of the year or years when the change occurred. At certain stations there were clear shifts in the base curve, as illustrated in figure 2b for Marengo and Aledo. The dates of these shifts, which can usually be determined to the nearest year or two, were compared with dates of observer changes, changes in observation times, or instrumentation changes at each of the two stations being compared. In the case of Aledo vs. Marengo (figure 2b), the major change found in 1981 was attributable to the shift in observation time from the afternoon to the morning at Marengo. This shift produced lower temperatures at Marengo relative to those of the past and to those at Aledo, and thus a shift in their double mass curve.

The third test was based on a statistical procedure derived by Easterling and Peterson (1995). This statistical test incorporates the historical data of the test station against data from up to 100 stations in the surrounding region. The test identifies years of "statistical discontinuities," and it further calculates the amount of change in temperature that would be required in the years prior to the discontinuity (and back to 1901) to adjust for it. The results of this analysis will be discussed further in the following text.

Comparative Differences Testing

The stations compared by measuring relative differences, based on annual average temperature values, are shown below. The stations selected for each candidate station were those nearest to the candidate. For example, temperature values at Walnut and Marengo were each compared with the values at Mt. Carroll.

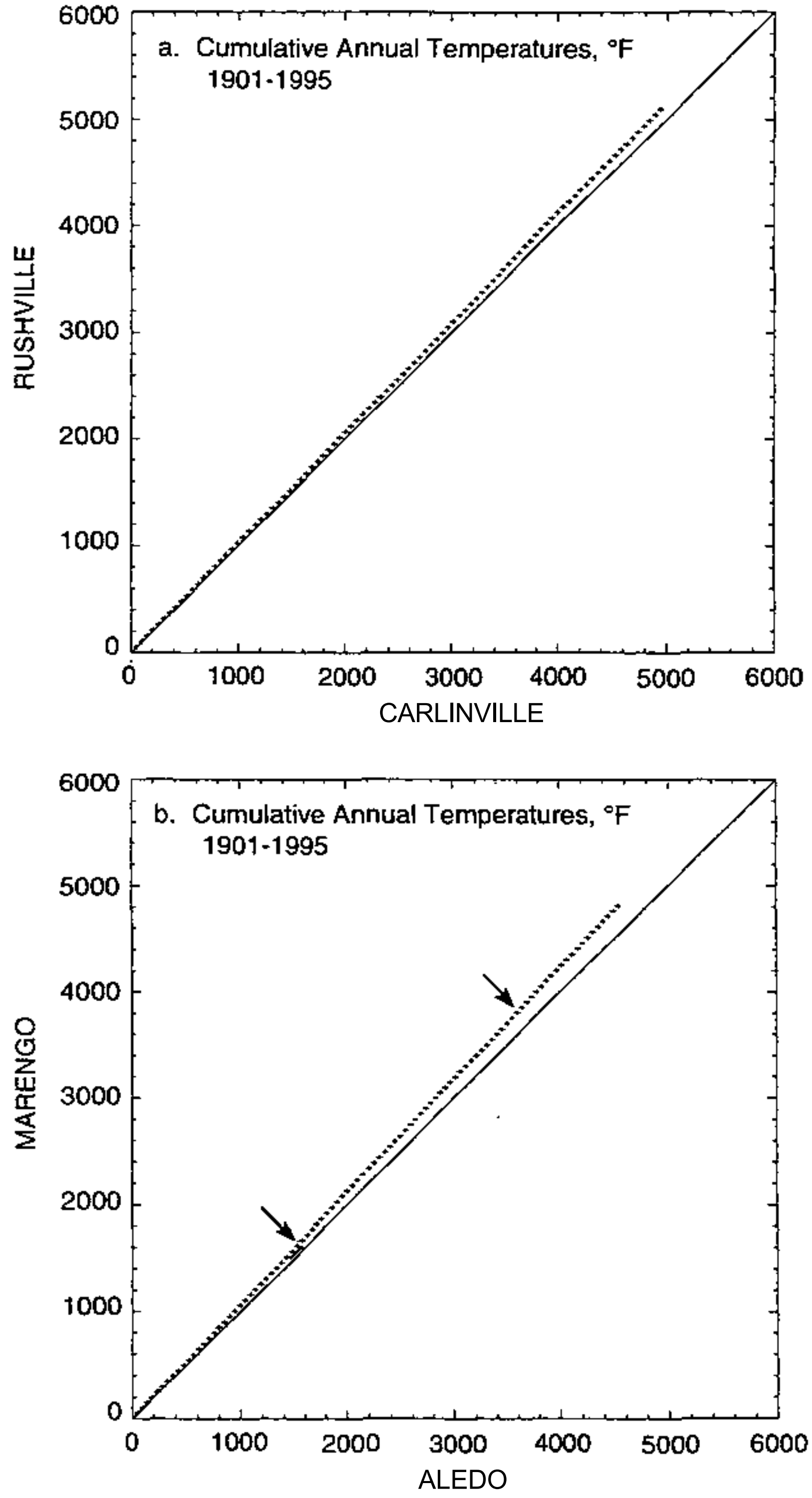


Figure 2. Double mass curves comparing 1901-1995 annual temperatures at two pairs of benchmark stations: a) Rushville and Carlinville, and b) Marengo and Aledo. The first-year values of each station (1901) are plotted in the lower left corner, and each dot represents a year, increasing towards 1995 in the upper right corner of each graph.

Candidate	*Stations compared with candidate station*
Aledo	Minonk, Rushville, and Walnut
Mt. Carroll	Walnut, Marengo
Marengo	Mt. Carroll, Walnut, Minonk
Walnut	Aledo, Minonk, and Marengo
Minonk	Hoopeston, Walnut, Aledo
Hoopeston	Minonk, Windsor, Rushville
Rushville	Carlinville, Minonk, Aledo
Carlinville	Rushville, Windsor, Sparta
Windsor	Hoopeston, Carlinville, McLeansboro
Sparta	McLeansboro, Anna, Carlinville
McLeansboro	Sparta, Anna, Windsor
Anna	Sparta and McLeansboro

Appendix B lists results of the comparisons for each station.

Examination of the comparisons for the 12 stations led to the following conclusions about temperature values for each station.

- Marengo data appear questionable because 1950-1970 values are too warm.
- Mt. Carroll data appear questionable because values are relatively cool in 1900-1915, and again from the 1970s until 1995.
- Walnut becomes relatively cooler during the 1960s, a trend which continues.
- Aledo has a satisfactory record.
- Minonk gets cooler in the late 1970s.
- Hoopeston has a satisfactory record.
- Rushville has a satisfactory record.
- Carlinville has a satisfactory record.
- Windsor has a satisfactory record.
- Sparta has a satisfactory record.
- Anna is questionably warmer during 1901-1925, but satisfactory thereafter.
- McLeansboro values are too low after 1970.

Double Mass Curve Test

The test using double mass curves was based on a series of 12 comparisons (one for each station). Appendix C describes each test for each pair of stations and the findings.

Analysis of the findings for the 12 double mass curve tests suggests consistency problems exist in the data at six stations. The causes of the problems at the six stations are as follows.

- Marengo: observation time change and a station move in 1981
- Mt. Carroll: a station move in 1915
- Walnut: observation time change in 1981
- Minonk: observation time change in 1976
- McLeansboro: observation time change in 1973
- Anna: station relocation during 1901-1925

Statistical Homogeneity Test

The time series of the 12 candidate stations were analyzed for their homogeneity in a statistical manner described by Easterling and Peterson (1995). Output from the homogeneity test program provides: 1) the year of a supposed discontinuity, 2) the magnitude of the discontinuity, and 3) the years used in the comparison between the candidate and reference series. The homogeneity program compares the time series of a candidate station to the series of many (perhaps 100) sites surrounding the station. In this manner, changes at each candidate site were flagged. The program was structured to assume that the most recent years of data are "correct". Changes were computed and applied to earlier data that did not match the current reference series. For example, a discontinuity was identified at Aledo in 1990. This was based on a comparison of Aledo's temperatures to a subsection of the reference series from 1981-1995, a period selected subsequent to the next prior discontinuity in 1981. The difference between the Aledo values and the reference data series was -1.81 ° F. Thus, the analytical method calculates that for all years from 1901-1990, the raw values of annual mean temperature are 1.81 ° F too high and therefore should be lowered by this amount to more closely match the reference time series. Similarly, the discontinuity in 1981 of -0.49 ° F was based on a comparison with the reference series data from 1968-1990. The technique computed an adjustment for the Aledo time series of -0.49 ° F for the period 1901 to 1981, an alteration in "addition" to the -1.81 ° F adjustment described above. In a similar fashion, as each antecedent point of discontinuity is determined, the computed adjustment factor becomes cumulative backwards in time. This produces a total adjustment of -1.12° F (the sum of all adjustment factors at Aledo) for the years prior to the earliest discontinuity (1901-1911).

Station histories were checked for the dates of station moves, time-of-observation changes, and instrument changes, since such alterations can cause changes in the long-term temperature records. This formed a basis for assessing the discontinuities.

Past examination of computed discontinuities revealed they have not always flagged the year of an actual site alteration (Easterling and Peterson, 1995). That is, there is enough noise in a site's data record that the computations may not precisely identify the year of change. Easterling and Peterson (1995) accepted a match of a computed discontinuity and a site alteration *if* their dates were as much as two years apart. The benchmark investigation also used a two-year window for agreement.

Appendix D lists the results of the tests for homogeneity at each station. It was concluded that some changes in a station should be followed by certain changes in subsequent temperature values. The following relationships were considered in interpreting the results for each station.

1) A time-of-observation change (from p.m. to a.m., or from p.m. to midnight), should result in lower mean temperatures. Thus, the computed adjustment factors should be negative (and vice versa if a.m. to p.m.).
2) A station move from an urban to a rural site should result in lower mean temperatures. Therefore, the computed adjustment factors should be negative (or vice versa if rural to urban).
3) Installation of MMTs at sites has been widely reported as lowering mean values. Therefore, computed adjustment factors should be negative.

Review of the findings for the 12 stations (Appendix D) reveals that the Easterling and Peterson homogeneity test indicates the values are "off in most years at all 12 stations. However, most discontinuity departures are less than 1 ° F.

Over the 1901-1995 period the number of "discontinuous" periods found at the 12 stations varied from three to eight. However, 11 stations had six, seven, or eight discrete periods of changed values.

The range of indicated departures (based on the highest and lowest values) is listed below:

Station	*Negative ° F*	*Positive ° F*
Aledo	-1.81	+1.03
Anna	-1.55	+1.87
Carlinville	-1.30	+1.04
Hoopeston	-0.90	+1.69
Marengo	-1.52	+0.98
McLeansboro	-1.65	+1.35
Minonk	-1.06	+1.79
ML Carroll	-1.03	+1.45
Rushville	-1.11	+1.29
Sparta	-0.85	+1.34
Walnut	-1.96	+1.05
Windsor	-1.31	+0.83
Maximum	-1.96	+1.87

Ten stations had negative changes greater than 1 ° F, and six stations had negative changes greater than 1.3° F. Ten stations had positive changes greater than 1 ° F.

Based on station histories, the presence of discontinuities when known changes occurred at the 12 stations was assessed. The results were as follows:

Observation Time Changes

- 3 stations had no observation time changes
- 4 stations had a change *and* a discontinuity (magnitude of these changes: -1.52° F, -1.03° F, -0.98° F, and -0.85° F)
- 5 stations had observation time changes and no discontinuity

Station Relocations

- 10 stations had no discontinuities with any station relocations
- 2 stations had discontinuities (Anna had -1.55° F and +1.27° F with relocations, and Marengo had +1.35° F)

Installation of MMT Devices

- 6 stations had no MMT installed
- 4 stations had an MMT installed but no discontinuity
- 2 stations had an MMT installed and a discontinuity (magnitude of these changes: -1.38° F, and -0.44° F)

This analysis suggests the Easterling and Peterson (1995) discontinuity analysis did not detect the effects of two-thirds of the six MMT installations and did not detect changes due to station moves at 10 of the 12 stations. The technique detected only four of nine major changes in observation time. Further, the discontinuities with changes in observation times were relatively small. Numerous other discontinuities listed for each station appear due 1) to the statistical approach inherent in the method ("noise"), or 2) other unknown changes (such as a broken thermometer or some form of systematic observer error).

The lack of a strong relationship between factors known to affect temperatures—station moves, changes in observation times, and MMT installations—and any statistical discontinuities make the technique appear to be a questionable procedure to use to adjust the historical data. The magnitudes of the discontinuity associated with known shifts was often small, and less than the larger discontinuity values at most stations that could not be related to a recorded change at the station. However, it might be appropriate to adjust for the observation-time discontinuities at Marengo, McLeansboro, and Mt. Carroll. There was also a station move discontinuity of +1.35 ° F at Marengo, and Anna had two moves causing -1.55° F and +1.27° F shifts.

Summary

The results of the three tests of the quality of the temperature data revealed two general findings. First, the findings of the statistical homogeneity tests were not considered convincing enough to adjust the station values based on them. The analysis produced questionable results on many unsubstantiated discontinuities and did not detect several major changes in station sites, observation times, and equipment changes. Second, the test of comparative differences and double mass test yielded similar results: both indicated that the temperature data were of quality at six stations: Aledo, Carlinville, Hoopeston, Rushville, Sparta, and Windsor. As shown in figure 1, these stations are well distributed across Illinois.

The conclusion is that the data of these six stations can be used for monitoring climate change. Temperature data at Marengo exhibited several shifts, and Marengo does not appear suitable for use in monitoring past and future temperature changes. It was concluded that adjustments of the questionable data periods at five other candidate stations (Anna, Minonk, Mt. Carroll, McLeansboro, and Walnut) would be necessary if they are to be used in climate evaluation analyses. These adjustments could be made using values allowing for explainable shifts in the observed data (Karl et al., 1986). For example, the 1901-1925 data at Anna were adjusted to allow for the effect of a major site change in 1925. The data at Anna for 1901-1925 were adjusted based on relationship differences determined from Sparta and McLeansboro data. Temperatures for the 1901-1915 period at Mt. Carroll were too low (due to a different location), and the annual adjustment values were determined using comparisons with data from Aledo and Walnut. Three adjustments resulted from relatively recent shifts in observation times from p.m. to a.m. at McLeansboro (1973), Minonk (1976), and Walnut (1981). Table 2 lists the adjusted temperature values recommended for the five stations. These adjustments create synthetic 95-year records that can be used in climate monitoring, given recognition of the adjustments to portions of the record.

To illustrate the effects of applying the homogeneity adjustment technique, the actual decadal values of mean annual temperatures at Rushville are shown in table 2 along with those derived from the adjustment. These show that the adjusted values are lower by 0.4° - 0.7° F in 1951-1980, but are higher by 0.6° - 1.3° F in the decades of 1901-1950. They differ markedly except in 1981-1990 when the technique assumes the local records are correct. However, the Rushville values, on the basis of the tests of comparative differences and double mass curves, were assessed as homogeneous and without need for adjustment.

Table 2. Adjustments to Mean Annual Temperature Values

Adjustments based on comparisons of differences with surrounding stations

Station	*Period of adjustment*	*Amount of adjustment to original value, ° F*
Anna	1901-1925	-1.2
McLeansboro	1973-1995	+1.0
Mt. Carroll	1901-1915	+0.9
Minonk	1976-1995	+1.1
Walnut	1981-1995	+1.5

Adjustments based on the homogeneity method applied at Rushville

Period	*Temperature, ° F*	
	Actual	*Adjusted*
1901-1910	52.2	53.5
1911-1920	52.5	53.3
1921-1930	53.1	53.7
1931-1940	53.7	54.5
1941-1950	53.0	53.4
1951-1960	53.3	52.9
1961-1970	51.8	51.1
1971-1980	51.7	51.2
1981-1990	52.6	52.6

TESTING OF PRECIPITATION DATA

Assessment of the historical precipitation data was done to detect possible inhomogeneities due to station relocations (and possible changes in raingage exposure) or to gage measurement problems. Comparison of a station's values with those of other benchmark stations has limitations because of the potential for major multi-year differences due to normal natural spatial variability in convective rainfall in Illinois. That is, differences in values between pairs of stations located 50 to 100 miles apart may be due to rainfall differences or to station sampling problems.

Evaluation of the precipitation data for the 12 stations involved three different assessments of the values to develop a general evaluation. The first analysis assessed whether the time distribution of precipitation related reasonably well with time distributions at nearby stations, assuming that major prolonged wet and dry periods would extend over large parts of Illinois. At each station, the three periods of peak precipitation and three periods of lowest precipitation were identified and plotted on maps to ascertain regional homogeneity. That is, if three of the four benchmark stations in southern Illinois all showed a peak in precipitation during the 1940s and one station did not, this was noted and the station was further investigated. Such differences were also compared with observer changes to seek possible explanations.

Figure 3 shows the maps for stations with high rainfall values in the 1940s and for stations with major low values in the 1950s. Examination reveals that the values at Mt. Carroll appear to be at odds with those at all surrounding stations. A precipitation peak in the 1940s occurred at stations in southwestern Illinois and not at northern Illinois stations except at Mt. Carroll. Similarly in the 1950s, stations across central Illinois exhibited a major low in precipitation, but all northern Illinois stations, except for Mt. Carroll, did not experience this low precipitation period. This regional analysis of major high and low precipitation periods suggested that the Mt. Carroll precipitation record, at least in mid-century, was questionable.

A second analysis of the precipitation data involved intercomparison of the 9-year moving annual precipitation values of adjacent stations in a fashion recommended by Karl and Williams (1987). Figure 4 shows these curves for Aledo and Mt. Carroll. Ratios of values were computed and used to detect systematic differences considered to be indicative of questionable data. This comparative analysis found that the Mt. Carroll values over time showed a systematic shift of precipitation with major oscillations around the mean—a distribution unlike that of any other nearby station.

A third analysis of the precipitation data of the 12 stations involved a determination of those years when major shifts in the annual precipitation occurred and led to $\geq$ 10 years of much higher or much lower precipitation. The year or years of these shifts were then compared with years when observer changes occurred, suggesting events with the potential to change precipitation site sampling. The resulting list of precipitation shifts and observer changes, if they occurred at or near the time of the precipitation shift, was then examined with respect to the previously determined periods of extremely high or low precipitation. For example, Anna exhibited major shifts in its annual

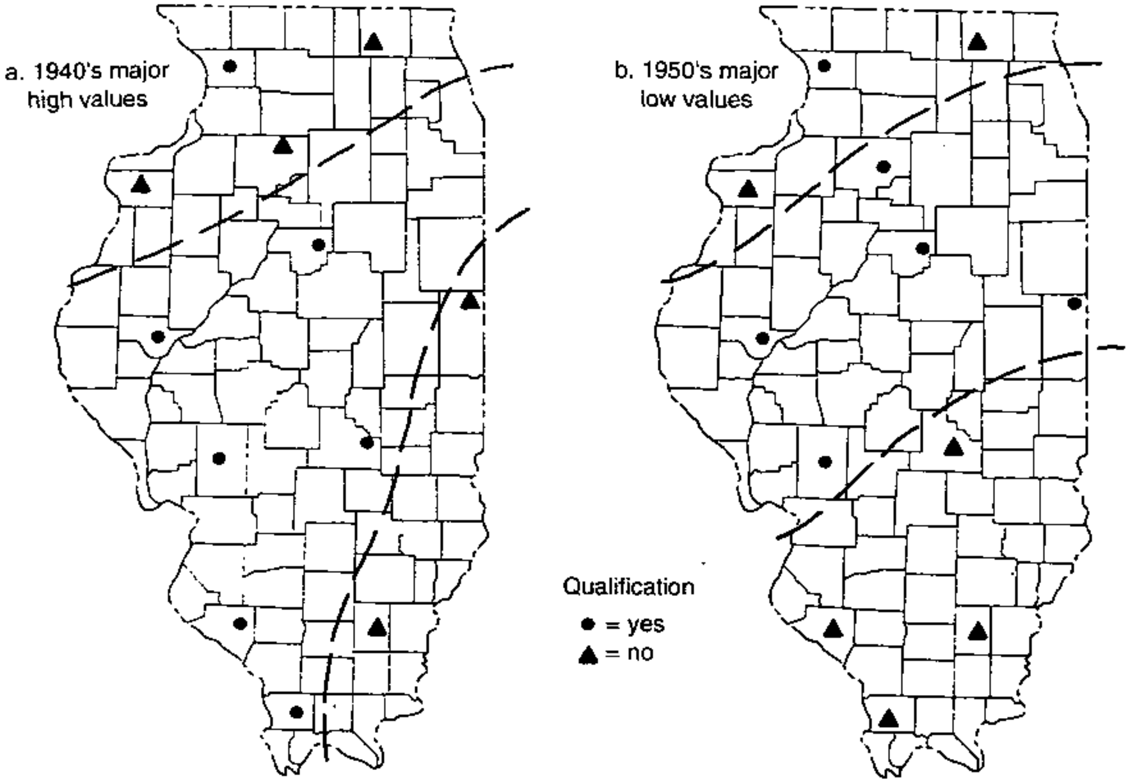


Figure 3. The incidence of high and low precipitation values in two periods at the 12 benchmark stations. If a station had high values in the 1940s, or low values in the 1950s, it qualified. Dashed lines indicate areas where stations qualify. Anomalies such as at Mt. Carroll (extreme northwestern Illinois) can be easily detected.

precipitation in 1909-1910, during the mid-1930s, and in 1950-1951. An observer change occurred there in 1938 (but not in 1909-1910 or 1950-1951), an event that could explain the 1930s shift in precipitation values. The shift at Anna in the 1930s occurred with a widespread low precipitation period (1930s). Hence, it was concluded that these aberrant events at Anna were not associated with observer changes, but rather were a result of natural shifts in local precipitation. Three stations exhibited sudden shifts in precipitation that 1) were associated with an observer change and 2) were not associated with a regional shift in precipitation of the type shown at the individual station. There was a major decrease in precipitation at Mt. Carroll during the 1950s (observer change in 1954), a decrease at Carlinville in the mid-1940s (observer change in 1946), and a decrease in precipitation beginning in the early 1920s at Sparta (observer change in 1923).

In summary, it was concluded that the Mt. Carroll precipitation data were not suitable for long-term monitoring of precipitation fluctuations. Further, the data at Carlinville and Sparta are suspect and should be used with caution.

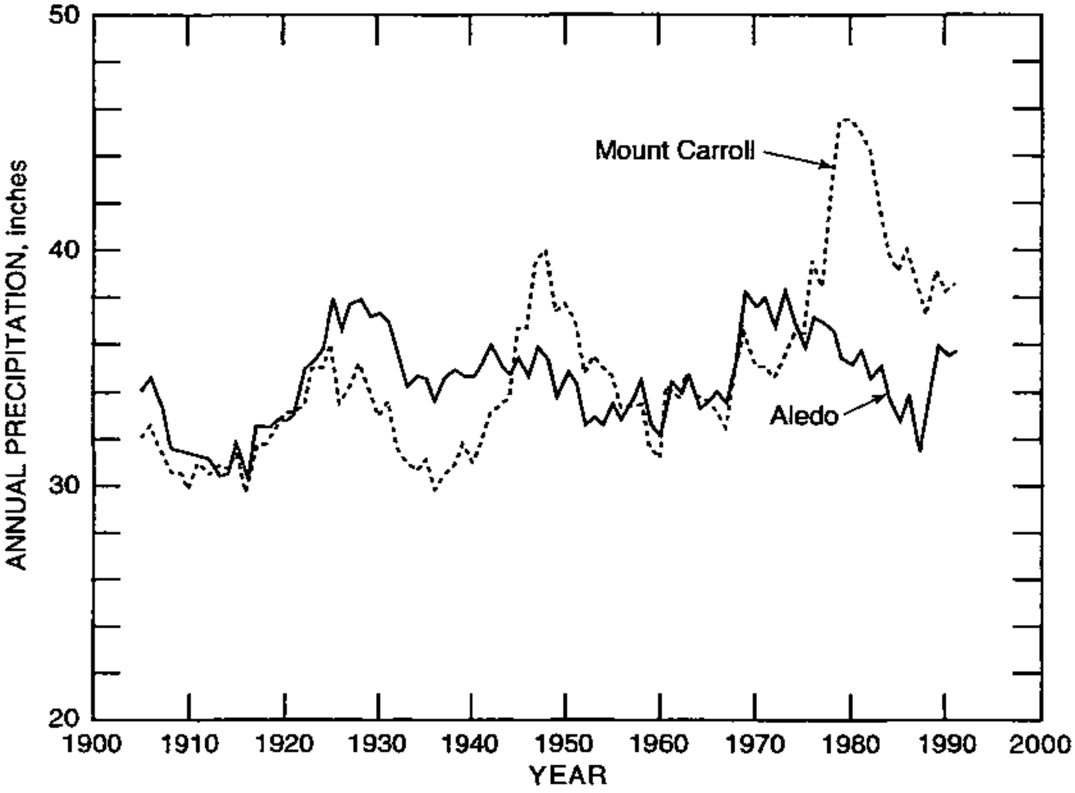


Figure 4. Comparison of annual 1901-1955 precipitation values at Aledo and Mt. Carroll.

FLUCTUATIONS IN HISTORICAL TEMPERATURE DATA

The temperature data from the benchmark stations (Marengo excluded) for 1901-1995 were analyzed in various ways to examine their historical fluctuations as a basis for using these values in assessing the onset of climate change. A key question is: "What temperature values may change?" It could be in the maximum temperatures, the minimum temperatures, or both, and the change could be more profound in certain seasons.

Karl et al. (1995) set forth four indicators of a greenhouse climate response index (GCI) in the United States: the percent of the United States with much above normal minimum temperatures, the percent of the United States with above normal precipitation during the cold season (October-April), the percent of the United States in extreme or severe drought during May-September, and the percent of the United States with a much greater man normal proportion of its precipitation derived from extreme one-day precipitation events (>2 inches). Since Illinois and the Midwest are expected to experience the more extreme effects of climate change (Karl et al., 1991), then it is reasonable to assume that most if not all of Illinois should be a part of the areas experiencing the four GCI indicators.

The present study looked at the temperature and precipitation indicators of Karl et al. (1995), and examined seasonal and annual temperature values as indicators of global warming. Tables 3-5 present the 5-year average values for the annual maximum, annual minimum, and annual mean temperatures for each station.

Table 3.5-Year Mean Values of Annual Maximum Temperature

Period	*ALEDO*	*ANNA*	*CARLN*	HOOPS	MINOK	MCLEN	MTCAR	RSHVL	SPRTA	WLNUT	WNDSR
1901-1905	59.7	68.0	64.9	60.4	60.3	65.6	58.5	61.8	65.7	60.0	62.1
1906-1910	60.3	69.5	65.6	61.6	62.6.	66.1	58.7	62.7	67.3	61.2	64.7
1911-1915	61.1	69.1	66.1	62.2	62.9	67.5	58.7	62.7	67.6	60.4	65.2
1916-1920	61.0	68.0	65.1	62.4	61.8	67.1	58.1	63.2	67.0	60.7	64.0
1921-1925	61.9	69.4	66.3	63.0	62.9	69.3	60.4	64.2	69.2	60.6	65.3
1926-1930	60.9	66.6	65.0	62.2	60.7	68.2	59.1	62.3	68.2	59.9	63.5
1931-1935	62.9	68.6	67.4	64.3	63.0	69.0	60.6	64.9	69.9	62.3	65.1
1936-1940	62.4	68.2	66.5	63.2	62.3	70.1	59.9	63.8	69.1	61.2	64.2
1941-1945	61.4	66.8	65.9	62.3	61.1	69.0	59.9	62.1	68.6	60.7	64.3
1946-1950	61.8	67.5	64.6	62.5	61.7	68.6	59.8	63.8	68.1	61.4	64.4
1951-1955	63.1	69.1	67.0	63.2	62.7	69.4	59.8	65.1	69.8	62.3	65.5
1956-1960	60.5	67.3	65.2	61.7	61.1	67.3	58.3	63.8	67.3	63.7	63.5
1961-1965	61.3	68.0	65.7	61.4	62.0	67.9	59.1	63.8	68.0	60.1	64.4
1966-1970	60.4	66.4	64.2	60.4	61.1	65.7	58.7	62.2	66.0	59.6	63.0
1971-1975	60.8	66.7	64.9	61.1	61.5	66.0	59.4	62.6	67.2	59.7	64.1
1976-1980	60.2	66.3	64.3	60.3	60.4	64.3	56.8	62.4	66.4	59.0	62.8
1981-1985	60.5	67.1	64.2	60.6	59.3	64.9	57.9	62.3	66.4	59.7	63.3
1986-1990	62.3	68.4	64.8	62.5	61.9	66.6	60.0	63.6	68.3	62.2	64.3
1991-1995	59.3	67.2	63.8	61.5	61.2	66.1	58.7	61.2	66.8	58.4	63.6

Table 4.5-Year Mean Values of Annual Minimal Temperature

Period	*ALEDO*	*ANNA*	*CARLN*	HOOPS	MINOK	MCLEN	MTCAR	RSHVL	SPRTA	WLNUT	WNDSR
1901-1905	38.9	45.6	41.5	40.4	37.9	45.3	35.2	41.3	43.9	39.2	40.2
1906-1910	39.9	46.5	42.7	41.5	39.8	45.6	35.5	42.9	45.2	40.5	41.4
1911-1915	40.9	47.5	43.0	41.6	40.7	45.4	36.7	43.8	46.0	40.2	42.4
1916-1920	38.9	47.2	41.6	40.2	39.0	45.1	36.7	41.7	45.0	39.2	40.8
1921-1925	39.9	48.5	43.4	41.6	41.1	45.5	37.7	43.5	46.5	40.7	42.1
1926-1930	39.7	46.8	42.8	40.7	39.4	44.7	36.9	42.4	45.4	40.0	42.3
1931-1935	41.8	48.6	44.6	42.0	41.5	46.2	38.7	43.5	47.2	41.9	44.4
1936-1940	41.1	47.0	43.7	41.3	40.5	45.5	38.2	42.5	46.1	40.8	43.2
1941-1945	40.9	47.4	43.5	41.5	40.1	46.5	38.7	42.9	46.4	41.0	43.2
1946-1950	41.1	46.2	42.6	41.5	40.0	46.7	38.3	42.8	46.2	40.6	42.7
1951-1955	40.3	46.8	43.4	42.4	40.4	46.2	38.9	43.1	47.0	40.8	43.1
1956-1960	38.7	46.7	43.2	41.7	38.9	45.3	38.2	41.2	46.2	39.7	42.4
1961-1965	39.0	46.0	42.7	40.9	38.7	45.2	37.9	41.0	45.8	39.2	41.6
1966-1970	39.4	45.4	41.8	40.8	39.2	45.2	36.8	40.1	44.5	39.2	42.4
1971-1975	40.9	46.9	43.7	42.3	40.3	44.7	37.5	41.3	46.5	40.0	44.2
1976-1980	39.1	45.3	41.8	40.2	37.7	42.5	33.3	40.6	45.0	38.0	41.8
1981-1985	40.7	46.1	43.5	41.7	38.2	44.0	34.0	42.3	46.1	37.5	43.2
1986-1990	41.3	46.8	44.6	42.5	39.5	43.6	33.0	42.4	46.7	38.7	43.8
1991-1995	40.0	47.0	45.0	42.5	39.8	43.3	34.8	41.9	44.9	39.2	44.3

Table 5.5-Year Average Values of Annual Mean Temperature

Period	*ALEDO*	*ANNA*	*CARLN*	HOOPS	MINOR	MCLEN	MTCAR	RSHVL	SPRTA	WLNUT	WNDSR
1901-1905	49.3	56.9	53.2	50.5	49.1	46.9	55.5	51.6	54.9	49.6	51.2
1906-1910	50.1	58.0	54.2	51.6	51.2	47.1	55.8	52.8	56.3	50.9	53.1
1911-1915	51.0	58.3	54.5	51.9	50.9	47.7	56.5	52.6	56.7	50.3	53.8
1916-1920	50.0	57.6	53.4	51.3	50.4	47.9	56.1	52.5	56.0	49.3	52.4
1921-1925	50.9	58.9	54.9	52.3	51.6	49.1	57.4	53.9	57.9	50.7	53.7
1926-1930	50.3	56.6	53.9	51.5	50.1	48.0	56.5	52.3	56.8	50.0	52.9
1931-1935	52.4	58.6	56.1	53.2	52.2	49.7	57.7	54.2	58.6	52.1	54.8
1936-1940	51.8	57.6	55.2	52.3	51.4	49.1	57.8	53.2	57.6	51.1	53.7
1941-1945	51.2	57.1	54.7	51.9	50.6	49.3	57.6	52.6	57.6	50.8	53.8
1946-1950	51.5	56.8	53.6	52.1	50.9	49.1	57.7	53.3	57.2	51.0	53.6
1951-1955	51.5	58.0	55.2	52.9	51.6	49.4	57.8	54.1	58.4	51.6	54.3
1956-1960	49.7	57.0	54.1	51.7	50.0	48.3	56.3	52.4	56.7	50.6	53.0
1961-1965	50.2	57.0	54.2	51.2	50.4	48.5	56.6	52.3	56.9	49.7	53.2
1966-1970	49.9	56.0	53.1	50.6	50.2	47.8	55.4	51.2	55.3	49.4	52.8
1971-1975	50.9	56.8	54.3	51.7	50.9	48.5	55.4	52.0	56.9	50.0	54.2
1976-1980	49.5	55.8	53.1	50.3	49.2	44.9	53.5	51.5	55.7	48.6	52.3
1981-1985	50.5	56.6	53.9	51.2	49.0	46.0	54.5	52.3	56.3	48.7	53.3
1986-1990	51.9	57.6	54.7	52.5	50.7	46.5	55.2	53.0	57.5	49.8	54.0
1991-1995	49.8	57.1	54.4	52.0	50.5	46.8	54.7	51.6	55.9	48.9	54.0

Table 6. Decadal Values of Coefficient of Variation (%) for the Benchmark Annual Mean Temperatures

Period	*ALEDO*	*ANNA*	*CARLN*	HOOPS	MINOK	MCLEN	MTCAR	RSHVL	SPRTA	WLNUT	WNDSR
1901-1910	1.68	1.66	1.72	1.93	2.69	1.38	1.20	1.65	1.91	1.96	2.28
1911-1920	2.78	2.45	2.71	2.79	4.01	2.41	3.20	3.68	2.51	2.93	2.88
1921-1930	3.28	2.89	3.05	3.22	3.69	2.77	4.02	3.23	3.14	3.28	3.12
1931-1940	3.13	2.40	2.55	2.80	2.78	1.95	3.26	3.16	2.61	3.12	2.48
1941-1950	2.50	1.72	2.05	2.52	2.13	2.05	2.74	2.31	1.80	2.64	2.23
1951-1960	2.76	2.13	2.64	2.48	2.75	2.38	2.57	2.74	2.92	2.67	2.94
1961-1970	1.55	1.23	1.42	1.29	1.44	1.37	1.44	1.78	1.77	1.46	1.76
1971-1980	2.51	1.74	1.96	2.28	2.46	2.50	4.30	1.94	1.86	2.42	2.44
1981-1990	2.61	1.76	2.39	2.24	2.71	2.24	4.12	2.29	1.81	2.62	1.82

Table 6 presents the coefficients of variation of the mean annual temperatures for each decade, 1901-1990, to measure time shifts in the interannual variability. Examination of these values shows a similar tendency at all 11 stations. The values are low in 1901-1910 and again in 1961-1970. The highest values occurred in the decades of 1911-1940, being highest at eight stations in 1921-1930. Based on the six stations with unquestionable temperature data (Aledo, Carlinville, Hoopeston, Rushville, Sparta, and Windsor), the greater variability over the 95 years is found in the north and central stations, with the least in the south and south-central regions.

Annual Temperatures

Figure 5 presents curves based on the annual mean temperatures at selected stations, and figure 6 presents the annual values smoothed by 9-year running averages (plotted on the mid-year of the 9-year period) for all stations. In general, all stations experienced peaks during the 1930s with secondary peaks in the 1950s. Values were lowest early in the century and during 1960-1985. Figure 7 presents the "adjusted" annual temperature curves for Anna, McLeansboro, Minonk, and Mt. Carroll.

To help interpret the station values, linear trends were fit to the 1995 annual values of each station, and these are depicted in figure 8 based on the unadjusted values. Table 7 includes the slopes (expressed in degrees per year) of the linear trends and the results of the Students T test of significance of each trend. For the 1901-1995 period eleven stations show slight downward trends. Only Windsor had values exhibiting a very minor 0.004 ° F per year upward trend. None of the trends were statistically significant. Also shown in table 7 are the trends fit to those stations for which adjustments were made to their annual mean temperatures. Trends of these adjusted values show less of a decrease, as expected since the values in recent years were reduced due to shifts from p.m. to a.m. observations times at Minonk, McLeansboro, and Walnut. The trend analyis reveals that ten of the benchmark stations had slight downward trends ranging from 0.001-0.009° F per year.

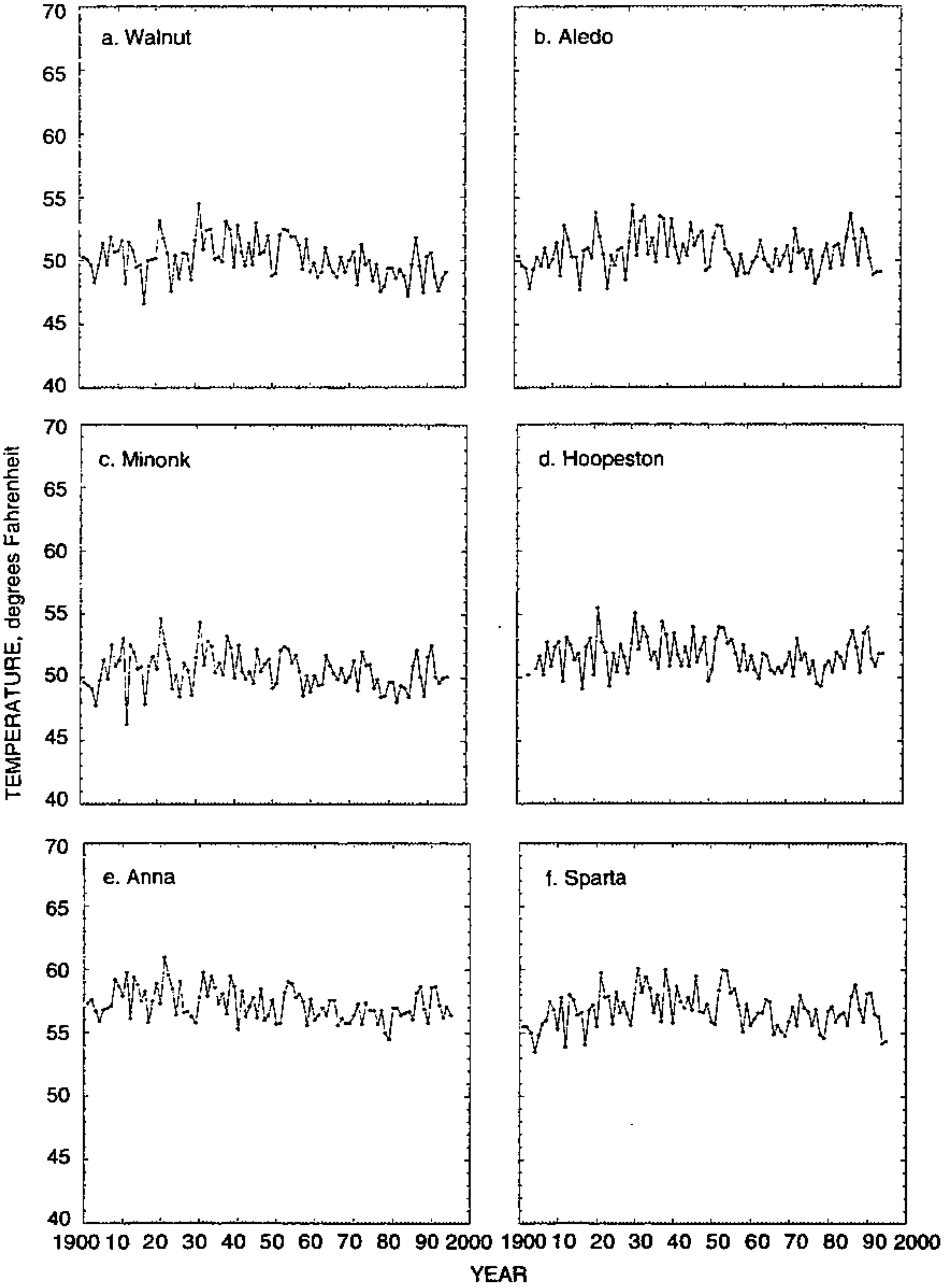


Figure 5. Annual mean temperature values at six of the 12 candidate benchmark stations.

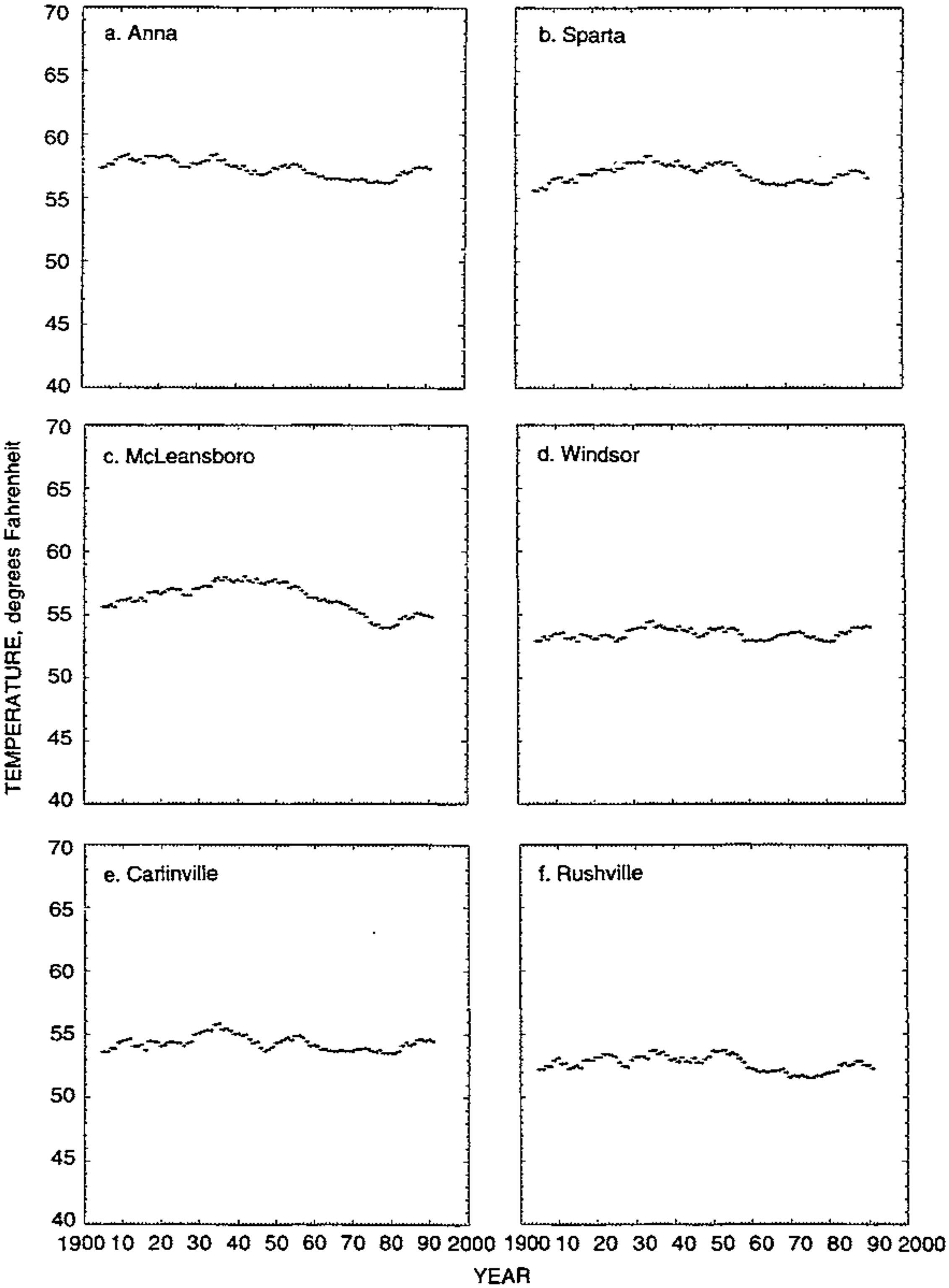


Figure 6. Annual mean temperatures at the 12 benchmark stations, smoothed by 9-year running averages. The average of each 9-year period is plotted as the mid-year of the 9-year period; thus the average for the period 1901-1909 is plotted at 1905.

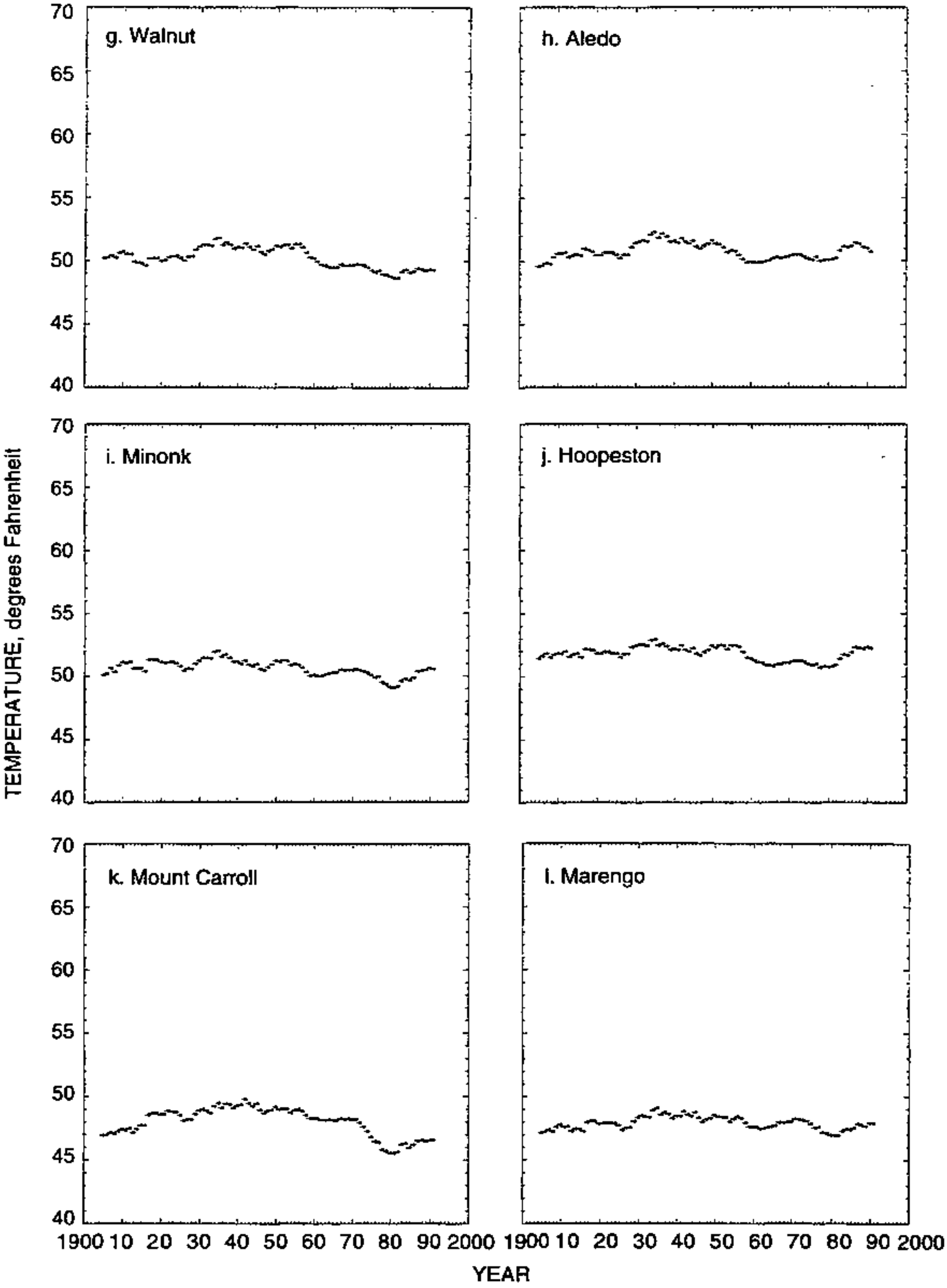


Figure 6. Concluded

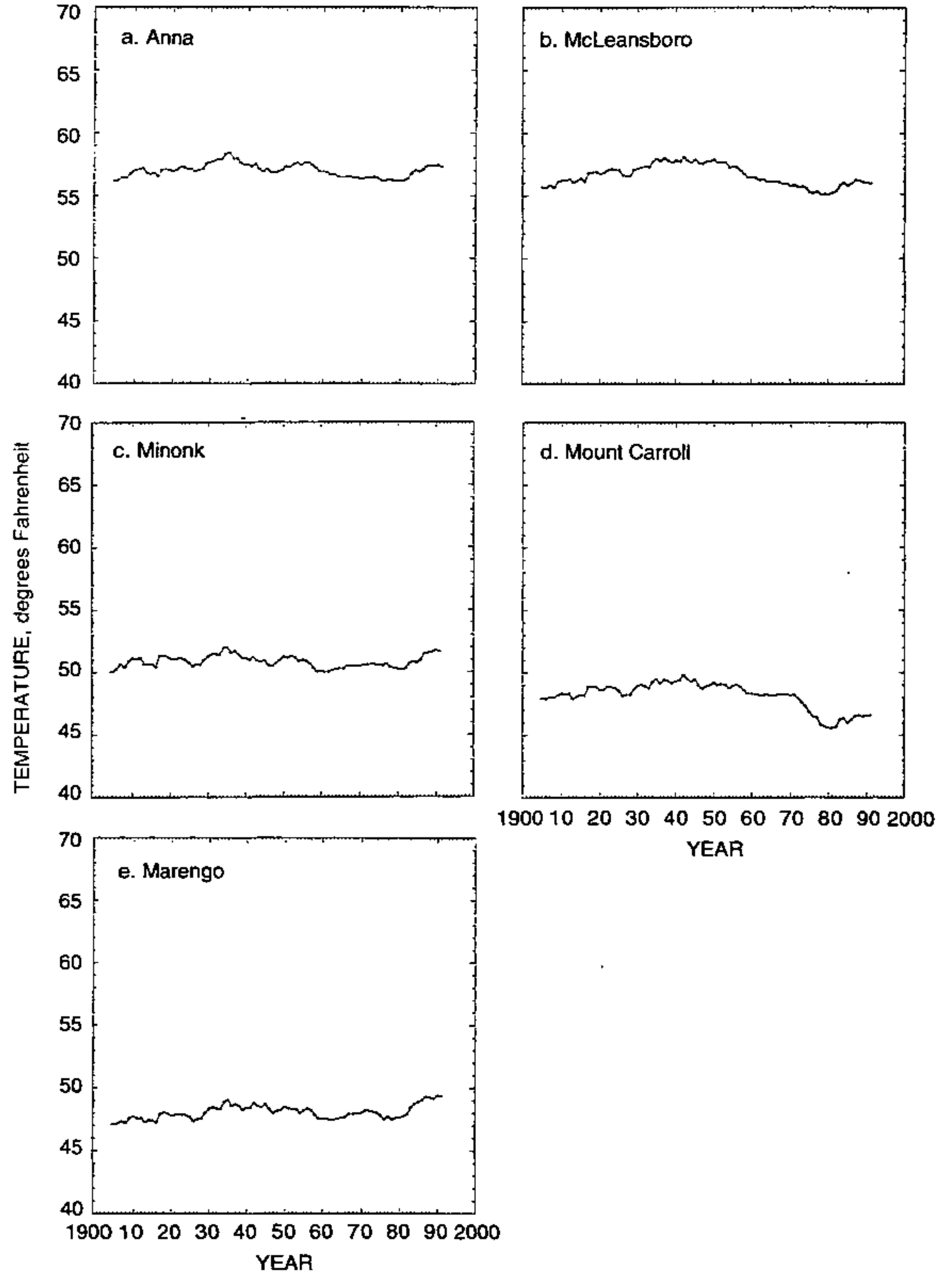


Figure 7. The annual mean temperatures, based on 9-year running averages, for the five benchmark stations which had periods of their records adjusted based on adjustment values presented in table 2. The average of each 9-year period is plotted as the mid-year of the 9-year period (for example, the average for the period 1901-1909 is plotted at 1905).

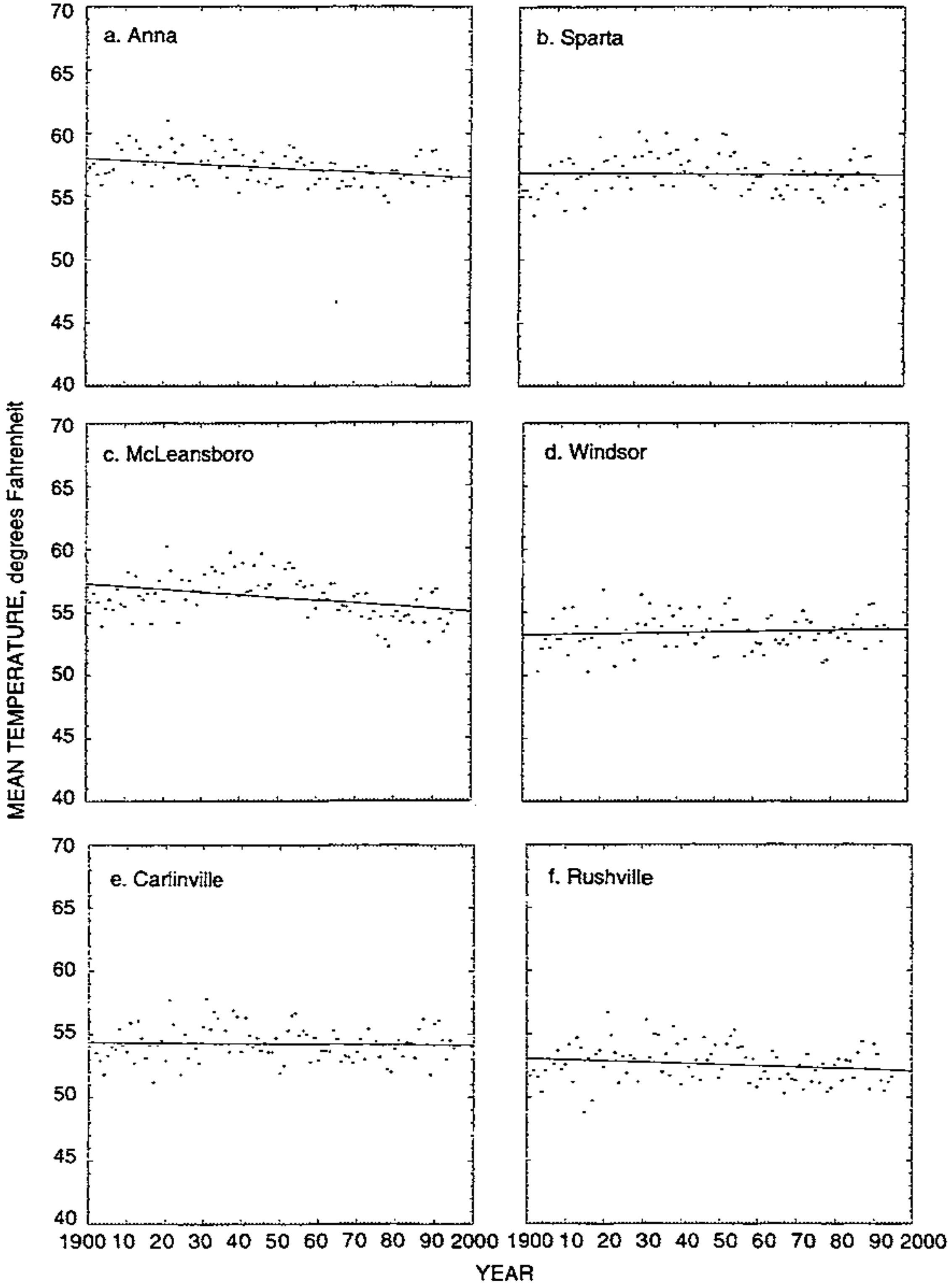


Figure 8. Linear trends for 1901-1995 mean annual temperature values for the 12 benchmark stations (based on unadjusted values for Anna, McLeansboro, Minonk, Mt. Carroll, and Marengo).

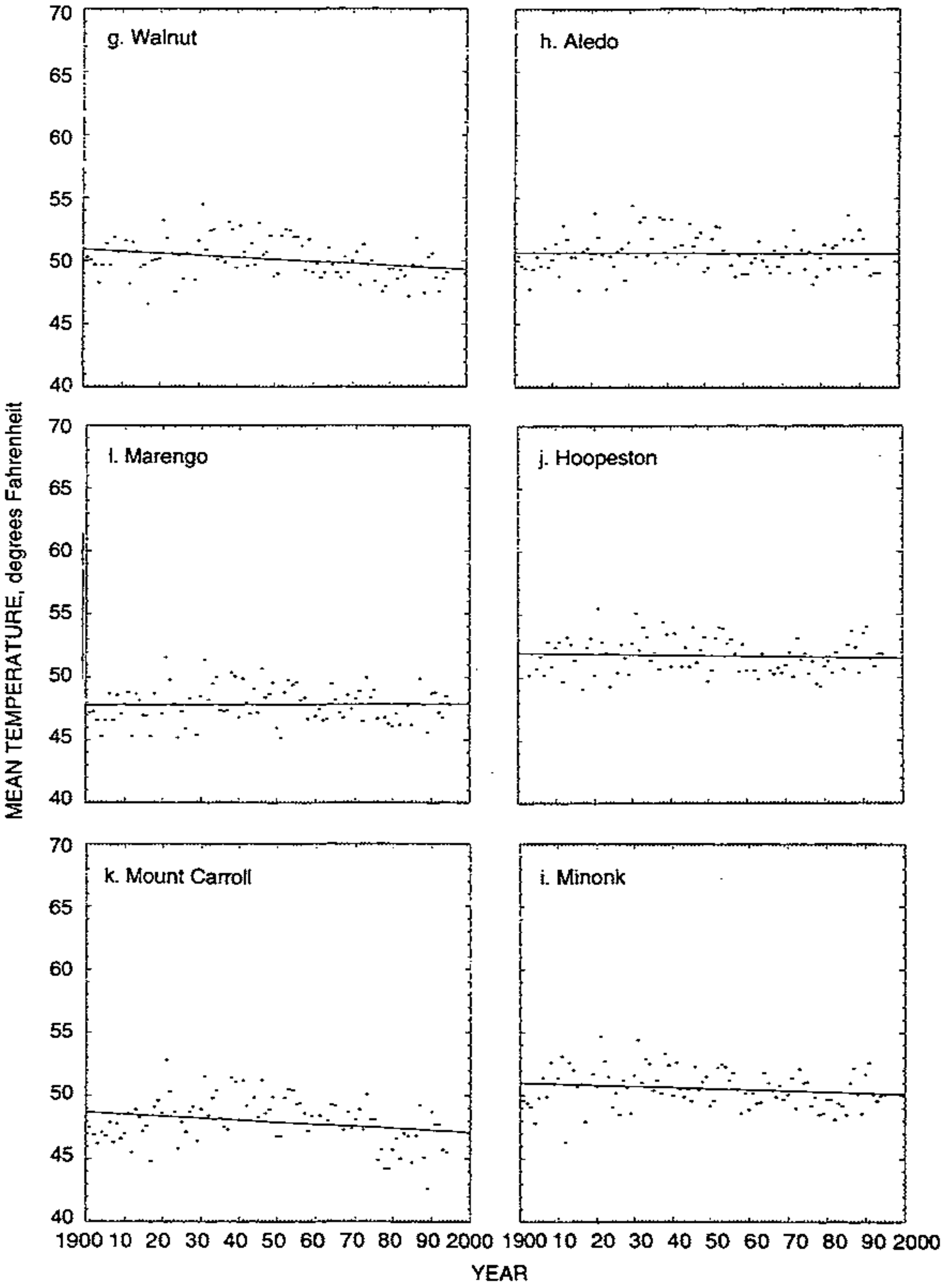


Figure 8. Concluded

Table 7. Slope and Test of Statistical Significance of Annual Mean Temperatures at Illinois Benchmark Sites, 1901-1995

Station	*Slope (° F per year)*	*Significance based t-test*	*Slope (° F per year) with adjusted values*
Aledo	-0.000213	0.038671	
Anna	-0.014953	-3.302208	-0.0003
Carlinville	-0.002117	-0.413243	
Hoopeston	-0.004215	-0.783894	
Minonk	-0.008828	-1.589885	+0.0027
Mount Carroll	-0.016111	-2.439512	-0.0236
McLeansboro	-0.022236	-3.853775	-0.0106
Rushville	-0.009828	-1.770928	
Sparta	-0.001265	-0.229287	
Walnut	-0.015911	-2.898544	-0.0033
Windsor	+0.004563	0.847940	

Table 8. Decadal Values of Differences between Annual Mean Maximum and Annual Mean Minimum Temperatures

Year	*ALEDO*	*ANNA*	*CARLN*	*HOOPS*	*MINOK*	*MTCAR*	*MCLEN*	*RSVL*	*SPRTA*	*WALNT*	*WNDSR*	*6-STATION MEANS**
1901-1910	20.6	22.7	23.1	20.0	22.6	20.4	23.2	20.1	22.0	20.8	22.8	21.4
1911-1920	21.2	21.3	23.3	21.4	22.6	22.0	21.8	20.2	21.8	20.8	23.0	21.8
1921-1930	21.6	20.4	22.5	21.4	21.5	23.6	22.4	20.4	22.8	19.9	22.2	21.8
1931-1940	21.2	20.6	22.8	22.1	21.7	23.8	21.8	21.3	22.8	20.4	20.9	21.9
1941-1950	20.6	20.3	22.2	20.9	21.4	22.2	21.4	20.1	22.0	20.2	21.4	21.2
1951-1960	22.4	21.4	22.8	20.4	22.3	22.6	20.5	22.3	21.9	22.7	21.8	21.7
1961-1970	21.7	21.5	22.7	20.0	22.7	21.6	21.6	22.5	21.9	20.6	21.6	21.7
1971-1980	20.6	20.4	21.9	19.4	21.8	21.5	22.8	21.5	21.0	20.3	20.5	20.8
1981-1990	20.4	21.3	20.4	19.4	21.8	22.0	25.4	20.6	21.0	22.8	20.3	20.4

Note: *These decade values are the means of Aledo, Carlinville, Hoopeston, Rushville, Sparta, and Windsor.

Table 8 presents the decadal differences between the mean maximum and mean minimum temperatures at the 11 benchmark stations. In general, the values indicate a narrowing of the difference over the past 20 years. This is largely due to the fact that the mean minimum values were not trending downward as fast as the mean maximum values. In the first seven decades the differences at all stations ranged from 21-23° F, whereas those in the two most recent decades have been 19° -21 ° F apart, reflecting a decrease in the range of 1.9° -1.5° F. Table 8 also shows the mean differences based on the six stations with the highest quality temperature data. These stations display a similar difference from 1911-1920 to 1961-1970 (smaller differences existed in 1901-1910 and 1949-1950). In 1971-1980, the mean difference decreases by 1.0° F, followed by a decline of 0.4° F in the 1981-1990 difference. Such a decrease could be the result of added cloudiness since 1960, a condition that has been observed in the sky and cloud cover records (Changnon, 1981; Seaver and Lee, 1987). Additional cloudiness observed in the Midwest since the late 1960s has been partially explained as a result of the effects of jet-created contrails that act as high cirrus clouds from extensive jet aircraft traffic across the Midwest (Travis, 1996).

Application of the Easterling-Peterson (EP) adjustment technique to the annual temperature values of the 12 stations produced a wide range of outcomes. Figure 9 shows the differences between the actual values and the EP adjusted values for five of the Illinois benchmark stations without major recent changes (since 1970) in observation times or instrument changes.

At Hoopeston the early values (1911-1945) are indicated as being one to two degrees higher than the EP adjusted values, with values of 0.4-0.5 ° F higher from 1955-1985. The differences for Carlinville ranged from 1.5-2.5 ° F higher than the 1901-1975 adjusted values. Rushville's differences indicate the actual values were less than the 1901-1950 adjusted values, then shifted and became about 0.5 ° F higher from 1956-1985. The time distribution of the differences for Aledo and Sparta (and Windsor, not shown) are similar to those for Hoopeston and Carlinville, with peaks in the 1921-1955 period, and lesser but higher values before 1921 and from 1956 to about 1980.

It seems odd that most of the best quality benchmark stations had very similar adjustment distributions (and magnitudes). Such a systematic series of similar, supposedly incorrect values at five quality stations is difficult to explain. Since the EP technique calculates differences from the most current year (1995) backward, and thus assumes that the most current temperature values are correct, the potential exists for the adjustment outcomes for the benchmark stations to be biased. Many surrounding temperature stations used as comparative references in the EP adjustment technique have experienced recent changes in observation times, from p.m. to a.m. This would cause their recent values to be relatively "lower" than earlier values. Such a circumstance could explain why the earlier (pre-1980) values calculated at the six Illinois benchmark stations *without recent changes in observation times or shifts to MMT instruments* were assessed by the EP approach as too high. That is, the data of the reference stations used in the process are potentially in error in that their recent values are lower man their earlier values because of these widespread recent changes in observation times and instrumentation.

If one accepted the EP adjusted annual temperature values for Aledo, Carlinville, Hoopeston, Sparta, and Windsor as valid, the resulting 1901-1995 values would yield flat long-term trends rather than the slight declines shown in the actual data (figure 8). The change in the Rushville data would steepen its 95-year declining trend, making it quite different than the trends at the other five stations. In general, the results of EP adjustments of the mean annual temperature data at the Illinois benchmark stations do not appear realistic and are not recommended for use.

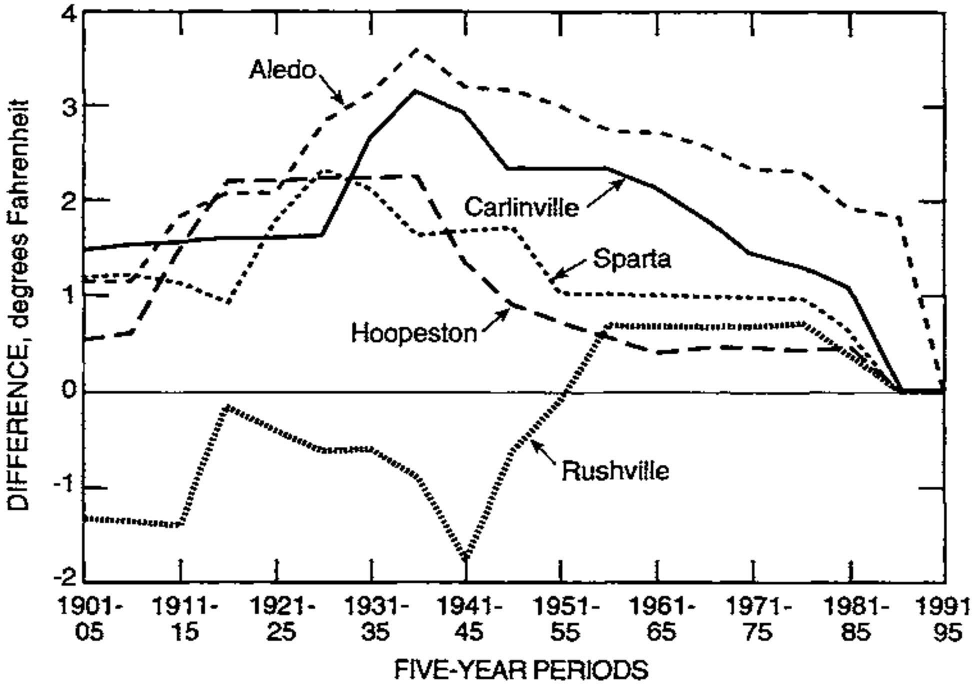


Figure 9. The differences between the actual 5-year annual mean temperatures and the adjusted 5-year values based on use of the Easterling-Peterson (1995) statistical homogeneity test.

Seasonal Temperatures

Figure 10 shows the seasonal *mean minimum temperatures* for three stations distributed north-south across Illinois (Anna, Minonk, and Aledo). The spring (March-May) values show generally flat trends for 1901-1995 (figure 10a). The summer curves (figure 10b) show interannual oscillations greater than in spring, but generally downward trends. All stations peaked in the 1930s and are lowest in the late 1950s-early 1960s. Since these high values, the last 45 years have had cooler summers (figure 10b).

The fall curves show downward trends of one to two degrees for 1901-1995 (figure 10c). The winter mean minimums (figure 10d) display their highest values early in 1910-1940, with ever-decreasing values reaching the century's lowest values in 1980, and then increasing values since 1980.

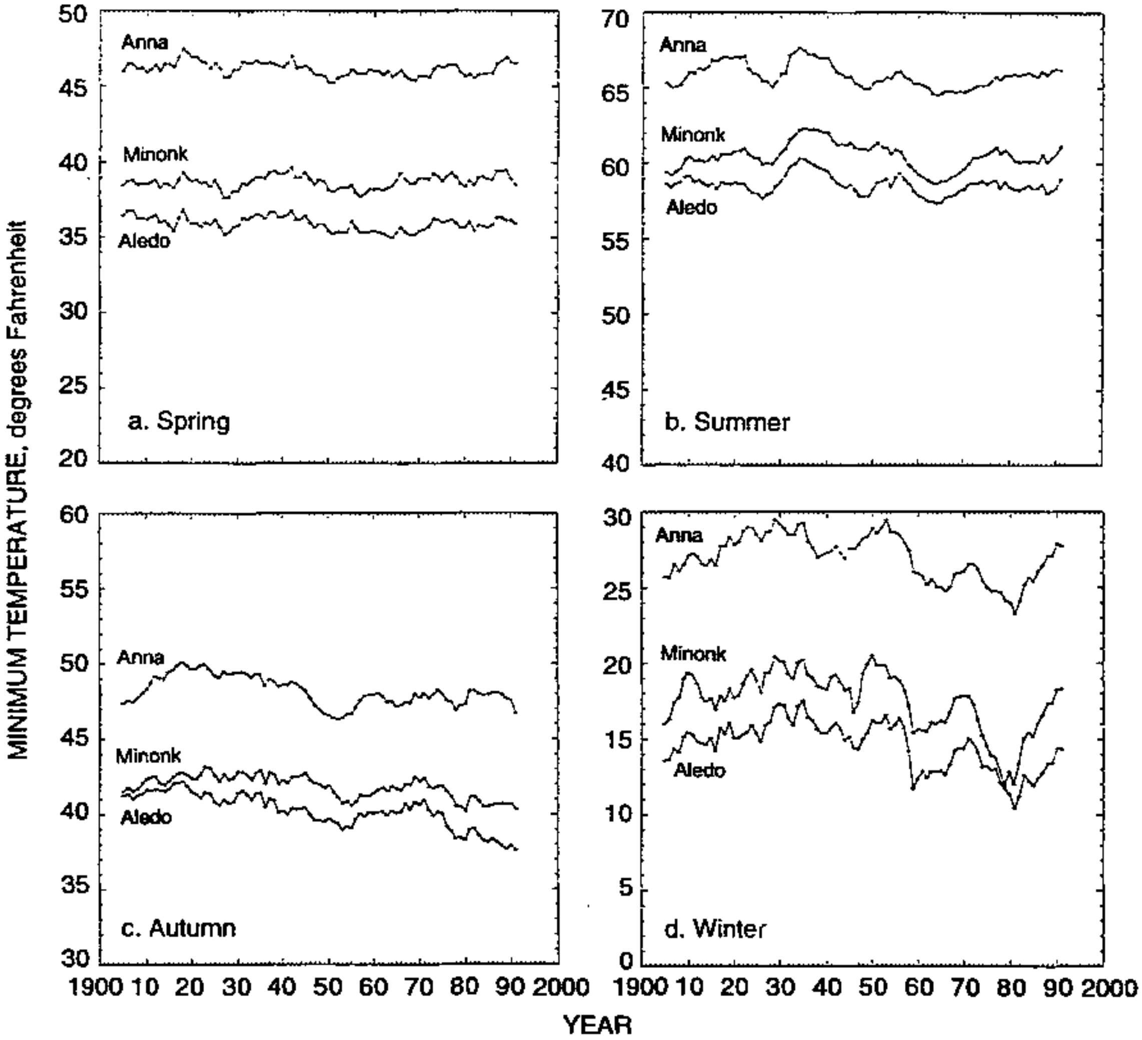


Figure 10. Annual mean minimum temperatures at Anna, Minonk, and Aledo for the 1901-1995 spring, summer, autumn, and winter (December-February) seasons. These are 9-year running averages plotted at the mid-year of the 9-year period.

Figure 11 presents the seasonal *mean maximum temperatures* for the three stations. Spring values (figure 11a) peak early in the century followed by slight decreases. The summer values (figure 11b) all peaked in the 1930s (as did the minimums), and then decrease with 60-year changes of 2 ° F. Fall maximum values (figure 11c) all display highs around 1910 followed by decreases of one to two degrees by 1995. The winter values (figure 11d) reveal the century's highest values came in the 1950s, followed by cooling until 1980, then a rapid increase. The maximum winter values for the last 40 years average 1.5 - 2° F lower than the winter maximums for the 1901-1950 period.

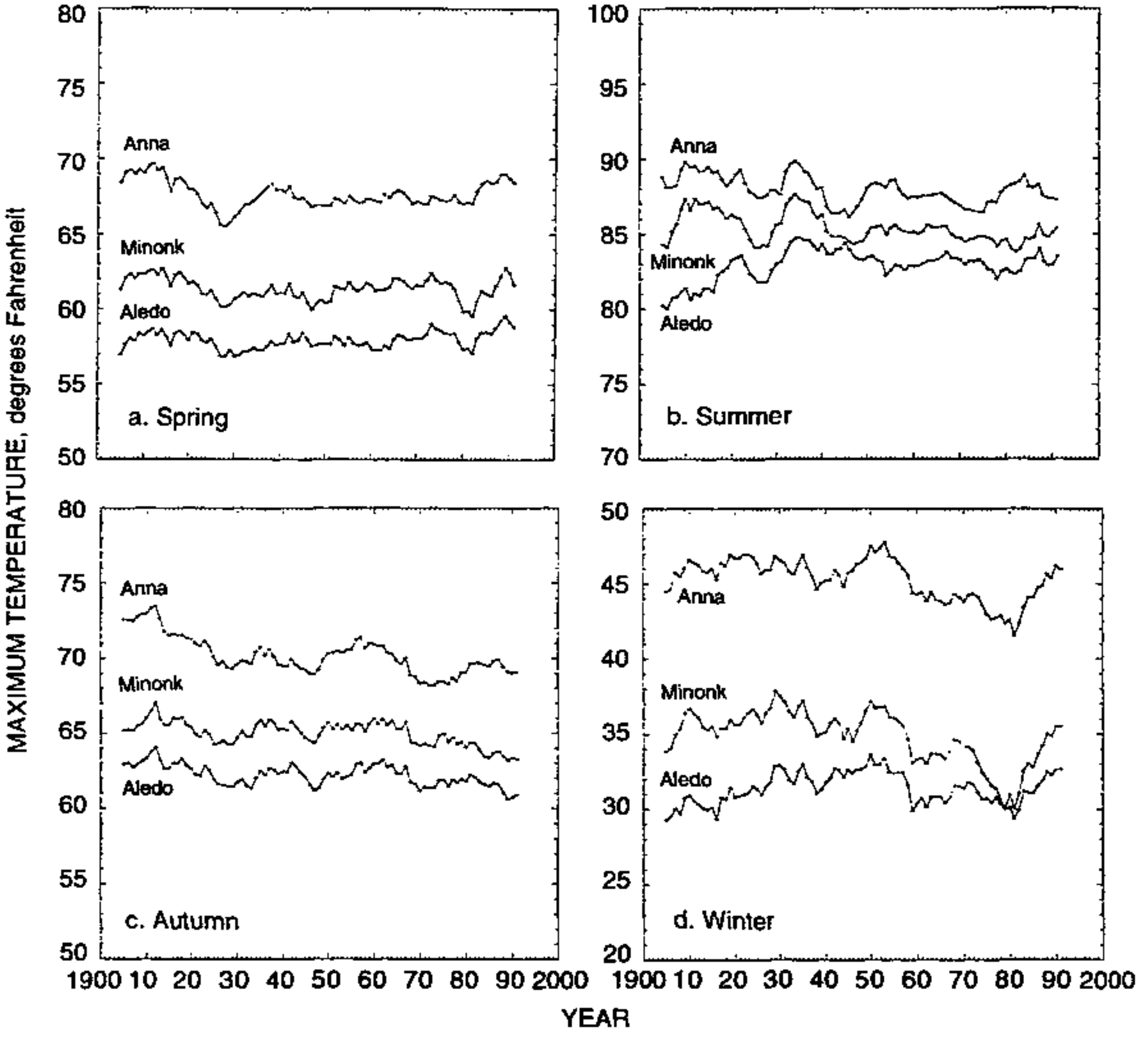


Figure 11. Annual mean maximum temperatures for the 1901-1905 seasons at three benchmark stations, Anna, Minonk, and Aledo. The values are 9-year running averages plotted at the mid-year of the 9-year period.

Summary

Interpretation of the seasonal maximum and minimum temperatures of fluctuations reveals that the spring season has lacked notable trends in either the maximum or minimum values with little interannual variability. Springs in 1901-1915 were slightly warmer than those since.

The summer maximum and minimum temperatures both peaked in the 1930s and have generally decreased over the last 40 years by one to two degrees Fahrenheit. The maximum and minimum mean values of the fall season both peaked early during 1901-1920, and they have been gradually decreasing by one to two degrees Fahrenheit from 1920-1995. The mean maximums and minimums of the winter season both peaked in mid-century, became lowest in the late 1970s-early 1980s, and showed increases since then. As a result, winters of the past 40 years are 1-1.5 ° F cooler than those of the century's first 50 years.

FLUCTUATIONS IN HISTORICAL PRECIPITATION DATA

Annual Precipitation

Table 9 presents a descriptive analysis of the 1901-1995 distributions at each station. The 1901-1995 annual precipitation values of each station were used to develop nine-year moving averages, and figure 12 presents the resulting curves (the value of each period is plotted on the mid-year). Values are shown for all 12 stations although the data for Mt. Carroll are considered questionable, and data for Carlinville and Sparta are suspect for use in detecting effects of a climate change.

Table 9. Annual Precipitation Distribution at Benchmark Stations

Station	*Precipitation trends*
Aledo	Generally flat from 1901-1995. Lowest in 1910-1920, and highest in 1920s and 1970s.
Marengo	Flat from 1901-1950, then wetter regime from 1951-1995. Driest in 1930s and wettest in 1970s.
Mt. Carroll	General long-term trend to ever wetter conditions from 1901-1995 with three peaks: 1920s, 1940s, and 1970s. Driest in 1910-1920 and 1935, and wettest in late 1970s.
Walnut	Flat trend from 1901-1965, then shift to wetter regime. Driest in 1910-1920 and late 1950s, and wettest in 1970s.
Minonk	Generally flat long-term trend. Peaks in 1915, 1920s, 1940s, and 1980s. Wettest in 1940s and driest in 1930s.
Hoopeston	General decline in precipitation from 1901-1995. Peaks in 1920s and early 1970s, and driest in 1950s.
Windsor	General decline with time from 1901-1995. Wettest in 1950s and driest in 1990s.
Rushville	Continuing upward trend from 1901-1995. Wettest in early 1970s and driest 1910-1915.
Carlinville	Generally flat trend from 1901-1995. Wettest in early 1970s and 1925, and driest in 1950s.
Sparta	Generally flat trend. Wettest in 1940s and 1980s, and driest in 1930s.
McLeansboro	Generally flat from 1901-1995. Wettest early 1980s and driest in 1910-1912 and 1960s.
Anna	Generally flat from 1901-1995. Wettest in 1940s, and driest in 1955-1965.

The linear trends determined for the annual precipitation values revealed that the 1901-1995 trend was essentially unchanging (flat) at six stations (Aledo, Minonk, Carlinville, Sparta, McLeansboro, and Anna). Note that most of these stations are in the southern half of Illinois. Peaks of precipitation occurred at most stations in the 1940s and late 1970s. Hoopeston and Windsor

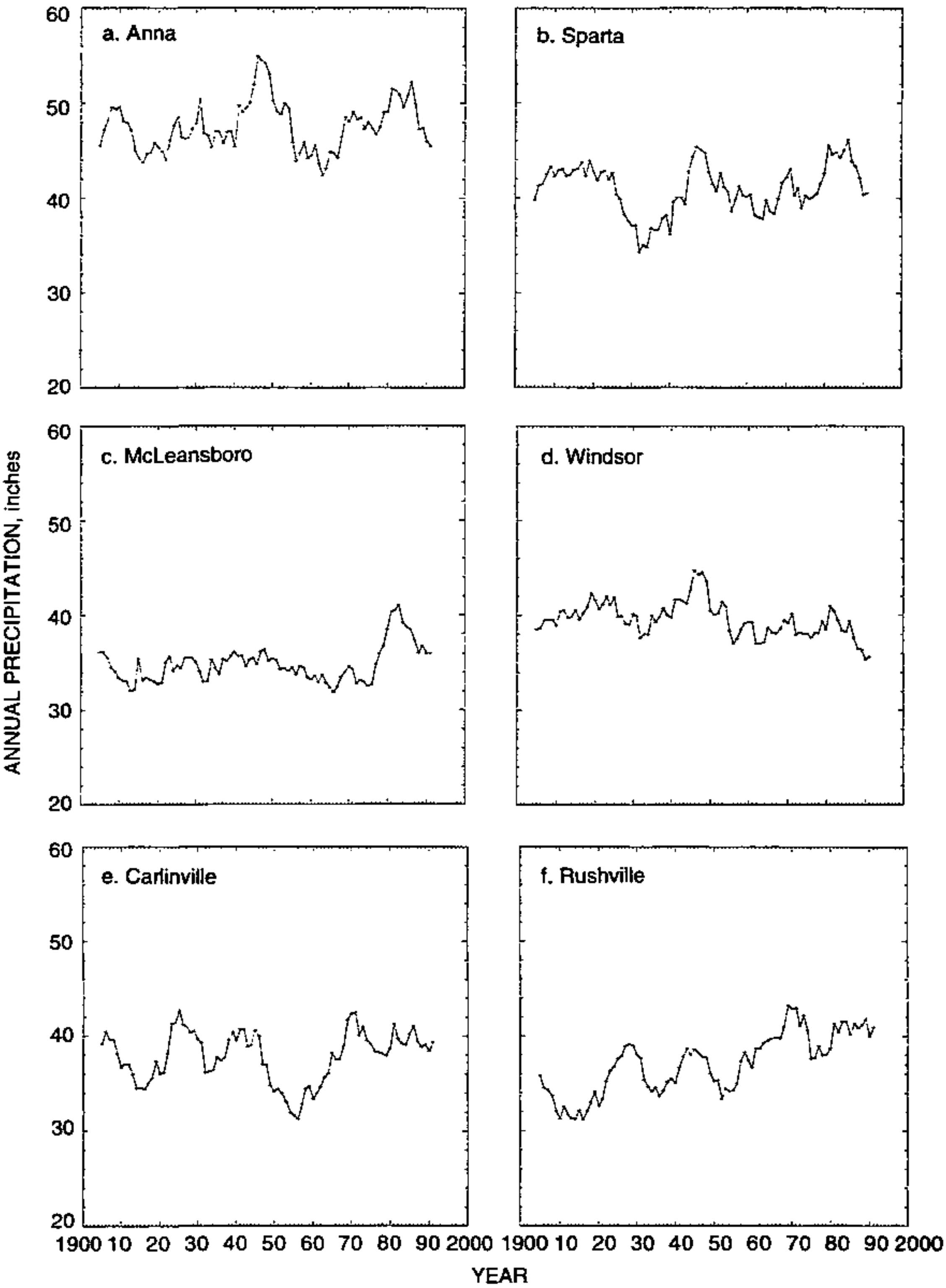


Figure 12. Nine-year running averages of 1901-1995 annual precipitation values at the 12 benchmark stations. The average of each 9-year period is plotted at the mid-year of each 9-year period.

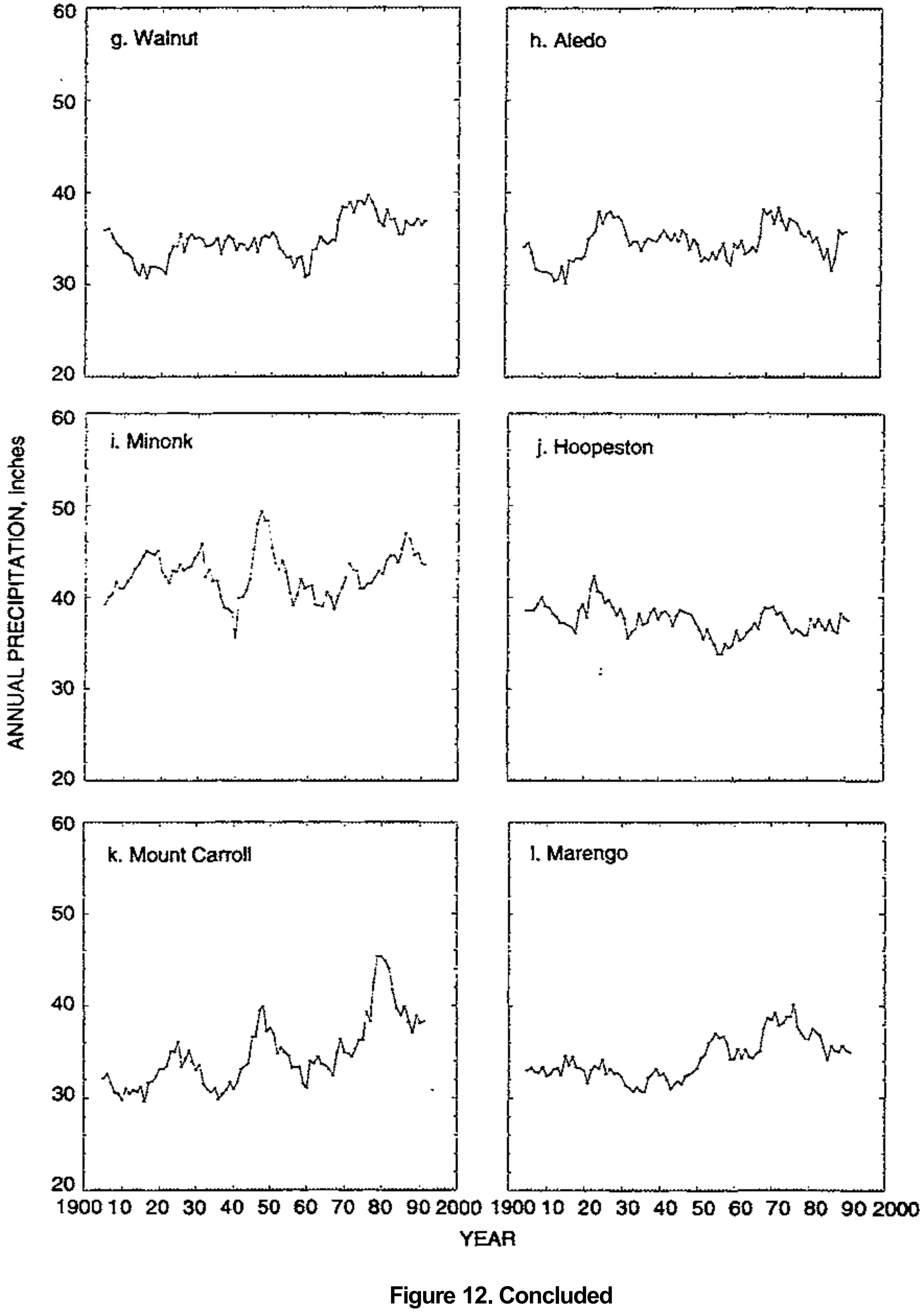


Figure 12. Concluded

(adjacent stations) had slight downward trends for 1901-1995, with a decrease of 0.1 inch every 10 years. Stations in western and northern Illinois showed upward linear trends, becoming wetter with time. This included Marengo, Mt. Carroll, Walnut, and Rushville, which all increased between 0.5-0.7 inch per decade from 1901-1995. The trends suggest three regions each with different long-term shifts. Karl et al. (1991) indicated that a shift in Midwestern precipitation would take several decades to detect with certainty due to the considerable natural variability.

Winter Precipitation

Figure 13 presents the 1901-1995 precipitation values for winter (December-February) at the 12 benchmark stations. Every station reached a peak in the 1940s with lesser peaks in the mid-1980s at six stations (Aledo, Anna, Carlinville, McLeansboro, Sparta, and Windsor). These stations are largely in the southern half of Illinois. Analysis of 1901-1995 linear trends showed essentially flat, unchanging values at eight stations, two decreasing with time (Hoopeston and Minonk), and two increasing with time (Rushville and Mt. Carroll, the latter with very questionable data).

Summer Precipitation

Figure 14 depicts the 1901-1995 summer values, and the curves for all stations in northern Illinois (except Aledo) and western Illinois show increases in summer rainfall. Values for Hoopeston and Windsor (both in the east-central area) show decreasing summer rain with time, which is reflected in their annual precipitation curves (figure 12). Summer rainfall trends at the other five stations in central and southern Illinois were generally unchanging from 1901-1995. The linear trends supported these observations. Major peaks in summer rainfall occurred in the 1970s at seven stations in the central and north sections, the 1980s were quite wet at four stations in the south, and the 1940s were wet in the central and southern sections. The driest summers came during 1910-1920 and in the 1930s. Summer rainfall trends define the three regions revealed in the annual precipitation: 1) west-north increasing, 2) east-central decreasing, and 3) south not changing.

Distribution of Heavy Rain Events

The frequency of heavy rain days was investigated since one expectation under a greenhouse-enhanced climate change is for more heavy rain days to occur. The analysis involved days with 2 inches or more, 3 inches or more, and 4 inches or more of rain.

Figure 15 also plots the 2-inch totals (table 10). The curve reveals below average values for 1901-1940. Then high values occurred in 1941-1950, 1961-1970, and 1981-1990. The 1981-1990 value was the highest of all the values, being 23 percent above the 90-year average.

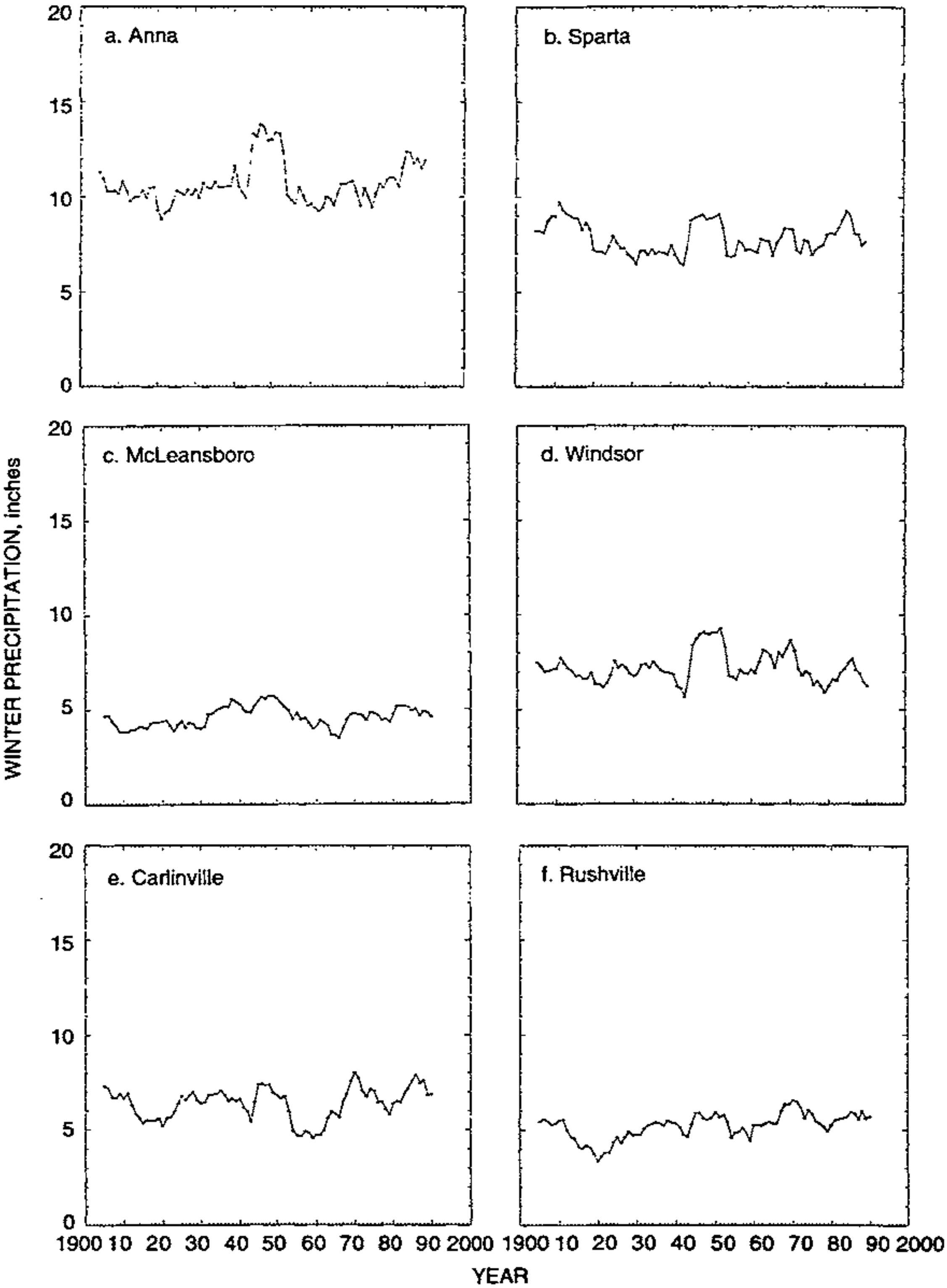


Figure 13. The 1901-1995 mean winter (December-February) precipitation values presented as 9-year moving averages for the 12 benchmark stations. Each 9-year average is plotted at the mid-year of the period.

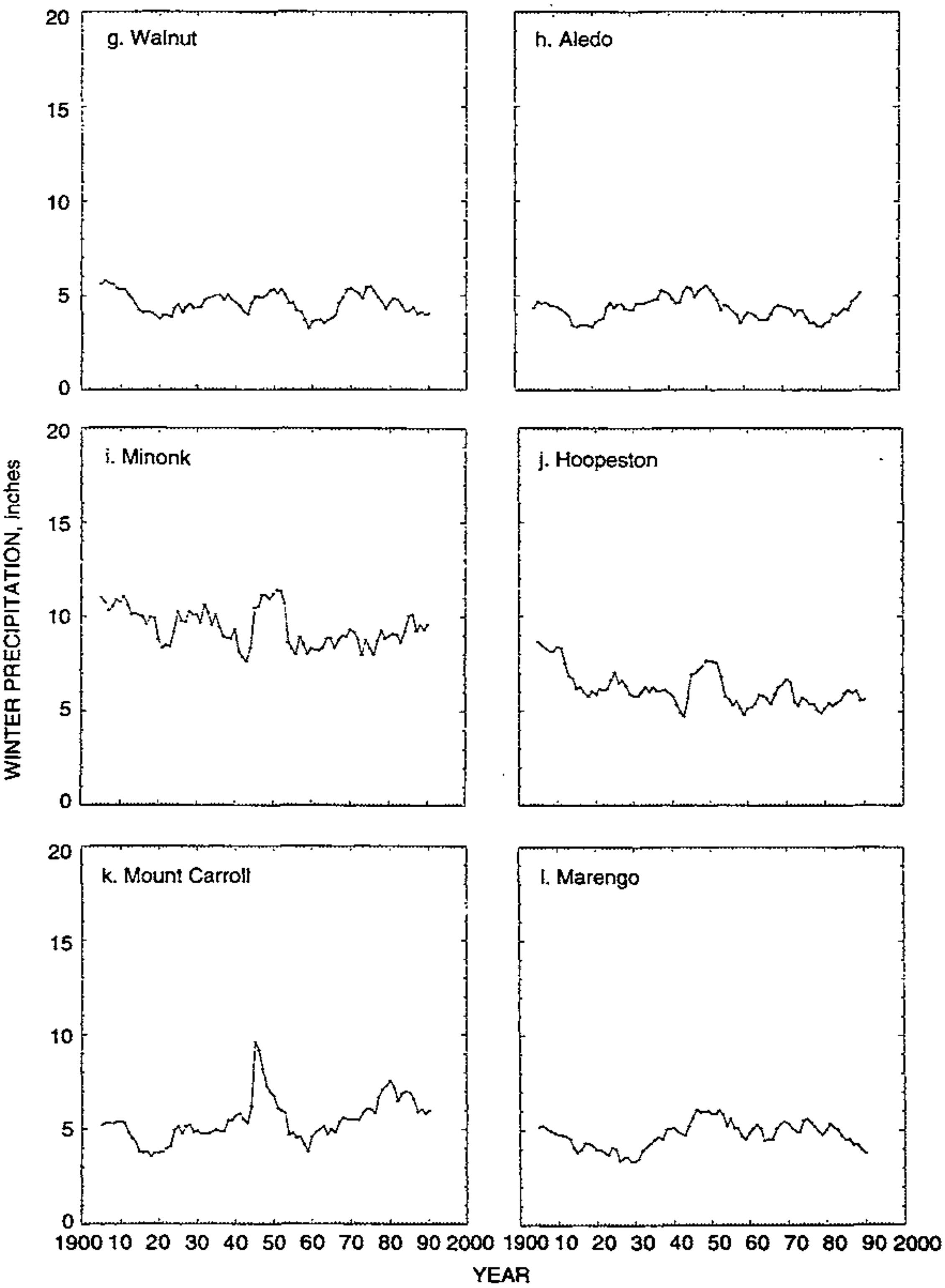


Figure 13. Concluded

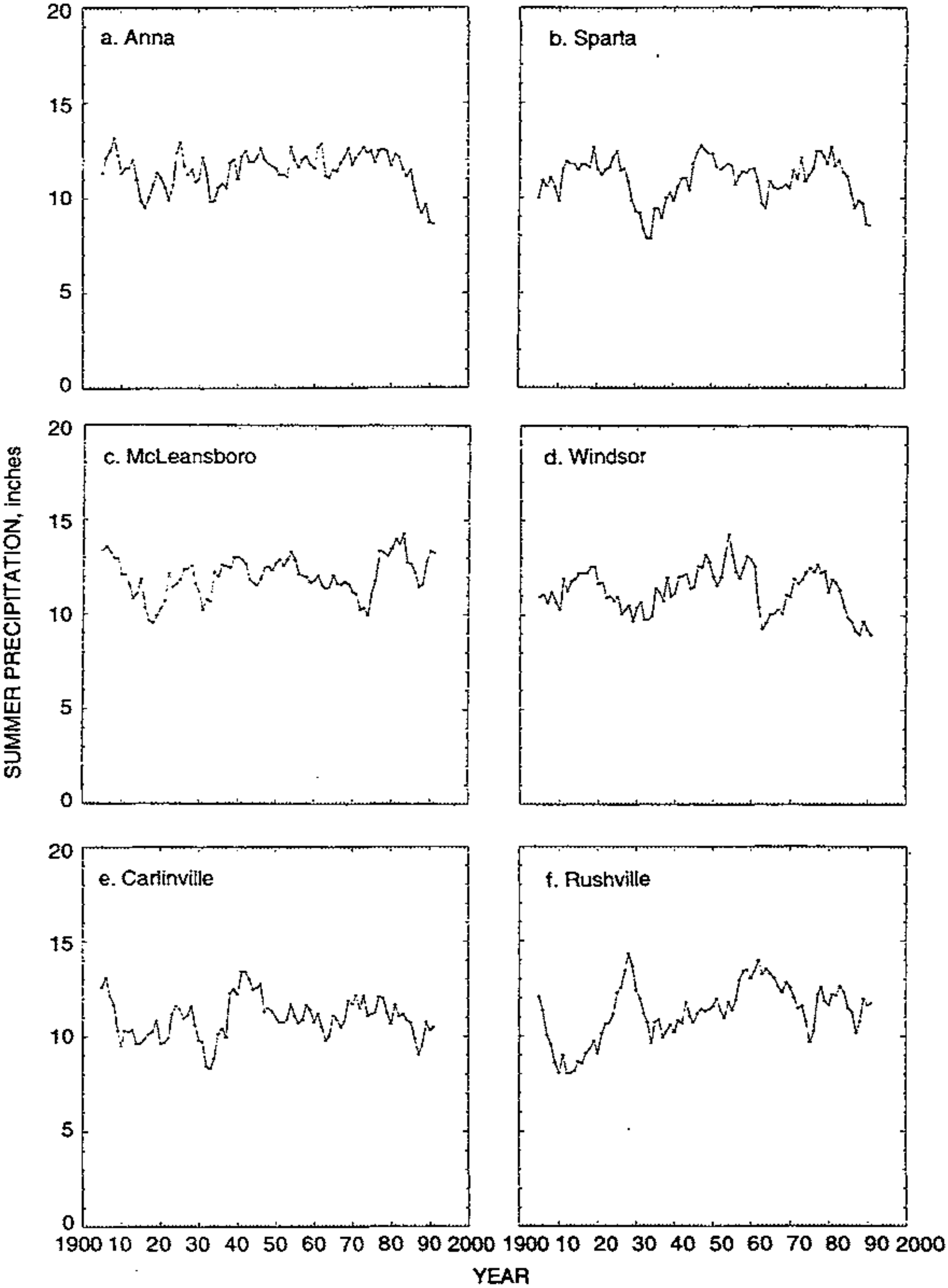


Figure 14. The 1901-1995 mean summer (June-August) precipitation values presented as 9-year moving averages for the 12 benchmark stations. Each 9-year average is plotted at the mid-year of the period.

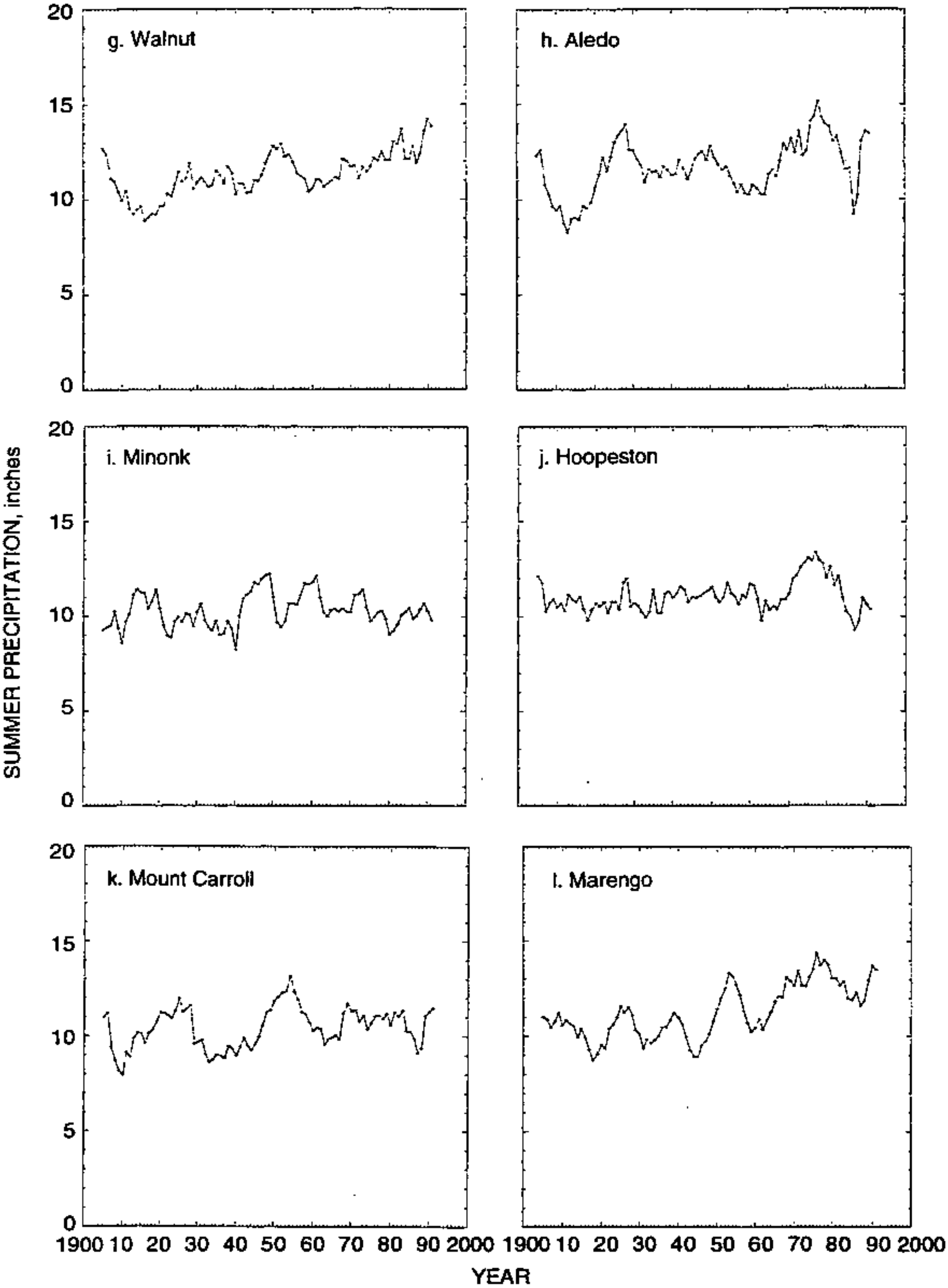


Figure 14. Concluded

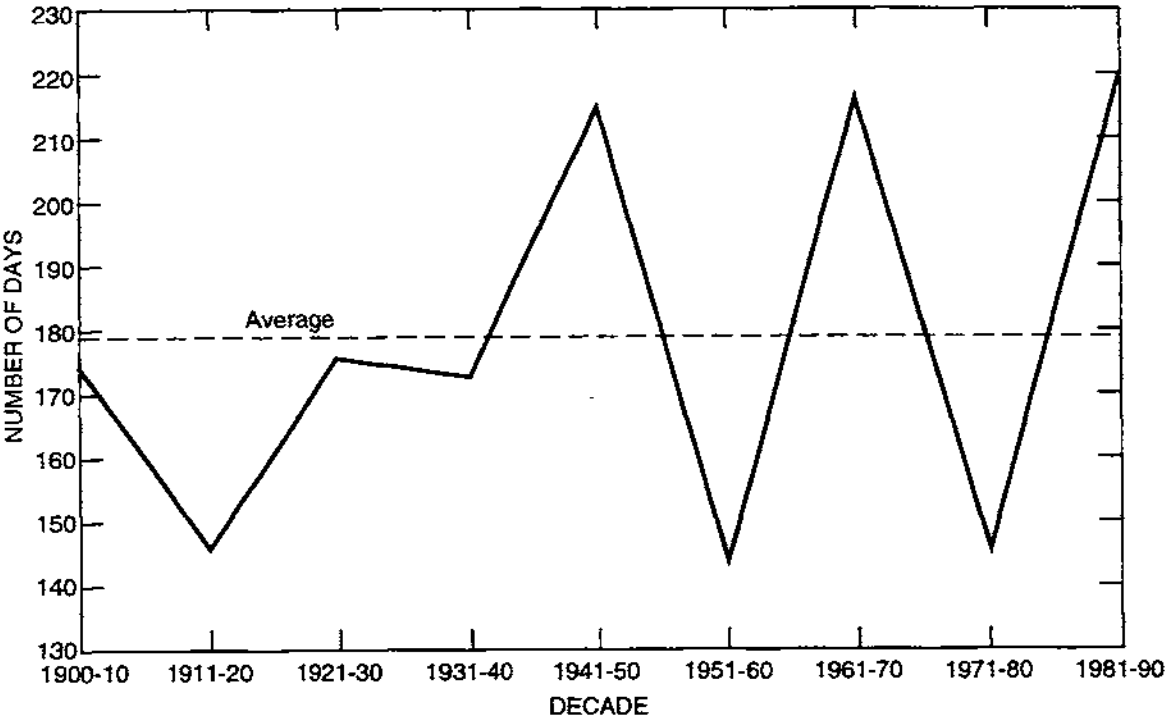


Figure 15. Number of days with 2 inches or more precipitation at 11 benchmark stations, expressed as the number of days per decade, 1901-1990.

Table 10 shows the decadal values of 2-inch events for 11 stations (Mt. Carroll was omitted due to its questionable data) and their total for each decade. There is considerable north-to-south variation across Illinois. For example, the decadal average number of days with ≥ 2 inches of precipitation at Anna is 28.5 days, as opposed to 11.0 days at Marengo.

Inspection of the higher and lower decadal values at each station reveals major temporal differences. For example, Anna peaked with 44 days in 1981-1990, whereas nearby Sparta peaked with 29 days in 1941-1950. Values at Anna were lowest in 1951-1960, but values at Sparta were lowest in 1971-1980. Peak decadal values were most prevalent in 1961-1970 (four stations), 1981-1990 (three stations), and 1971-1980 (two stations)—all recent decades.

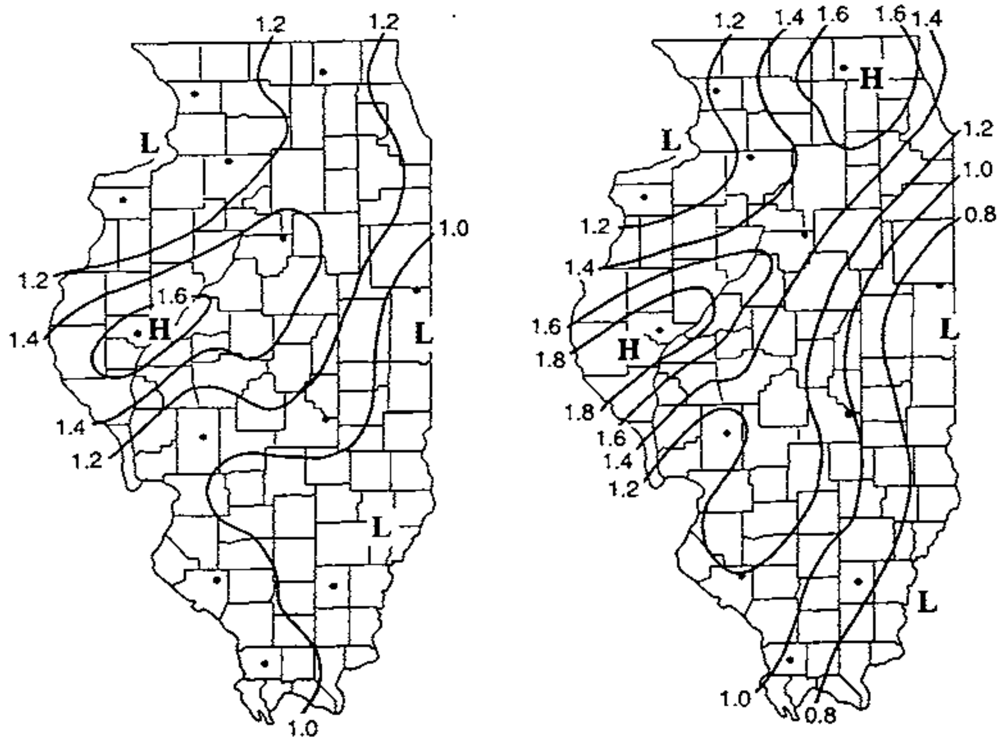
Table 10. Distribution of Heavy (≥ 2 inch) Rain Days from 1901-1995

Period	*ALEDO*	*ANNA*	*CARLN*	*HOOPS*	*MRNGO*	*MCLEN*	*MINOK*	*RSHVL*	*SPRTA*	*WLNUT*	*WNDSR*	*Totals*	
												2-inch	*4-inch*
1901-1910	12	33	13	16	11	16	8.	18	17	19	11.	174	15
1911-1920	12	22	9	10	8	19	9	8.	25	9.	15	146	14
1921-1930	16	27	18	17	11	19	10	14	14	13	17	176	9
1931-1940	11	24	14	17	9	25	11	11	16	17	18	173	7
1941-1950	11	40	16	15	12	31	15	12	29	14	20	215	12
1951-1960	12	21	9.	9	9	9.	13	8.	20	17	18	145	11
1961-1970	13	30	19	17	12	18	16	30	22	15	24	216	9
1971-1980	16	18	16	11	14	13	8.	14	14.	11	13	148	12
1981-1990	15	44	12	11	13	26	19	20	27	19	15	221	12
Average	13.2	28.5	13.9	13.4	11.0	20.0	12.4	15.6	20.2	15.0	17.0	179	11.2

Temporal changes in the frequency of heavy daily rainfall events were further investigated through comparisons of values in the early and late parts of the century. Events with daily rainfall amounts equaling or exceeding 2, 3, and 4 inches were examined.

Figure 16a shows the pattern derived from dividing the total frequency of 2-inch days in 1946-1990 (last 45 years) by the total frequency for the 1901-1945 period. The ratios indicate an increase in frequency between the two 45-year periods except in the extreme eastern and southeastern portions of the state where the total rain trends for 1901-1995 were also downwards. The most pronounced changes occurred in northeastern, central, and west-central parts of the state where the statewide maximization of 2-year and 5-year recurrence interval storms occurred (Huff and Angel, 1989). The median ratio for the 12 stations shown in figure 16a was 1.11.

Figure 16b shows the late versus early ratio pattern for 3-inch rain days. The spatial pattern is very similar to figure 16a, except that the changes are larger in the area of maximum change. The median ratio is 1.15 for 3-inch rain days in 1946-1990. Thus, the general increase in the frequency of 2-inch and 3-inch rain days in Illinois was between 11 percent and 15 percent between the two 45-year sampling periods.



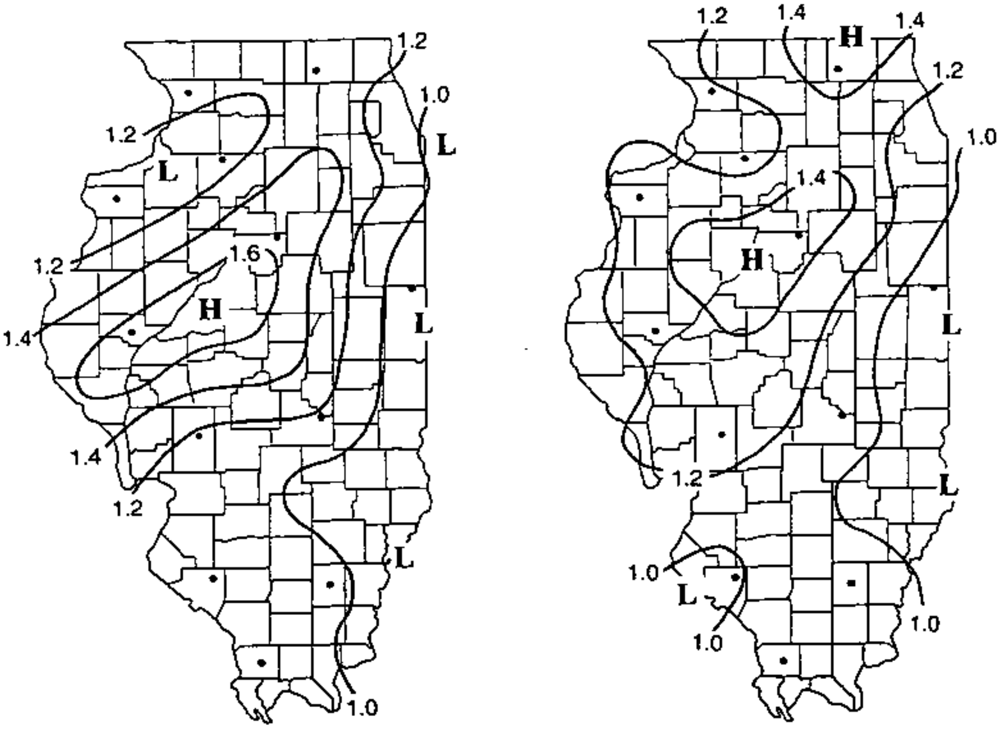
a. Ratio (1946-1990/1901-1945)
for total frequency of 2-inch rain days

b. Ratio (1946-1990/1901-1945)
for total frequency of 3-inch rain days

Figure 16. Maps based on the ratios of current versus early frequencies of heavy rain days based on data from the benchmark stations.

The 90-year sampling period was divided into three 30-year periods for another comparison. Figure 16c compares the last and first 30-year period for 2-inch rain days. The ratio pattern is similar to that in figure 16a. The location of the maximum change area and the ratios in this area are comparable and the median ratio is 1.15. Figure 16d shows the ratio pattern resulting from comparing the 2-inch rain days in the last 20-year period (1971-1990) with those in the first 20 years (1901-1920). The spatial pattern of ratios is similar to those in figures 16a-16c. The median ratio is 1.17.

The frequency of days with 4 inches or more of rain did not show an increase with time at most stations. Minonk, Rushville, and Walnut had their peak decadal values of the 1901-1995 period during 1981-1990. Peak values in 4-inch rain days occurred at Anna, McLeansboro, and Sparta during the two earliest decades of the century. Table 10 shows the decadal totals, based on the 11 benchmark stations with qualitydata in Illinois. The two peak decades were 1901-1910 and 1911-1920. Thus, the temporal increase found in 2-inch and 3-inch raindays did not appear in 4-inch rain days.



c. Ratio (1961-1990/1901-1930)
for total frequency of 2-inch rain days

d. Ratio (1971-1990/1901-1920)
or total frequency of 2-inch rain days

Figure 16. Concluded

Droughts in Illinois

Data on past warm season droughts, as defined by precipitation departures for May-September, were used to develop table 11. To qualify as a drought, the statewide mean rainfall value for the May-September period had to be less than 80 percent of the 1901-1995 average. The temporal distribution of these droughts does not suggest an increase with time. Further, recent decadal values fit within the range of values experienced in the 1901-1950 period.

Table 11. Warm Season Severe Droughts in Illinois

Period	*Number of droughts*
1901-1910	2
1911-1920	1
1921-1930	1
1931-1940	4
1941-1950	0
1951-1960	2
1961-1970	1
1971-1980	2
1981-1990	2

STATEWIDE VALUES

Another assessment of the behavior of the state's climatic conditions over time employed averaging the value of benchmark stations. This tends to eliminate any single station biases caused by inhomogeneities, and it provides a statewide portrayal of change rather than the point presentation of a single station. Data for all 11 benchmark stations were combined to provide annual statewide averages for precipitation, snowfall, and temperatures.

Annual Precipitation and Snowfall

Figure 17a shows mean annual precipitation values for Illinois from 1901-1995. There is a great deal of variability. Notable dry years occurred in 1901, 1914, 1936, 1953, 1963, and 1988; and very wet years occurred in 1927, 1982, 1990, and 1993. There is no obvious periodicity in the 95-year record. Annual precipitation trends are difficult to detect, although groups of years occasionally record relatively high values (1901-1909, 1944-1951, and 1982-1985), or relatively low values (1953-1956 and 1961-1963).

Figure 17b presents the mean winter snowfall values from 1901-1902 to those of the winter of 1994-1995. As with precipitation, long-term trends or cycles are not apparent. Particularly high snowfall occurred in 1911-1912, 1959-1960, 1977-1978, and 1978-1979. Winters with relatively little snowfall in Illinois include 1901-1902, 1920-1921, 1921-1922, and 1994-1995.

Mean Annual Temperatures

Figure 18a shows statewide mean annual temperatures from 1901-1995 based on 11 stations (Marengo excluded). Relatively high temperatures occurred in 1921, 1931, 1938, 1953, and 1954, and relatively low temperatures occurred in 1904, 1915, 1917, 1972, 1978, and 1979. There are two apparenttrends in these data, with a warming of one to two degrees Fahrenheit from the turn of the century to the late 1930s, and an apparent cooling of about two degrees Fahrenheit from 1940 to present.

The values in figure 18a offer no support to the hypothesis of recent warming due to the greenhouse effect. Although global warming may be occurring, there are regions of the earth including Illinois where no signs of warming exist. This does not disprove or prove the concept of global warming, it merely represents the regional condition.

Figure 18b shows mean annual maximum temperatures. Years exhibiting relatively high values include 1921, 1931, and 1953, and years with relatively low values include 1917, 1978, 1979, and 1991. Trends in the statewide mean annual minimum temperatures (figure 18c) are similar to those of the mean annual and mean annual maximum temperatures. However, the years with relatively high

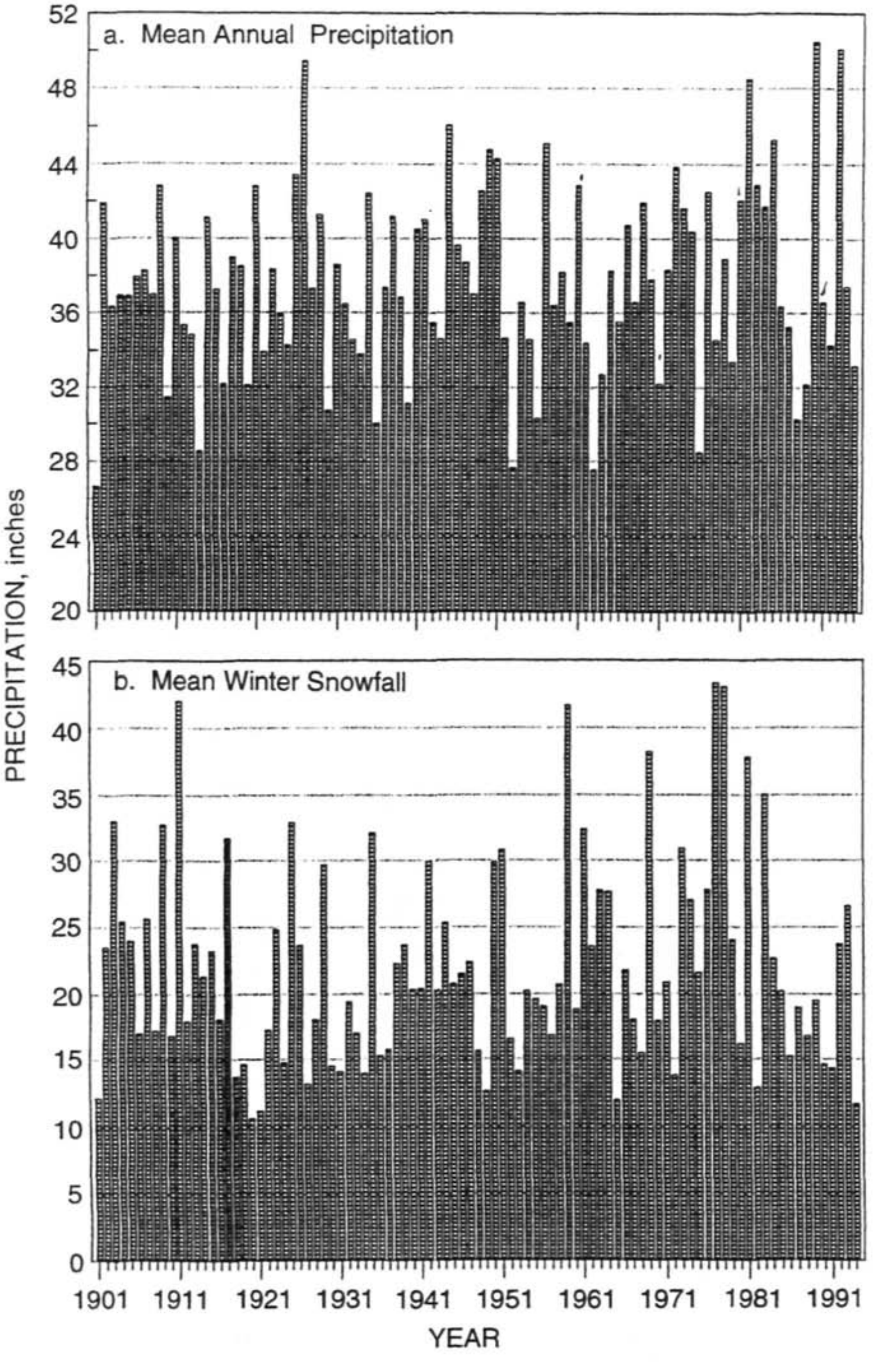


Figure 17. Stationwide a) mean annual precipitation values, and b) mean winter snowfall totals, based on the values of the benchmark stations.

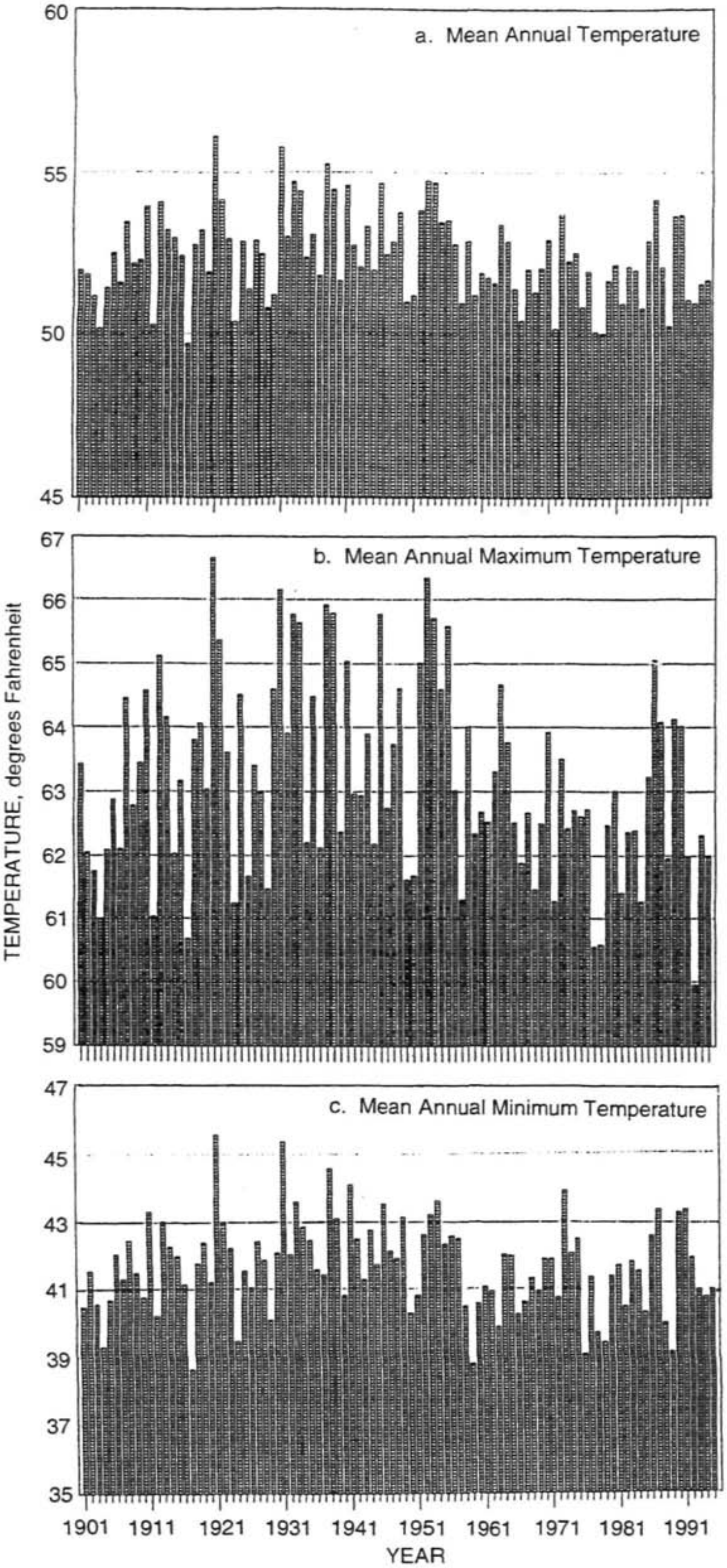


Figure 18. Statewide 1901-1995 a) mean annual temperatures, b) mean annual maximum temperatures, and c) mean annual minimum temperatures based on the averages of the benchmark stations.

annual minimum temperatures are somewhat different, being 1921, 1931, 1938, 1941, and 1973. Those with low minima were 1904, 1917, 1924, 1959, 1976, 1979, and 1989.

Differences between Mean Annual Maximum and Minimum Temperatures

Figure 19 presents annual values based on differences between high and low annual temperatures. There is no clear trend within the mean annual diurnal temperature differences, although years with relatively large differences have been more frequent within recent decades. Relatively large differences are seen in 1919, 1963, 1976, and 1988, and relatively small differences in 1915, 1935, 1973, and 1993. It is particularly interesting that 1988 exhibited an exceptionally large diurnal temperature range, along with 1919, 1963, and 1976, and 1993 exhibited an exceptionally low diurnal range, along with 1915, 1935, and 1973. The former might be attributed to relatively low relative humidities and/or relatively lower frequency of cloud cover during the drought of 1988, and the latter (1993) to relatively high relative humidities and/or higher cloud frequency in Illinois in wet 1993.

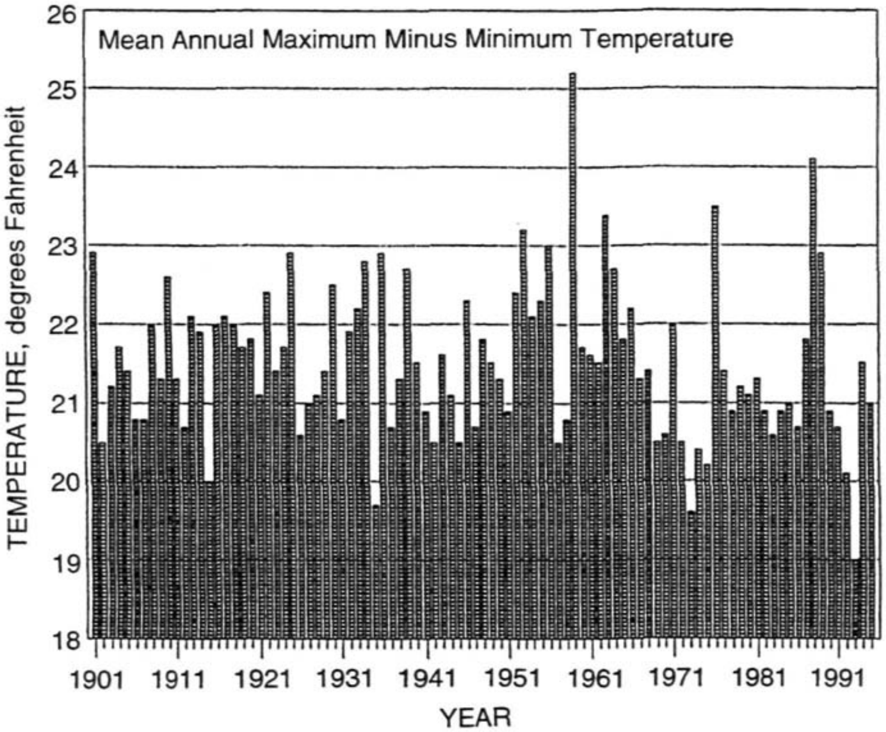


Figure 19. The difference between the mean annual maximum temperatures and the mean annual minimum temperatures for Illinois, based on the data from the benchmark stations.

CLIMATE CHANGE IN ILLINOIS

We live in an interdependent world. This means that the changing economy and demographics of Illinois can be explained only in terms of a combination of state, national, and global factors. Similarly, the climate of Illinois and climate change in Illinois can be explained only in terms of factors operating at state, regional, and global scales.

In seeking to explain climate change in Illinois, it is appropriate to start by defining climate as a statistical representation of a number of climatic elements, such as temperature, precipitation, cloudiness, and wind velocity over a period of time. The most common time period for characterizing climate is 30 years so that a variety of statistical analyses can be applied for a particular site or over a geographical region. Climate can then be characterized by mean or median values of the various climatic elements. It can also be characterized by the frequency of such climatic events as storms, freezing rain, droughts, and floods.

Until quite recently, the consensus of the international community was that present-day climates are quite stable; that is, a 30-year period was sufficient to characterize climate and that such a characterization would adequately characterize climate for the next 30-year period. Scientists now know that in many parts of the world 30 years is too short a period to adequately characterize past or future climatic conditions. Climates in many parts of the world are highly variable and change over time; climatic conditions a century ago were not the same as conditions today and conditions in the future may be different. Such knowledge and information is of great importance when managing environments, societies, and economies that are sensitive to variations in climatic conditions.

This report demonstrates that Illinois is one of the regions where climatic conditions have changed considerably over the last century. This section summarizes what is known about climate change in Illinois, identifies natural and anthropogenic factors that can contribute to climate change, discusses the extent to which scientists can explain climate change, relates historical climate change in Illinois to changes in regional and global climates, discusses the reliability of climate models, and suggests bounds of potential future climate changes in Illinois.

Temperature Changes in Illinois

Earlier sections of this report demonstrate that climatic conditions in Illinois have changed considerably during the twentieth century. In particular, state-average mean annual temperature increased by approximately 2 ° F from the start of the century to the 1930s and then declined by 2.5 ° F by the 1970s. The 1980s were somewhat warmer by about 1 ° F than the 1970s, but temperatures have declined again in the 1990s, and 1996 was the seventh coldest year this century in Illinois. Although a continuous, homogeneous climate record does not exist prior to 1900, data available from a small number of stations indicates that the early twentieth century temperature rise in Illinois was a continuation of an increasing temperature trend that dates back to at least the mid-nineteenth century (figure 20). Mean annual temperature in Illinois seems to have increased by about 4° F from the mid-

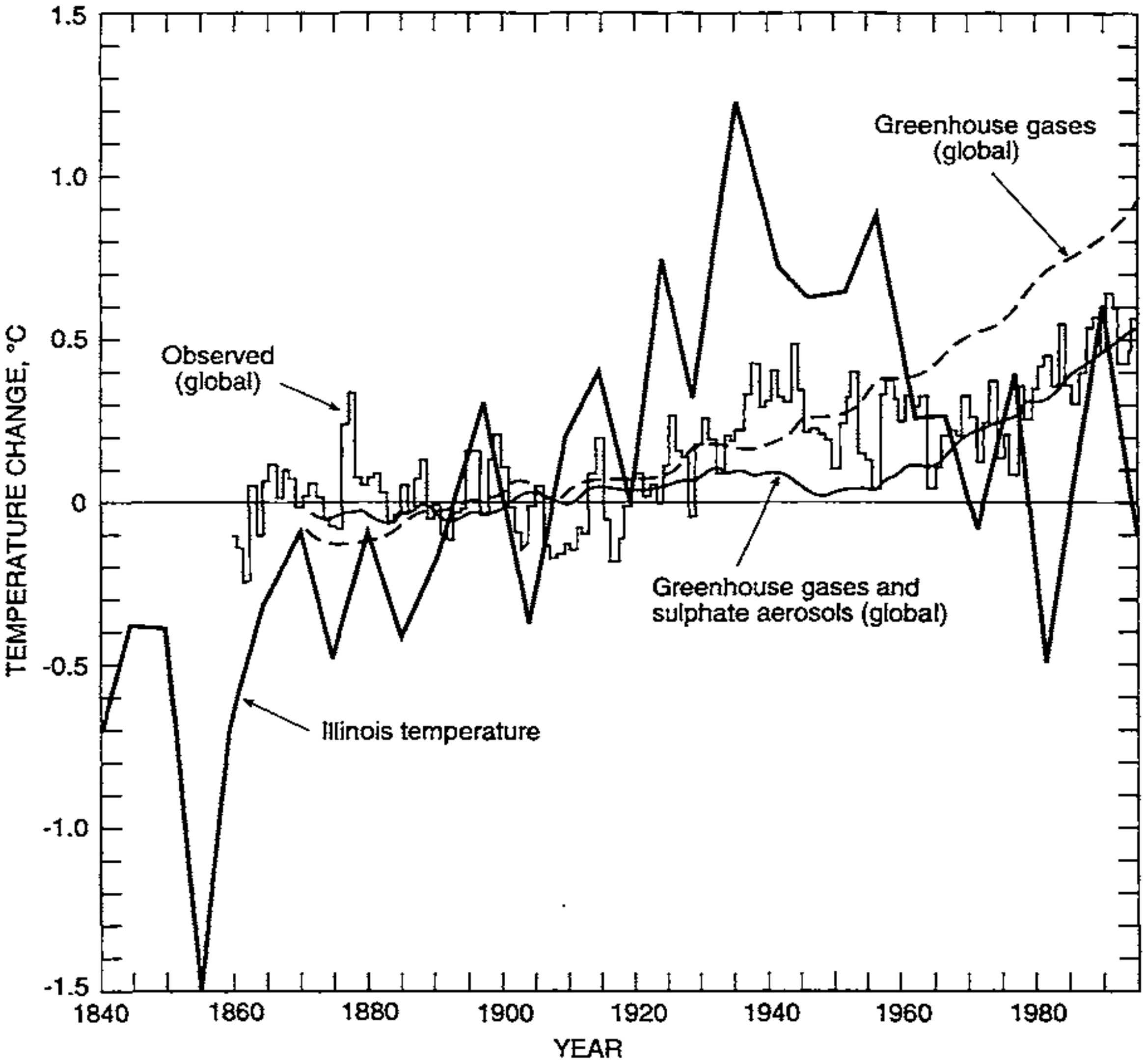


Figure 20. This graph presents four long-term temperature curves. The heavy solid line is based on Illinois' mean annual temperatures, as averaged for 5-year periods, from 1840 to 1996. The number of temperature-measuring stations with data used in these calculations prior to 1890 was considerably less than the number available for 1890-1996. The three other curves are based on global temperatures presented by the Intergovernmental Panel on Climate Change (1995), and they are departures from the 1880-1920 mean. One graph is based on the global annual temperature values; another is based on 10-year moving averages of estimates of the global temperatures resulting from an enhanced greenhouse effect; and a third curve is based on 10-year moving averages of estimates of the global temperatures resulting from an enhanced greenhouse effect and sulfate aerosols.

ninteenth century to the mid-twentieth century. This change in temperature in Illinois on a centennial scale is dramatic in its magnitude and clarity.

Regional Temperature Changes

Evidence from Minnesota (Skaggs and Baker, 1989) also shows that the mid-nineteenth century was markedly cooler than the twentieth century. The warming during this period in Minnesota is consistent with the 4° F warming observed in Illinois. Interestingly, the early part of the nineteenth century was considerably warmer than the mid-nineteenth century. The Minnesota data also suggest some cooling since about 1940 and a rise in temperature in the 1980s.

Temperature data are available for the entire Midwest since 1895. Trends in eight nearby states were compared with the Illinois trends. The temporal behavior in southern and central portions of the Midwest (Missouri, Indiana, Iowa, Kentucky, and Ohio) is very similar to that observed in Illinois. In each of these states, mean annual temperature rose by about 2° F from 1900 to the 1930s, fell by 2-3 ° F from the 1930s to the 1970s, rose by 1-2 ° F in the 1980s, and fell again in the 1990s. This temperature rise in the early part of the twentieth century is less pronounced in the northern tier of states (Minnesota, Wisconsin, and Michigan), or, in the case of Michigan, is not observed at all and the decrease from the 1930s to the 1970s is less pronounced. However, the rise in temperature in the 1980s in the north is more pronounced than in the remainder of the Midwest. Thus, the Illinois temperature trends appear to be indicative of trends in the entire Midwest, although there are some regional (north to south) differences in the magnitude of the trends.

Global Climate Change

Global mean surface temperature increased by 0.6-0.7 ° F from the mid-nineteenth century to the period from the 1930s to the 1950s (figure 20), decreased by about 0.3 ° F from the 1950s to the 1970s, and has increased by about 0.5 ° F to the present. The Illinois temperature increase from the mid-nineteenth century to the mid-twentieth century occurred at a rate about three times greater than the global mean, and then fell more than the global mean (1950-1970). Temperatures in Illinois generally increased in the 1980s but decreased in the 1990s, whereas global temperature has steadily increased. Indeed, the Intergovernmental Panel on Climate Change (IPCC, 1995) finds that "the recent warmth has been greatest over the continents between 40 ° N and 70 ° N." Illinois lies about 40 ° N, but the climate is cooling.

Clearly, there is not a simple correlation between temperature change in Illinois and global temperature change, either in magnitude or direction.

Causes of Climate Change in Illinois

Scientists cannot explain why the temperature in Illinois increased dramatically for a century and has now been declining for about half a century. The causes could be entirely natural, or due to a combination of natural and anthropogenic factors. At this stage, scientists can only speculate on potential causes.

Natural factors that could lead to climate change include possible changes in the receipt of energy from the sun, volcanic activity, changes in oceanic and atmospheric circulations on a regional or global scale, and changes in land cover and soil moisture. The mathematical models used to simulate climate change do not accurately simulate the increase in global temperature in the first half of the twentieth century, even though the models are structured to simulate internal changes in the climate system.

The IPCC recognizes that global temperature changes up to the mid-nineteenth century are probably due to natural causes, but finds that for the past two decades there is "a discernible human influence on global climate" (IPCC, 1995). Figure 20 shows that the increase in global mean temperature since the 1970s is generally consistent with the changes simulated by a global circulation model (GCM), a mathematical model that includes forcing by greenhouse gases and sulfate aerosols. Simulation of global temperatures with forcing only by greenhouse gases produces a higher rate of warming than was actually observed, but this is moderated by the cooling associated with sulfate aerosols. Clearly, the recent decrease in temperature in Illinois is not related in a simple manner to the warming expected from an enhanced greenhouse effect.

Anthropogenic influences on the climate of Illinois result from two major factors: land use changes and emissions of moisture, heat, and various pollutants into the atmosphere. These human-induced changes began with the rapid settlement of the state during the latter half of the nineteenth century. Prairies were converted to farmland, forests were cut and forested areas changed into farmland and pastures, and cities grew, creating moderate local or regional changes in climate. For example, in 1850, Chicago's population was 30,000, and by 1900 it was 2 million. Extensive development of industry in Illinois after the 1870s led to ever-growing emissions of gases and particulates, which affected visibility, clouds, and various other atmospheric conditions, but generally on a local scale (Changnon and Semonin, 1979). Subsequent twentieth-century changes leading to the huge metropolitan areas of Chicago and St. Louis, and the development of major transportation corridors with their emissions of gases and particulates due to vehicles and jet aircraft, have led to regional-scale influences on some aspects of Illinois' climate (Changnon, 1984). These various changes occurring since about 1860, have compounded the natural variability of Illinois' climate, making it difficult to measure how much change was due to natural influences and how much was due to human influences.

Extensive Water Survey studies have defined and explained the natural regional-scale influences on climate due to Lake Michigan and the southern Illinois hills (Changnon and Jones, 1972; Huff et al., 1975). Other Water Survey studies have also documented localized and regional anthropogenic influences on climate due to land use changes, cities, and jet aircraft (Changnon, 1977). A warming trend found in the state's average temperatures (Figure 20) from the 1860s until the 1940s could be a manifestation of large-scale land use changes that lead to higher surface temperatures (Changnon, 1973). More clouds due to cities and jet aircraft may help explain the growth in cloudiness during this century and the decrease in temperatures since 1960, as shown in figure 20 (Changnon, 1981). Growth of emissions from the state's industry, large cities, and transportation corridors has had an influence of clouds and precipitation leading to conditions conducive to more precipitation over time, another trend that has been notable since the 1930s (Changnon, 1984). Emissions of aerosols in the Midwest from burning of fossil fuels, including the emission of sulfur dioxide, which has increased sulfate aerosols into the atmosphere, have led to increases in the acidity of rainfall and the visibility degradation notable in Illinois since the 1940s (Changnon, 1982, 1987). Sulfate aerosols act to increase clouds and affect the albedo, both acting to produce negative radiative forcing and surface cooling. Recent calculations indicate a reduction of radiative forcing in the eastern half of the United States that is comparable to the expected increase in radiative forcing by greenhouse gases (IPCC, 1995). The notable increase in Illinois' cloudiness since 1940 may be in part the result of the influence of added aerosols, as well as a result of jet contrails and natural variations in atmospheric conditions.

Reliability of Mathematical Models of Climate

Important questions for Illinois and the rest of the world relate to the reliability of GCMs in simulating historical climates and in providing scenarios of possible future climate changes. The IPCC Summary for Policymakers (IPCC, 1995) notes that "considerable spread exists among model projectionson the regional scale...." More detailed chapters in the IPCC report present considerable data that allow an assessment of the reliability of the GCMs in simulating present-day regional climates.

For central North America, an area that includes Illinois, most model estimates of summer temperature are significantly higher than the present-day temperatures observed, in one case by almost 30° F. Model estimates of winter temperature vary from about 10° F cooler to 10° F warmer than the temperatures observed. There is also a great range in model estimates of precipitation. For summer precipitation, most models are within 15 percent of the precipitation observed. However, three models estimate a significantly drier (30-70 percent) summer climate. Model estimates of winter precipitation are generally wetter, by up to 120 percent, than the precipitation observed, although one model is drier by 30 percent. Although some models appear to produce smaller errors in the estimates overall, no single model is able to simulate the observed climate for both seasons within the observed interannual variability. Thus, there is considerable uncertainty about the capability of models to simulate and project regional or national climate variations and the climate effects of anthropogenic influences.

Future Temperature Scenarios

There is no reliable method for predicting climate in Illinois in the twentieth century, and it is difficult to construct credible future climate scenarios using the two approaches available. The first method is to assume that the future can be represented by a statistical characterization of past climatic conditions. The second approach uses mathematical models to project future climate changes.

The trend towards lower temperatures over the past few decades is so strong and well established that one scenario must be a continuation of the trend towards lower temperatures. It is unknown how long this downward trend could continue or the magnitude of cooling. Further cooling of about 2° F would produce temperatures in Illinois similar to the levels observed in the mid-nineteenth century. There is evidence from some parts of the world of a "Little Ice Age" during the sixteenth to eighteenth centuries, and it is likely that temperatures in Illinois were lower in this period than in the mid-nineteenth century. It is also possible that temperatures in Illinois in the twenty-first century could be lower than those in the mid-nineteenth century. The probability of a continuation of a downward trend in temperature is not known.

Scientists also use mathematical models to construct scenarios of future climate change. IPCC scenarios of possible future global warming associated with the increase in greenhouse gases, and accounting for possible cooling associated with sulfate aerosols, are generally within the range of +1.8 to + 6.3 ° F. These scenarios are based on a set of assumptions about a number of factors, including economic growth rates and demographic changes, which largely determine the emission rates of greenhouse gases and aerosols. The IPCC also recognizes that regional temperature changes could differ substantially from the global mean value. For example, the IPCC scenarios for the Midwest indicate changes in summer temperature ranging from +2° F to +10° F and in winter temperature from +2° F to +11 ° F, a very large range. The models are in close agreement, indicating small changes in winter precipitation with wetter conditions by 5 to 20 percent, although a few models indicate drier conditions. These uncertainties in projecting future climates must be considered in the context of the lack of model reliability in simulating present-day regional climates, as well as the uncertainties about projecting climate changes in the future. It is also important to note that no model has incorporated the full range of natural and anthropogenic forcing effects. A temperature increase at the lower range of the enhanced greenhouse scenarios would bring Illinois temperatures back to the level experienced in the mid-twentieth century. A temperature increase in the mid-range of the greenhouse scenarios would bring Illinois temperatures back to the levels prevalent during the mid-Holocene some 5,000 years ago. A temperature increase at the upper end of the greenhouse scenarios would be unprecedented over temperatures of the past 10,000 years or more.

The range of possible temperature conditions in Illinois in the twenty-first century is not known with much confidence; it could be either much warmer or colder than today. One thing is certain, however: the climate of the future is likely to be different than that of today. This wide spread of possible future climatic conditions has a wide range of important implications for the social, environmental, and economic well being of Illinois. Hence, it would seem wise to invest in research to help determine the causes of climate change and to narrow the range of uncertainty on future climate scenarios and predictions. Future data will help scientists assess climate shifts of the future, which necessitates high-quality data and the maintenance of the Illinois benchmark stations identified in this report.

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APPENDIX A.
STATION HISTORIES

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
ALEDO, IL				
1887	Taylor McWhorter	41° 12', 90° 45'	?	
1889	?			
1890	?			
11/1900	WB. Frew	41° 11', 90° 47'	sunset	station in town
7/1914	EN. Taylor	41° 12', 90° 45'	sunset	
2/1920	C.N. Vertrees	41° 12', 90° 45'	1800	
6/1932	LaVern Morgan	41° 12', 90° 45'	1800	
4/1933	John W. Parkinson	41° 12', 90° 45'	1800	
1942	John W. Parkinson	41° 12', 90° 45'	1930	
1943	John W. Parkinson	41° 12', 90° 45'	1900	
1946	John W. Parkinson	41° 12', 90° 45'	1800	
11/1951	Will O. Egbert	41° 12', 90° 45'	1800	
8/1955	Hugh Nesbitt	41° 12', 90° 43'	1800	farm residence
11/1958	Floyd R. Utsinger	41° 13', 90° 45'	1800	
7/1963	Gene L. Burgess	41° 13', 90° 45'	1800	0.3 mi N of PO
8/1986	Connie Newswander	41° 14', 90° 45'	1800	
7/1987	George M. Korns	41° 14', 90° 44'	1800	1.0 mi NE of PO
6/1991	Donald C. Korns	41° 14', 90° 44'	1800	1.0 mi S of PO
2/1994	Donald C. Korns	41° 14', 90° 45'	0700	
ANNA, EL				
1/1875	F.W. Mercer & J.D. Newbegin	37 ° 28', 89° 15'	?	town residence
1/1896	John Buck	37° 31', 89° 17'	?	
3/1914	James I. & E.V. Hale	37° 28', 89° 15'	1700	
5/1925	C.E. Kirkpatrick	37° 28', 89° 15'	1700	
10/1925	Floyd Davis	37° 28', 89° 15'	1830	
3/1926	Roy C. Walker	37° 28', 89° 15'		
9/1938	L.E. Foley	37° 28', 89° 15'		
8/1945	J. Bon Hartine	37° 28', 89° 14'	1900	rural site, 1.0 mi NW of PO
8/1955	Dana Cross	37° 28', 89° 14'	1800	

Appendix A. Continued

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
CARLINVILLE, IL				
2/1891	R.O. Purviance	39° 17', 89° 53'	1700	town residence
5/1911	W.T. Eddy	39° 17', 89° 53'	sunset	
7/1912	W.A. Challacombe	39° 17', 89° 53'	1630	
6/1913	F.D. Conley & W.H. Erens	39° 17', 89° 53'	1700	
1920	W.H. Erens		0800	
1921	W.H. Erens		1630	
9/1925	Theodore C. Loehr	39° 17', 89° 53'	1800	0.5 mi SE of PO
1943	Theodore C. Loehr		2200	
4/1946	Henry B. Hoelting	39° 17', 89° 49'	1800	3.7 mi E of PO, in orchard
3/1957	Henry B. Hoelting	39° 17', 89° 52'	1800	0.5 mi SW of PO, in town
10/1957	Jack A. Campbell	39° 17', 89° 52'	1800	
HOOPESTON, IL				
1887	C. Jean Trego	40° 30', 87° 47'	?	
8/1902	R.M. Hoskinson	40° 28', 87° 40'		0700, 1400, & 1800 in town
11/1905	S.F. Hoskinson	40° 28', 87° 40'	1700	
9/1918	John I. Martin	40° 28', 87° 40'	1700	site over cultivated ground
10/1920	J.M. Mattoon	40° 28', 87° 40'	sunset	
1/1921	Charles I. Beeman	40° 28', 87° 40'	1700	
11/1922	George W. Tanner, Jr.	40° 28', 87° 40'	1700	0.5 mi SE of PO
11/1926	Charles S. Flexman	40° 28', 87° 40'	1800	0.5 mi WSW of PO
5/1951	John F. Mushrush	40° 28', 87° 40'	1800	0.6 mi NE of PO
1970	John F. Mushrush			1800 (T), 0700 (P)
MARENGO, IL				
5/1855	O.P. Rogers	42° 13', 88° 36'		3 mi S of Marengo PO in Riley
10/1860	E. Babcock & John W. James	42° 13', 88° 36'		0700, 1300, & 2100(P) Riley
1/1893	John W. James	42° 13', 88° 36'	sunset	Riley
6/1918	Nebelow V. Woleben	42° 17', 88° 36'	1830	Marengo
6/1937	Frank J. Mack	42° 15', 88° 36'	1800	0.6 mi E of PO, in town
11/1954	Ernest G. Woolley	42° 15', 88° 36'	1800	0.5 mi E of PO, in town
8/1954	Claire L. Loofburrow	42° 15', 88° 37	1800	

Appendix A. Continued

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
8/1956	Harold Hyde	42° 15', 88° 36'	1800	0.5 mi ESE of PO
1974	Harold Hyde	42° 15', 88° 36'		0700 (P), 1800 (T) in town
1975	Harold Hyde	42° 15', 88° 36'	1800	(T)
1978	Harold Hyde	42° 15', 88° 36'		1800 (T), 0700 (P)
1980	Jerome L. Hoch	42° 15', 88° 36'	0700	0.5 ESE of PO, in town
McLEANSBORO, IL				
4/1882	W.P. Gibbs	38° 05', 88° 32'		0700, 1400 & 2100 5.0 mi NW of town
1/1895	John & Chester Judd, and R.C. Robinson	38° 05', 88° 32'		0700 & 1900, in town
1903	John & Chester Judd, and R.C. Robinson	38° 05', 88° 32'		0700 & 1900, in town
10/1911	W.C. Fairweather	38° 05', 88° 32'	1800	in town
6/1913	Thomas W. Biggerstaff	38° 05', 88° 32'	?	in town
2/1914	Dan P. Campbell	38° 05', 88° 32'	1800	in town
1915	Dan P. Campbell	38" 05', 88° 32'	0700	in town
4/1915	A.E. Wilson	38° 05', 88° 32'	1630	in town
9/1921	Charles N. Burnett	38° 05', 88° 32'	?	in town
11/1921	J.C. Carner	38° 05', 88° 32'	sunset	in town
9/1941	J.H. Braden	38° 05', 88° 32'	1800	0.2 mi S of PO, in town
11/1943	Fred G. Frazier	38° 05', 88° 32'	1800	at PO
5/1970	George W. Martin	38° 05', 88° 30'	1800	?
11/1972	William Campbell	38° 06', 88° 32'	1800	?
10/1973	Richard G. Brown	38° 06', 88° 30'	0700	2.3 mi ENE of PO, rural
3/1987	Jennilyn M. Brown Postletheweight	38° 06', 88° 30'	0700	
MINONK, IL				
1/1886	?	40° 54', 89° 02'	?	town residence
10/1895	O.M. Dauson	40° 54', 89° 02'		0700, 1400, & 2100 (T)
1898	O.M. Dauson	40° 54', 89° 02'		0700 & 1900 (T)
6/1911	M.H. Pfaffle	40° 54', 89° 02'	sunset	town residence
10/1912	B.R. Borris	40° 54', 89° 02'	?	town residence
1/1912	John C. Danforth	40° 54', 89° 02'	sunset	
9/1923	M.H. Pfaffle	40° 54', 89° 02'	sunset	
6/1925	Henry Defreis	40° 54', 89° 02'	?	town residence
10/1925	August Schneider	40° 54', 89° 02'	?	

Appendix A. Continued

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
2/1926	John C. Cassens	40° 54', 89° 02'	1830	0.3 mi SW of PO, in town
11/1949	Virgil E. Dishinger	40° 54', 89° 02'	1900	0.3 mi WSW of PO, in town
6/1933	Homer C. Parks	40° 54', 89° 02'	1900	0.5 mi WSW of PO, in town
10/1969	Gene A. Kalkwarf	?	1800	?
10/1970	Kay Gaspardo	?	1800	
8/1975	Robert D. Quick, Sr.	40° 54', 89° 03'	1800	0.2 mi W of PO, in town
1976	Robert D. Quick, Sr.	40° 54', 89° 03'	0700	
1/1981	Robert O. Weakley	40° 54', 89° 03'	0700	0.3 mi SW of PO, in town
1982	Robert O. Weakley	40° 54', 89° 03'	0800	
MT. CARROLL, IL				
1887	?	40° 54', 89° 02'	?	town residence
1888	H. Beeler	40° 54', 89° 02'	?	
6/1892	?			
4/1895	M.N. Wertz	42° 50', 89° 54'	1900	Lanark
4/1916	S.P. Calahour	42° 05', 89° 58'		Mt. Carroll
1/1917	J.H. Browning	42° 05', 89° 58'	1730	0.7 mi S of PO, in town
4/1920	B.E. Beedy	42° 05', 89° 58'	1730	0.2 mi S of PO, in town
8/1920	C.R. Bovles	42° 05', 89° 58'	1630	0.5 mi S of PO, in town
6/1921	EL. Seck, Jr.	42° 05', 89° 58'	?	
7/1921	C.F. Ritchie	42° 05', 89° 58'	1630	
6/1923	F. McCray	42° 05', 89° 58'	1700	0.5 mi NW of PO, in town
1954	F. McCray	42° 05', 89° 58'	1900	(T),0600(P)
1966	Levi C. Zink	42° 05', 89° 59'	0600	(T), 0700 (P)
1972	Glen Doty	42° 05', 89° 59'	1600	(T),0800(P)
1974	Lawrence Irwin	42° 06', 89° 59'	1600	(T),0800(P)
3/1975	Ronald Morgan	42° 05' 89° 59'	0800	0.6 mi SSW of PO, in town
4/1990	Terry Bausman	42° 06', 89° 59'	0800	0.2 mi W of PO, in town
RUSHVILLE, IL				
1/1899	Prof. N.T. Veatch	40° 8', 90° 34'	?	
11/1901	Howard F. Dyson	40° 8', 90° 34'	1800	in town
9/1930	Loren P. Wetherbee	40° 8', 90° 34'	1900	in town
11/1938	Mrs. Hal Corbridge	40° 8', 90° 34'	1900	0.4 mi S of PO
9/1946	Gain Brothers Greenhouse	40° 87', 90° 34'	1800	0.5 mi SW of PO
6/1974	City of Rushville	40° 07', 90° 33'	0700	?

Appendix A. Continued

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
6/1976	Richard H. Boehm	40° 07', 90° 35'	1700	0.5 mi WSW of PO, in town
6/1986	James Farrarr	40° 07', 90° 33'	1700	1.0 mi N of PO, in town
1988	James Farrarr	40° 07', 90° 33'	0800	

SPARTA, IL

1/1887	J.S. Cathcart	38° 12', 89° 42'		Jordan's Grove, ~6 mi N of Sparta 0700, 1400 and 2100, daily
3/1898	J.A. Caldwell	38° 12', 89° 41'	?	Tilden, -6 mi N or Sparta
1910	J.A. Caldwell	?		residence in Sparta
11/1913	W.F. Clendenin	38° 08', 89° 42'	sunset	residence
7/1918	J.A. Tate	38° 08', 89° 42'	sunset	0.5 mi NE of PO
3/1923	Howe V. Morgan	38° 08', 89° 42'	1800	0.3 mi SE of PO
1953	Howe V. Morgan	?		0.4 mi NNW of PO
10/1966	William H. Morgan	38° 08', 89° 43'	1800	1.0 mi NNW of PO, in town
2/1975	Glenn I. Coffey	38° 08', 89° 43'	1800	0.5 mi N of PO, in town
4/1990	John L. Luthy	38° 10', 89° 42'	1800	3.0 mi N of PO, on farm
1991	John L. Luthy	38° 10', 89° 42'		1800 (T), 0600 (P)
8/1993	Mike Hoefft	38° 07', 89° 43'	0600	1.2 mi W of PO, rural

WALNUT, IL

1/1892	O.C. Nussle	41° 33', 89° 35'	1700	0.2 mi N of PO, in town
1/1940	Carl F. Nelick	41° 33', 89° 35'	1700	0.4 mi ENE of PO, in town
1960	Victor Valt	41° 33', 89° 35'	1700	(T)0800(P)
1969	Victor Valt	41° 33', 89° 35'	1800	
1980	Delmar Peach	41° 33', 89° 36'	1800	
1981	Delmar Peach	41° 33', 89° 36'	0800	
1984	Jim Lamkin	41° 33', 89° 36'	0800	

Appendix A. Concluded

Beginning date	*Observer*	*Specific location*	*Time of observation*	*Comments*
WINDSOR, IL				
1885	A.H Hatch	39° 26', 88° 36'	?	
1/1901	Herbert Rose	39° 26', 88° 36'	1700	3.5 mi NW of PO, on farm
1/1926	Mrs. Herbert Rose	39° 26', 88° 36'	1700	0.4 mi NE of PO
10/1951	Raymond R. Hall	39° 26', 88° 36'	1800	
3/1971	Orris A. Seng	39° 26', 88° 36'	1800	0.4 N of PO, in town

Notes:
? = unknown, T = temperature, and P = precipitation

APPENDIX B.
COMPARATIVE DIFFERENCES

The differences shown in temperatures are the average difference calculated for the period shown.

Mt. Carroll

1. Mt. Carroll values are too low by 1.0° (1900-1915).
2. Mt. Carroll values became lower in the 1970s, with 1.3° below Walnut and Marengo values.

Marengo

1. Marengo values are warmer in early years by 0.8° over Mt. Carroll values.
2. Marengo values are warmer than Mt. Carroll values after 1975 by 1.3° .
3. Marengo values are warmer than Walnut values after 1970 by 0.6° .
4. Marengo and Minonk distributions were alike from 1940-1995 but wider apart in 1901-1940. Either Marengo warmed more in the 1980s, or Minonk values were too high (1901-1940).

Walnut

1. Walnut values are identical to Minonk values (1925-1964). Before 1925 and after 1964, the Minonk values are higher than Walnut values, 0.7° (1901-1924) and 1.1 ° (1965-1995).
2. Aledo values are identical (1901-1964); then Walnut values are lower by 0.5° (1965-1973) and by 1.2° (1974-1995).

Aledo

1. Aledo values approximate Walnut values until 1965 when Aledo becomes warmer (or Walnut becomes cooler).
2. Minonk values are close to Aledo values until 1975 when Aledo becomes warmer (or Minonk gets cooler) by 0.9° .
3. Rushville values have a close relationship to Aledo values.

Appendix B. Continued

Minonk

1. Minonk is warmer than Walnut in two periods: 1911-1923 by 0.8° , and 1960-1974 by 0.4° . Otherwise the values are close.
2. Minonk values are close to Aledo values until 1975 when Aledo gets warmer (or Minonk cooler) by 0.9° F.
3. Minonk values are close to Hoopeston values until ~ 1980 when Minonk becomes cooler by 1.0° .

Hoopeston

1. Minonk values are close to Hoopeston values, but Minonk got cooler than Hoopeston after the 1980s by 1.0° .
2. Rushville values are very close, but Rushville cooled in 1990-1995 by 0.3 ° F.
3. Windsor values are similar except for 1962-1980 when Windsor was warmer by 0.2 ° F.

Rushville

1. Aledo values are warmer than Rushville values by 0.4° from 1968-1995.
2. Minonk and Rushville values are alike until 1965 when Minonk is warmer by 0.3° , then cooler by 0.5° after 1977.
3. Carlinville values are similar to Rushville values.

Carlinville

1. Carlinville values approximate Rushville values.
2. Carlinville values have perfect agreement with Windsor values.
3. Sparta values are alike also.

Windsor

1. Hoopeston and Windsor values are alike except for 1962-1980 when Windsor is warmer by 0.2° .
2. Windsor values have good agreement with Carbondale values.
3. McLeansboro becomes cooler in late 1970 by 1.7° .

Appendix B. Concluded

Sparta

1. Carlinville and Sparta values are similar.
2. McLeansboro gets cooler by 1.8° in 1970.
3. Anna is warmer by 1.3° until 1925; after that, the Anna and Sparta values are in agreement.

Anna

1. Anna is warmer than McLeansboro and Sparta by 1.2-1.3° (1901-1925).
2. Anna, McLeansboro, and Sparta values are in close agreement after 1925.

McLeansboro

1. McLeansboro values are lower after 1970 than Anna, Windsor, and Sparta values.

APPENDIX C.
DOUBLE MASS CURVE ANALYSIS

Aledo vs. Marengo

Their curve is nearly straight: one bend occurs during 1970-1980, and a slight bend occurs in the 1925-1935 period, so that Marengo is cooling faster than Aledo.

Finding: There were no observer changes in the 1925-1935 period, a big discontinuity at Marengo in 1936, and observation time changed at Marengo in 1981.

Aledo vs. Mt. Carroll

There were three shifts in the curve: 1915-1920 (Aledo gets warmer or Mt. Carroll cooler), 1955-1960 (Aledo gets warmer), and 1975-1980 (Mt. Carroll getting relatively warmer or Aledo cooler).

Finding: After the Mt. Carroll station moved in 1915, the Mt. Carroll discontinuities don't agree; Aledo experienced discontinuity in 1984 (observation change), and values for 1981 agree.

Aledo vs. Walnut

There was very little difference in the curve: around 1975-1980 a slight shift occurs and Walnut gets warmer (or Aledo cooler).

Finding: Observation time shift, p.m. to a.m. in 1981 at Walnut, is the cause.

Aledo vs. Minonk

There was one slight shift: Minonk gets cooler (or Aledo warmer) around 1965-1975.

Finding: Observation time shift, p.m. to a.m. in 1976 at Minonk, is the cause.

Appendix C. Concluded

Hoopeston vs. Minonk

There was one slight shift: Minonk gets cooler (or Hoopeston warmer) around 1970-1975.
Finding: Observation time shift, p.m. to a.m. in 1975 at Minonk, is the cause.

Rushville vs. Hoopeston

The curve is straight.
Finding: Both data sets are consistent.

Rushville vs. Carlinville

The curve is straight.
Finding: Both data sets are consistent.

Windsor vs. Hoopeston

The curve is straight.
Finding: Both data sets are consistent.

Windsor vs. Sparta

The curve is straight.
Finding: Both data sets are consistent.

McLeansboro vs. Windsor

The slope changed in 1965-1973.
Finding: Observation time shift, (Windsor gets warmer or McLeansboro gets cooler) p.m. to a.m. in 1973, is the cause.

Anna vs. Sparta

There was one shift in the curve: 1925-1930.
Finding: Anna observers changed in 1925-1926 but there were no discontinuities for either station.

APPENDIX D.
STATISTICAL HOMOGENEITY TEST

Aledo

Small moves in July 1914, November 1958, and on 9/26/86, 7/1/87, and 6/1/91. Bad exposure and moved 9/22/94. MMTs installed 9/26/94. Observation time change (p.m. to a.m.) in February 1994.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1990	-1.81	1981 - 1995
1981	-0.49	1968-1990
1968	-0.48	1954 - 1981
1954	-0.40	1939 - 1968
1939	-0.50	1933 - 1954
1933	0.90	1925 - 1939
1925	0.63	1911 - 1933
1911	1.03	1901 - 1925

Findings: No relations were found between known site alterations and the computed discontinuities.

Anna

Move made in March 1914. Small moves in August 1945 and 1995. MMTs installed 10/3/89.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1979	1.03	1971 - 1995
1971	-0.51	1946-1979
1946	1.27	1939-1971
1939	-0.93	1913 - 1946
1913	-1.55	1907 - 1939
1907	1.87	1901 - 1913

Findings: 1914 move may be flagged by 1913 discontinuity, and also one in 1945. No other connections were found between site alterations and computed discontinuities.

Appendix D. Continued

Carlinville

Moves in April 1946 and March 1957. MMTs installed in June 1984.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1984	-1.30	1972-1995
1972	-0.48	1964-1984
1964	-0.45	1943 -1972
1943	-0.87	1934 -1964
1934	0.58	1910-1943
1910	1.04	1901 - 1934

Findings: Moves were not detected. The MMT installation occurred in the year of a discontinuity, and the sign of suggested change is correct.

Hoopeston

MMTs installed in May 1985.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1987	-0.41	1958 - 1995
1958	-0.29	1947 - 1987
1947	-0.59	1941 - 1958
1941	-0.90	1912 - 1947
1912	1.69	1902 - 1941

Findings: The MMT installation occurred two years away from a computed discontinuity, and the sign of suggested change is correct.

Appendix D. Continued

Marengo

Moves in June 1918 and 1937. Observation time change from p.m. to a.m. in January 1980. No MMT installed.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1978	-1.52	1963 - 1995
1963	0.68	1950 - 1978
1950	-0.94	1943 - 1963
1943	0.98	1936 - 1959
1936	1.35	1911 - 1943
1911	-0.67	1901-1936

Findings: Move in 1937 is a discontinuity. The time-of-observation change also occurred two years from a computed discontinuity, and the sign of the change is correct.

McLeansboro

Move in 1972, and observation time change from p.m. to a.m. in March 1972. No MMT installed.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1973	-0.98	1965 - 1995
1965	-0.80	1950 - 1973
1950	-1.65	1935 - 1965
1935	1.02	1929 - 1950
1929	-1.16	1919 - 1935
1919	0.98	1909 - 1929
1909	1.36	1901 - 1919

Findings: Move in 1972 was a discontinuity, and the time-of-observation change occurred one year from a computed discontinuity, and the sign of change is correct.

Appendix D. Continued

Minonk

Small station moves in August 1975 and May 1988. Observation time change from p.m. to a.m. in August 1975.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1979	-1.06	1967 - 1995
1967	-0.17	1960-1979
1960	1.18	1922-1967
1922	-0.67	1914 - 1960
1914	-0.49	1907 - 1922
1907	1.79	1901 - 1914

Findings: No connections were found between the site alterations and the discontinuities. Observation time change was four years away.

Mt. Carroll

Move in April 1916. Small moves in 1966, October 1979, and October 1991. Observation time change from p.m. to a.m. in September 1975 (and from 1966-1972), and no MMT installed.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1986	1.45	1975 - 1995
1975	-1.03	1946 - 1986
1946	-0.71	1901 - 1975

Findings: Moves not discontinuities. The time-of-observation change occurred in the year of a discontinuity. The sign of suggested change is correct.

Rushville

Small move in June 1974. Observation time change from p.m. to a.m. in November 1987, and MMTs installed in April 1987.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1983	-0.67	1954 - 1995
1954	0.93	1946 - 1983
1946	1.52	1939 - 1954
1939	-1.11	1922 - 1946
1922	-0.62	1915 - 1939
1915	1.29	1901 - 1922

Findings: Move not a discontinuity. No connections were found between installation of MMT and the discontinuities. Observation time change was four years away from discontinuity.

Sparta

Major station move in 1909; small moves October 1966, April 1990, and August 1993. February observation time change from p.m. to a.m. in 1987; observation time change from a.m. to p.m. in September 1989 and from p.m to a.m. in April 1990; and MMT installed in April 1990.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1987	-0.85	1979 - 1995
1979	-0.20	1950 - 1987
1950	-0.69	1934 - 1979
1934	-0.67	1922 - 1950
1922	1.34	1914 - 1934
1914	-0.23	1901 - 1922

Findings: Moves not flagged as discontinuities. A time-of-observation change occurred in the year of a discontinuity, and the sign of suggested change is correct.

Appendix D. Concluded

Walnut

Small move in 1980. Observation time change in from p.m. to a.m. in January 1981. MMT installed in August 1990.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1986	-1.96	1978 - 1995
1978	0.09	1969 - 1986
1969	-0.56	1958 - 1978
1958	-0.65	1949 - 1969
1949	1.05	1928 - 1958
1928	0.90	1915 - 1949
1915	-0.81	1910 - 1928
1910	-1.35	1901 - 1915

Findings: No connections were found between site alterations and the discontinuities. MMT installation was four years away.

Windsor

MMT installed April 1987.

Discontinuity Date	*Change, ° F*	*Assessment Period*
1985	-1.31	1976 - 1995
1976	-0.49	1965 - 1985
1965	-0.43	1940 - 1976
1940	0.83	1926 - 1965
1926	-0.98	1904 - 1940

Findings: The MMT installation occurred two years from a computed discontinuity. The sign of suggested change is correct.